GRID CONFIGURATION AND LAND USE: a syntactic study of Porto Alegre (Brazil)

by

DOUGLAS VIEIRA DE AGUIAR

A thesis submitted for the degree of
Ph.D. in Architecture at the
University of London

Unit for Architectural Studies
Bartlett School of Architecture and Planning
University College London
University of London
February 1991
Abstract

This thesis is about the configuration of the urban grid. Configuration is understood here as a particular manner of arrangement which differentiates the layout of the street grid from one part of the town to another. The problem of how to describe, in objective terms, the diversity of grid configurations that compose naturally evolved urban areas is a central concern in this investigation. This thesis is also about the scrutiny of relationships between grid configuration and the distribution of land use. It is conjectured in this respect that configurational factors given by the spatial nature of the grid may affect the way in which land use is distributed in urban areas.

A sample of urban areas - grid configurations and corresponding land use distributions - taken from the city of Porto Alegre (Brazil) is the object to be investigated. The simultaneity and interaction of markedly distinct grid configurations within the same city make of Porto Alegre a case where this research has fertile grounds for development. The investigation is centred on the study of the laws of the object. The urban grid will be assessed in terms of its internal laws and properties which, in a subsequent step, will be statistically compared with the socio-economic dimension of the urban phenomenon given by the distribution of land use.

Notes to the reader

The non-technical reader may first refer to chapter 7 which provides a summary of the findings produced out of this investigation.

The analytical procedure to be developed during chapters 4, 5 and 6 should be read simultaneously with the observation of the diagrams available from the back cover of this thesis.
Abstract

This thesis is about the configuration of the urban grid. Configuration is understood here as a particular manner of arrangement which differentiates the layout of the street grid from one part of the town to another. The problem of how to describe, in objective terms, the diversity of grid configurations that compose naturally evolved urban areas is a central concern in this investigation. This thesis is also about the scrutiny of relationships between grid configuration and the distribution of land use. It is conjectured in this respect that configurational factors given by the spatial nature of the grid may affect the way in which land use is distributed in urban areas.

A sample of urban areas - grid configurations and corresponding land use distributions - taken from the city of Porto Alegre (Brazil) is the object to be investigated. The simultaneity and interaction of markedly distinct grid configurations within the same city make of Porto Alegre a case where this research has fertile grounds for development. The investigation is centred on the study of the laws of the object. The urban grid will be assessed in terms of its internal laws and properties which, in a subsequent step, will be statistically compared with the socio-economic dimension of the urban phenomenon given by the distribution of land use.
Grid Configuration and Land Use:
A syntactic study of Porto Alegre (Brazil)

Contents

Acknowledgements vii
List of figures viii
List of tables xiv

Introduction 1

Chapter 1
Urban Land Use and Urban Morphology: Two distinct approaches for describing the same phenomenon 7
Land use as a de-spatialized variable 7
Land market and the distribution of uses 9
Transportation cost and land use 17
Attraction models 22
Human interaction theories 26
The natural zonning approach 28
Does space matter? 37
Built form as a central concern 38
The urban form as a spatial continuum 44
Notes on chapter one 65

Chapter 2
Grid Configuration and Land Use:
Methodology of Analysis 67

Urban systems as axial systems: a syntactic approach for describing the urban space 68
Measuring networks 72
Measuring the configuration of the street grid 76
On selecting the areas of study 86
Constitution as a land use measurement 91
Chapter 3
The Decomposition of the Urban Grid

A range of view on the problem of boundaries
Defining spatial boundaries
From the wholes to the parts
Further decompositions
SA west: the griddy half of sector A
SA east: the patchwork half of sector A
SB west: the griddy part of sector B
SB east: the patchwork part of sector B
Correlations between syntactic measurements: a search of regularities
Notes on chapter 3: three orders of decomposition

Chapter 4
Descriptions of Grid Configuration

Integration and Choice: mean values
Intelligibility, scale and size
Intelligibility and Integration
The polarity between axial fragmentation and tension
The urban grid as a pattern of rings
The urban grid as a pattern of connectivities
Figure-ground ratio

Chapter 5
Syntactic Descriptions for the Distribution of Productive Activities

Grid configuration and the density of productive activities
Acknowledgements

My gratitude is due to my family - Maria Angela, Julia and Pedro - who have patiently put up with my constant preoccupation with work over the past four years. My thanks are also due to Julienne Hanson, my supervisor, not only for supporting this project but also for acting as a source of ideas which have contributed largely in the accomplishment of this work.
List of Figures

Chapter 2

Fig. 2.01 Axial Representation of G; small town in the Var region of France 69

Fig. 2.02 A transcription of a road lay out from Hagget and Chorley 73

Fig. 2.03 The city of Pôrto Alegre (south of Brazil) 87

Fig. 2.04 Two 'sectors' of urban growth 89

Fig. 2.05 The grid configuration of sector A 89

Fig. 2.06 Fragment of sector A (west); orthogonal grid and its more deformed surroundings 89

Fig. 2.07 Fragment of sector A (east); the curvilinear 'garden city' pattern 89

Fig. 2.08 Housing Estates infilled in the street grid (sector A east) 89

Fig. 2.09 The grid configuration of sector B 89

Fig. 2.10 Fragment of sector A Convex spaces, axial lines and constitutions 93

Fig. 2.11 Convex superimposition 94

Fig. 2.12 Land use distribution in sector A 104

Fig. 2.13 Land use distribution in sector B 104

Fig. 2.14 Example of File containing syntactic and land use measurements 'per axial line' 105

Fig. 2.15 Example of file containing syntactic and land use measurements 'per system' 106

Chapter 3

Fig. 3.01 The same regular grid divided in five distinct 'zones'; after the Marterplan of Porto Alegre. 119
Fig. 3.02 'Traverse Permeability' in different 'sections' of the urban grid (south boundary of sector A) 124
Fig. 3.03 The raise and fall in traverse permeability 124
Fig. 3.04 Line chart for 'traverse permeability' (south boundary of sector A) 124
Fig. 3.05 Sector A: 'Artificial ruptures' and 'natural ruptures' 125
Fig. 3.06 Sector B: 'Artificial ruptures' and 'natural ruptures' 125
Fig. 3.07 Sector A: Ruptures in traverse permeability 128
Fig. 3.08 Sector B: Ruptures in traverse permeability 128
Fig. 3.09 Sector A: Axial representation of boundaries given by ruptures in traverse permeability 132
Fig. 3.10 Sector A: 5% highest choice value lines 132
Fig. 3.11 Sector B: Axial representation of boundaries given by ruptures in traverse permeability 135
Fig. 3.12 Sector B: 5% highest choice value lines 135
Fig. 3.13 Sector A: Integration Core 138
Fig. 3.14 Sector A: The global core and the local cores 140
Fig. 3.15 Sector A: Line charts for differences, definitions and overlaps 142
Fig. 3.15 Radius three integration core 148
Fig. 3.16 First order decomposition of sector A 150
Fig. 3.17 Sector B: Integration Core 151
Fig. 3.18 Sector B: The global core and the local cores 152
Fig. 3.19 Sector B: Line charts for differences, definitions and overlaps 153
Fig. 3.19 Radius three integration core 157
Fig. 3.20 First order decomposition of sector B 158
Fig. 3.20 Four 'systems of interaction' 159
Fig. 3.21 SA west: integration core 161
Fig. 3.22 SA west: The global core and the local cores 162
Fig. 3.23 SA west: The global core and the local cores 163
Fig. 3.24 SA west: choice core 165
Fig. 3.25 SA west: correlation analysis for choice and integration 165
Fig. 3.26 SA west: 5% most connected lines 165
Fig. 3.27 SA west: correlation analysis for connectivity against integration and choice 167
Fig. 3.28 SA west: 5% longest lines 167
Fig. 3.29 SA west: correlation analysis for length against integration, choice and connectivity 167
Fig. 3.30 SA east: integration cores 168
Fig. 3.31 SA east: the global core and the local cores 171
Fig. 3.32 SA east: choice cores 173
Fig. 3.33 SA east: correlation analysis for choice and integration (SA418) 173
Fig. 3.34 SA east: correlation analysis for choice and integration (SA299) 173
Fig. 3.35 SA east: 5% most connected lines 175
Fig. 3.36 SA east: correlation analysis for connectivity against integration and choice (SA418) 176
Fig. 3.37 SA east: correlation analysis for connectivity against integration and choice (SA299) 176
Fig. 3.38 SA east: intelligibility at the core level (SA418) 177
Fig. 3.39 SA east: 5% longest lines 177
Fig. 3.40 SA east: correlation analysis for length against integration, choice and connectivity (SA418) 178
Fig. 3.41 SA east: correlation analysis for length against integration, choice and connectivity (SA299) 178
Fig. 3.42 SB west: Integration Core 180
Fig. 3.43 SB west: The local core and the global core lines 181
Fig. 3.44 SB west: choice core 182
Fig. 3.45 SB west: correlation analysis for choice and integration 183
Fig. 3.46 SB west: 5% most connected lines 183
Fig. 3.47 SB west: correlation analysis for connectivity against integration and choice 184
Fig. 3.48 SB west: 5% longest lines 184
Fig. 3.49 SB west: correlation analysis for length against integration, choice and connectivity 185
Fig. 3.50 SB east: integration core 185
Fig. 3.51 SA east and SB east: comparison of integration cores before and after decomposition 186

Fig. 3.52 SB east: The local cores and the global core lines 188

Fig. 3.53 SB east: choice core 193

Fig. 3.54 The whole sector B: integration and choice cores 193

Fig. 3.55 SB east: correlation analysis for choice and integration 194

Fig. 3.56 SB east: 5% most connected lines 195

Fig. 3.57 SB east: correlation analysis for connectivity against integration and choice 195

Fig. 3.58 SB east: 5% longest lines 196

Fig. 3.59 SB east: correlation analysis for length against integration, choice and connectivity 296

Fig. 3.60 Comparison of cores 197

Fig. 3.61 Decomposition diagrams for sectors A and B 201

Chapter 4

Fig. 4.01 Typologies of urban grids 202

Fig. 4.02 Ranks of mean integration and mean choice values 205

Fig. 4.03 Housing estates and the global core lines 206

Fig. 4.04 Correlation analysis for integration and choice 207

Fig. 4.05 Correlation analysis for integration and size 210

Fig. 4.06 Barcharts for intelligibility: sector A 215

Fig. 4.07 Barcharts for intelligibility: sector B 219

Fig. 4.08 Correlation analysis for intelligibility and size 222

Fig. 4.09 Correlation analysis for intelligibility and size 224

Fig. 4.10 Ranks of intelligibility (local and global); correlation analysis for local and global intelligibilities 226

Fig. 4.11 Ranks of intelligibility and integration 228

Fig. 4.12 Correlation analysis for intelligibility and integration 229

Fig. 4.13 French and English settlements 232

Fig. 4.14 Ranks of axial fragmentation and tension 233

Fig. 4.15 Correlation analysis for axial fragmentation and tension 235
Fig. 4.16 Correlation analysis for axial fragmentation and tension 237
Fig. 4.17 Correlation analysis for axial fragmentation and tension 241
Fig. 4.18 Rank of ringyness/Correlation analysis for ringyness 244
Fig. 4.19 Correlation analysis for ringyness 246
Fig. 4.20 Ranks of connectivity and density of intersections 249
Fig. 4.21 Correlation analysis for mean connectivity and density of intersections 250
Fig. 4.22 Correlation analysis for mean connectivity and density of intersections 253
Fig. 4.23 Rank of figure-ground ratios 254

Chapter 5

Fig. 5.01 SA east: stages of development 259
Fig. 5.01 Ranks for densities of productive activities 263
Fig. 5.02 Ranks for densities of shops, offices and industries 265
Fig. 5.03 Correlation analysis for integration and densities of productive activities (shops, offices and industries) 266
Fig. 5.04 Housing estates in SA128 and SA184 267
Fig. 5.05 Correlation analysis for choice and densities of productive activities 270
Fig. 5.06 Correlation analysis for intelligibility and densities of productive activities 271
Fig. 5.07 Correlation analysis for axial fragmentation and tension against the densities of productive activities 272
Fig. 5.08 Correlation analysis for ringyness and densities of productive activities 274
Fig. 5.09 Correlation analysis for connectivity and density of intersections against densities of productive activities 276
Fig. 5.10 Correlation analysis for figure-ground ratios and densities of productive activities 277
Fig. 5.11 Areas of syntactic reference for SA west 281
Fig. 5.12 Distribution of shops in SA west 282
Fig. 5.13 Areas of syntactic reference for SA east
Fig. 5.14 Distribution of shops in SA east
Fig. 5.15 Areas of syntactic reference for sector B
Fig. 5.16 Distribution of shops in sector B
Fig. 5.17 Distribution of shops in sector B
Fig. 5.18 Distribution of shops in sector B
Fig. 5.19 Distribution of offices in SA west
Fig. 5.20 Distribution of offices in SA east
Fig. 5.21 Distribution of offices in sector B
Fig. 5.22 Distribution of offices in sector B
Fig. 5.23 Distribution of industries in SA west
Fig. 5.24 Distribution of industries in SA east
Fig. 5.25 Distribution of industries in sector B

Chapter 6

Fig. 6.01 Ranks for residential densities
Fig. 6.02 Fragment of SA184: housing estates 'infilled' in the street grid
Fig. 6.03 SA106: A curvilinear pattern
Fig. 6.04 Ranks for densities of houses and blocks of flats
Fig. 6.05 Ranks for densities of mixed buildings and housing estates
Fig. 6.06 Correlation analysis for integration and residential densities
Fig. 6.07 Correlation analysis for integration and residential densities
Fig. 6.08 Correlation analysis for intelligibility and residential densities
Fig. 6.09 Correlation analysis for intelligibility and residential densities
Fig. 6.10 Correlation analysis for axial fragmentation, tension and residential densities
Fig. 6.11 Correlation analysis for axial fragmentation, tension and residential densities 338
Fig. 6.12 Correlation analysis for ringyness and residential densities 340
Fig. 6.13 Correlation analysis for connectivity and density of intersections against residential densities 342
Fig. 6.14 Correlation analysis for connectivity and density of intersections against residential densities 346
Fig. 6.15 Correlation analysis for figure-ground ratios and residential densities 347
Fig. 6.16 Distribution of houses in SA west 355
Fig. 6.17 Distribution of houses in SA east 357
Fig. 6.18 Distribution of houses in sector B 359
Fig. 6.19 Distribution of houses in sector B 360
Fig. 6.20 Distribution of blocks of flats in SA west 363
Fig. 6.21 Distribution of blocks of flats in SA west 364
Fig. 6.22 Distribution of blocks of flats in SA east 365
Fig. 6.23 Distribution of blocks of flats in SA east 366
Fig. 6.24 Distribution of blocks of flats in sector B 367
Fig. 6.25 Distribution of blocks of flats in sector B 369
Fig. 6.26 Distribution of mixed residences in SA west 371
Fig. 6.27 Distribution of mixed residences in SA east 371
Fig. 6.28 Distribution of mixed residences in sector B 372
Fig. 6.29 Distribution of housing estates in SA east 376
Fig. 6.30 Distribution of housing estates in sector B 376
Chapter 3

Table 3.01 Traverse permeability' measurements for the south boundary of sector A 124
Table 3.02 Sector A: Measurements for differences, definitions and overlaps 142
Table 3.03 Sector B: Measurements for differences, definitions and overlaps. 153
Table 3.04 SA west: differences, definitions and overlaps. 162
Table 3.05 SA west: differences, definitions and overlaps. 163
Table 3.06 SA east: differences, definitions and overlaps. 171
Table 3.07 SB west: differences, definitions and overlaps. 181
Table 3.08 SB east: differences, definitions and overlaps. 188
Table 3.09 Sector A: correlations between syntactic measurements. 194
Table 3.10 Sector B: correlations between syntactic measurements. 194

Chapter 4

Table 4.01 Mean integration and mean choice values 205
Table 4.02 Intelligibility values for SA systems 215
Table 4.03 Intelligibility values for SB systems 219
Table 4.04 Measurements for axial fragmentation and tension 233
Table 4.05 Measurements of ringyness 244
Table 4.06 Measurements of connectivity and density of intersections 249
Table 4.07 Measurements of figure-ground ratio 254
Chapter 5

Table 5.01 Measurements for densities of productive activities 263
Table 5.02 Measurements for densities of shops, offices, and industries 265
Table 5.03 Distribution of shops and syntactic measurements for SA west: correlation analysis 282
Table 5.04 Distribution of shops and syntactic measurements for SA east: correlation analysis 285
Table 5.05 Distribution of shops and syntactic measurements for the whole sector B: correlation analysis 288
Table 5.06 Distribution of offices and syntactic measurements: correlation analysis (SA west) 299
Table 5.07 Distribution of offices and syntactic measurements: correlation analysis (SA east) 300
Table 5.08 Distribution of offices and syntactic measurements: correlation analysis (Sector B) 305
Table 5.09 Distribution of industries and syntactic measurements: correlation analysis (SA west) 309
Table 5.10 Distribution of industries and syntactic measurements: correlation analysis (SA east) 310
Table 5.11 Distribution of industries and syntactic measurements: correlation analysis (Sector B) 311

Chapter 6

Table 6.01 Measurements for residential densities 316
Table 6.02 Measurements for densities of houses and blocks of flats 318
Table 6.03 Measurements for densities of mixed residential buildings and housing estates 319
Table 6.04 Distribution of houses and syntactic measurements in SA west: correlation analysis 355
Table 6.05 Distribution of houses and syntactic measurements in SA east: correlation analysis 357
Table 6.06 Distribution of houses and syntactic measurements in sector B: correlation analysis 359
Table 6.07 Distribution of blocks of flats and syntactic measurements in SA west: correlation analysis 363
Table 6.08 Distribution of blocks of flats and syntactic measurements in SA east: correlation analysis 365
Table 6.09 Distribution of blocks of flats and syntactic measurements in sector B: correlation analysis 367
Table 6.10 Distribution of mixed residences and syntactic measurements in SA west: correlation analysis 371
Table 6.11 Distribution of mixed residences and syntactic measurements in SA east: correlation analysis 371
Table 6.12 Distribution of mixed residences and syntactic measurements in sector B: correlation analysis 372
Table 6.13 Distribution of housing estates and syntactic measurements in SA east: correlation analysis 376
Table 6.14 Distribution of housing estates and syntactic measurements in sector B: correlation analysis 376
Introduction

This research is focused on the study of the spatial configuration of the urban grid and moreover on the extent to which such a spatial configuration is related to patterns of land use distribution. From the study of these physical (configurational properties) and socio-economic (land use distribution) phenomena and their relationships this investigation intends to search for statements that might have general applicability to urban design theory and practice. The research seeks to establish a link between these two features of towns – urban morphology and land use – which have so far been studied separately.

Within the urban studies the spatial arrangement of land uses in cities has been mostly regarded as a by product of wider socio-economic factors, such as market forces, transportation costs and land value amongst others. As a consequence and despite its physical nature land use has been strictly considered as an economic variable embedded in urban planning procedures. The distribution of human activities in towns has been the object of ‘organizational strategies’ that have eventually led to zoning proposals which in theory aim to achieve a better quality of life in the urban environment. The results of these efforts have been in most cases an over-simplification of the commonly and traditionally accepted idea of urban environment as a rich, diversified and heterogeneous milieu. Towns designed according to the principles of zoning have shown an incapacity to generate and sustain new activities; especially economic activities different from the ones prescribed in the original plans. This is precisely the opposite of what happens in more traditional towns where human activities tend to emerge in diverse ways and locations and where the uses of land tend to follow dynamic tendencies which eventually come to be part of the very essence of urban life.
If on the one hand land use has been regarded just as an economic variable, on the other hand urban morphology has frequently been investigated as an autonomous field of study. In recent years architectural and urban theories with a morphological orientation have systematically criticized the modern approach to designing towns. Traditional cities have been taken as the paradigm to be followed as an alternative to the modernist or rationalist approach to town planning based on zoning strategies. According to this more recent tenet the street, the square and the urban block have become the repertoire to be utilized in urban design practice in order to restore lost urban qualities. Urban morphological studies developed in the last twenty years have for most part concentrated upon the description of cities as autonomous 'physical artifacts'. This is the case of the influential works of Rossi (1966), Rowe and Koetter (1978) and Krier (1979).\textsuperscript{1} The functional dimension of towns has been largely disregarded or simply considered as an implicit consequence of the adoption of this limited range of morphological archetypes. It has been assumed that if the design of towns is carried out according to the repertoire of tradition, the functional heterogeneity characteristic of traditional cities tends to emerge as a direct consequence.

This research intends to introduce another approach in respect of these questions: the performance of land use distribution, the description of the morphological features of towns and especially on the way these two relate. The hypothesis advanced here is that in traditionally evolved towns a natural or spontaneous distribution of land uses is strongly associated to inputs that come from the spatial arrangement of the town or, more precisely, from the spatial configuration of the street grid. The exact meaning of 'spatial configuration' within the context of this study would be worth clarifying at the outset, although this seems to be a too complex task at this stage. In effect much of this study will

concentrate on disentangling the wide range of standpoints from which the spatial configuration of the urban grid can be described.

Nevertheless the term 'configuration' has a more general understanding which refers to a particular manner of arrangement, shape or outline.\(^1\) This general meaning might be a reasonable point of departure yet the problem of how to describe such a 'manner of arrangement' in the street grid still remains. And it is precisely the diversity of configurations of the street grid - which are peculiar for different towns and also for different areas within the same town - what in effect brings about all the richness and complexity of the subject to be scrutinized in what follows. Hence the description of the 'object' urban grid (or street grid) in itself will play an effective role in defining in precise terms the different standpoints from which such a configurational character is understood in the context of this investigation.

For doing so this study will carry out a systematic analysis of a variety of urban areas, which comprise a representative selection of the potentially endless range of grid configurations that can be observed in large cities.\(^2\) The sample of grid configurations to be examined is taken from the city of Porto Alegre in the south of Brazil. The simultaneity and interaction of a large variety of grid configurations inside the same city make of Porto Alegre a case where this research seems to have fertile grounds for development. The configuration of the street grid of Porto Alegre carries in itself examples of baroque urbanism, garden city developments, modern housing estates and self-produced settlements, all interacting spatially inside the same city. In view of this 'morphological patchwork' Porto Alegre might be regarded not only as a paradigm of the contemporary south american large city but most

---


2 This does not mean that small towns cannot carry a variety of grid configurations, yet the range and distinctiveness of the arrangements that can be observed in large cities tend to be more conspicuous.
probably as representative of most spatial configurations available in western cities.

Having carried out the descriptive account of the urban grid this study intends to investigate the relationships between configurational characteristics of the urban grid and the empirically observed pattern of land use in the areas under scrutiny. In this respect, the current research does not assume that configurational factors are in themselves responsible for the generation of different patterns of land use distribution, although the investigation aims to show that the 'manner of arrangement' of the street grid is closely associated with and probably influential in the way such a distribution of land uses occurs. The conjecture here is that uses tend to distribute themselves according to 'inputs' coming both from the position of the urban spaces (streets, squares and their morphological variations) in relation to immediate surroundings (spatial surroundings) and also from their position in relation to the global spatial organization of the grid.

The distribution of land uses would be in this sense a feature correlated to the spatial configuration of each individual urban area as well as to the way the spatial configuration of each urban area interact with the spatial configuration of surrounding urban areas. In other words the conjecture here is that functional distribution is associated with the configurational or 'syntactic properties' of precisely defined groups of urban spaces which interact spatially with each other.\(^1\) Such an hypothesis implies that land use should not be dealt with as a quantitative parameter to be assigned to whole areas or 'zones' of towns, for each street of a town has its own syntactic identity and the concentration of shops, industries and even of residential use it carries.

\(^1\) The study of the combinatorial or 'syntactic' dimension of urban grid has been originally developed by Professor Bill Hillier and Dr. Julienne Hanson in the Unit for Architectural Studies (UAS) of the Bartlett School (University College London) and is published in Hillier, B. and Hanson, J. *The Social Logic of Space*, Cambridge University Press, Cambridge, 1984. The 'syntactic description' of the street grid will be the main analytic tool to be utilized during this thesis. The detailed presentation and discussion of the methodology of syntactic analysis of the urban grid is carried out in chapter two of this thesis.
is, it is conjectured, a feature linked to this syntactic or positional identity. Instead of dealing with the street grid as a by-product of predominant spatial 'types', as the authors referred to previously have suggested, this research will investigate the urban grid as a spatial continuum to which all land uses are attached and related.

The hypothesis stated above implies that it may not be possible to generate a functionally complex urban environment - in the traditional way - through the simple use of a repertoire of traditional urban components; street, square and urban block so reproducing a traditional street grid. If the syntactic properties of towns are influential in the distribution of land uses, different types of grids and even similar grids with different sorts of interaction with the surrounding areas might be expected to bring about totally different patterns of distribution of land uses. If this is the case it is useless for urban design practice any attempt to imitate an ideal spatial configuration based upon the traditional urban grid since functional heterogeneity and urban life cannot be guaranteed as a direct consequence of the adoption of these geometries.

Instead what seems to be required at the current stage of development of urban design studies is a careful investigation of the configurational properties of a wide range of different patterns of urbanization (as given by a range of grid configurations), their process of interaction within the spatial continuum of the street grid and how socio-economic variables behave in view of these spatio-morphological transformations (or deformations) that constitute the outstanding feature of the contemporary city. This research aims to clarify some of these complex issues which eventually comprise the dialectic between form and function at the urban level.

This thesis is organized in six chapters. It starts by reviewing briefly the literature on urban land use and urban morphology (chapter one). It
evolves to the presentation of the methodology of analysis (chapter two) which performs as an introduction for the empirical chapters where the case studies will be analysed and discussed so allowing in the first instance (chapters three and four) for a detailed description of what has been defined for the purposes of this study as 'configurational characteristics' of the street grid and, in a second instance (chapters five and six) for the matching of such configurational features with the patterns of land use distribution observed in a range of cases. As the structure outlined above suggests, the precise description of the configurational characteristics of the street grid plays a central role within the current research, not only for the sake of clarification of the laws of the object street grid in itself but moreover, for setting up a descriptive (or configurational) benchmark against which to compare the performance of different patterns of land use.
Chapter 1
Urban Land Use and Urban Morphology:
Two distinct approaches for describing the same phenomenon

This chapter provides a brief review of research works carried out in the fields of urban land use and urban morphology. Although many of the works to be discussed in what follows have little in common with the approach taken by the current research in relation to the urban phenomenon, it is precisely by presenting and discussing these works that the review aims to demonstrate the existing gap within the urban studies right at the complex interface between these two ways of approaching the urban phenomenon; one strictly concerned with function (urban land use studies) other restricted to form (urban morphological studies).

Land use as a de-spatialized variable

Contributions to a theory of urban land use have been made by researchers in a variety of disciplines: economists, sociologists, architects, geographers, civil engineers and ecologists have all contributed to the field. This review of selected research does not intend to be exhaustive, rather it is focused on those research works which appear to offer some attempt, in one way or another, to link land use distribution to the spatial dimension of cities. Thus this chapter does not intend to cover those material oriented towards the provision of guide-lines for policy formation, implementation of masterplans or theoretical studies related to zoning.

Nevertheless it can anticipated that the concept of space to be found in the urban land use works to be reviewed is not related to the spatio-morphological dimension of towns. Although the term space is often used in most of these works, it carries a different meaning from the one it will carry during this thesis, i.e. space in the sense of the urban
spaces belonging to an intra-urban scale; the scale of the street, the scale of each individual spatial component of the public open space of a town.

By contrast, the studies to be reviewed in this chapter are more committed to the urban process rather than with the dimensions of the urban form. The concept of space will be in some cases embedded inside an economic variable, such as transport cost, distribution of rent paying abilities or, as in other cases, applied in order to describe an area as a continuous urbanized whole, as if it were a region (generally made up of zones) where built forms and open spaces are indiscriminately assumed as featureless entities, from the spatio-morphological stand-point. In view of this, we suggest that perhaps the main challenge in this field at the present time is the development of a descriptive theory of land use from the spatio-morphological point of view.

This review on urban land use studies covers a range of the most significant contributions to the economic approach to urban land use. It includes studies committed to the relation between land market and land use patterns. These are Hurd (1903), Burgess (1925), Hoyt (1939), Harris and Ullman (1945) and Berry (1963). A second area covered includes those economic studies that explain the distribution of land use through the concept of transportation cost. Authors reviewed here are Von Thunen (1826), Weber (1909), Christaller (1933), Losch (1954), Wingo (1961) and Alonso (1964). Thirdly those studies committed to the notion of functional attraction, i.e. gravitational models, will be examined. They are Reilly (1931), Artie (1959), Clark (1951), Hansen (1959) and Lowry (1964) will be looked at under this heading.

The subsequent step covers what might be called 'socially rooted' approaches to urban land use although as expected the underlying presence of economic values seems to be a constant in these research works, just as socio cultural assumptions are present in most of the economic oriented works. This part of the review deals with what might
be called as 'human interaction' theories of which the work of Webber (1964) seem to be the classic representative. Finally this review discusses the work of two authors - Jacobs (1962) and Siegan (1973) - which, although not explicitly concerned with configurational variables, have depicted the character of functional diversity so often observed in naturally evolved or unplanned urban areas. Whilst remaining distinct in their nature, both these studies have detected what might be called the 'natural zoning' of unplanned land use distributions which, according to these authors, seems to be strongly affected by the physical characteristics of the urban environment.

**Land Market and the Distribution of Uses**

The model proposed by Hurd (1903) seems to be one of the earliest theoretical efforts which deal with patterns of urban growth and their relationship with land use distribution.¹ His theory proposes a pattern of urban growth based upon concentric zones. Although Hurd does not refer to the concept of concentric growth he originated the idea with his description of 'central growth' and the concomitant segregation of land uses into definite districts or zones.

Central growth is defined by Hurd as the clustering of activities around points of attraction. The concept is based on proximity. The mixture of 'utilities' around an attraction point result in a spatial pattern exhibiting observably distinct districts: 'Residences are early driven to the circumference, while business remains at the centre, and as residences divide into various social grades, retail shops of corresponding trades follow them, and wholesale shops in turn follow the retailers, while institutions and various mixed utilities irregularly fill in the intermediate zone, and the banking and office section remains at the main business centre.'² Despite the fact that his description of zones

---

² ibid. p.58.
is fairly crude, Hurd identify the concentric city as a paradigmatic type of urban form.

The role of economic factors in the distribution of land uses is central to Hurd's argument. In his identification of the economic factors contributing to the location of particular land uses, Hurd focuses on the principles of accessibility and proximity which form the bases for his hypothesis of a central growth. These principles underlie land values with businesses and individuals bidding for land: "Since value depends on economic rent, and rent on location, and location on convenience, and convenience on nearness, we may eliminate the intermediate steps and say that value depends on nearness. Land goes to the highest bidder, the highest bidder being the one who can make the land earn the largest amount." Furthermore, Hurd observes the dynamic nature of urban land use patterns which suggests that the distribution of uses in a growing urban area is continually in a state of disequilibrium. Two forces, the centripetal force of economy in the transaction of business and the centrifugal force of cheap land, are seen as conflicting factors leading to a continual readjustment process: "The uniform tendency as a city grows is toward greater concentration in the business centre and greater dispersion in the residence sections, and as long as there is an outward movement so long is there certain to be a continual readjustment at the business centre to conform to it." Hurd notices that this adjustment process is relatively slow and that in the absence of a known rate of adjustment, accurate predictions of future movements of urban growth are impossible.

Hurd's model has provided the basis for much of the subsequent research on urban land use theory. The basic ideas presented by Hurd were fully explored by Burgess, Hoyt and Ullman and Harris in the development of their principles of urban structure and growth. Hurd formally initiated the reliance on economic forces to explain location patterns, although he

---

1 ibid. p.77.
2 ibid. pp.79-80.
recognized that economic forces themselves must ultimately be explained as a social phenomena.

A more developed theory based upon the assumption of concentric growth was developed by Burgess (1925) who described distinctive locational patterns consisting of alternating layers of residential and non-residential zones. Burgess' proposal is directly associated to Robert Park's analogies between the human world and the plant world. The model assumes that the competitive urban land utilization process derives its energy from population and area expansion occurring in a pattern of concentric rings.

Assimilating Park's ideas and taking them one step further, Burgess proposes a 'concentric zone theory'. The first zone consists of the Central Business District. The second zone, encircling the first, is a transition area in which business and light manufacture advance gradually beyond residential land. This zone represents the outward expansion of the area of industry, commerce and business that will merge with high-density residential dwellings occupied by the poor population. The third zone is composed of working class homes whose inhabitants have escaped the transition zone, but desire to live in an area easily accessible to factories and shops. As a 'second-generation' settlement zone, this area represents the outcome of the process of successive land invasion. The fourth zone is a residential area of high-class apartments or of exclusive single-family districts, inhabited by white-collar and professional people. Burgess' model implies that increasing distance from the centre is associated with increasing social status. The fifth concentric ring is the commuters' zone, consisting of satellite cities or suburban areas. The theory suggests that the size and

2 Park, in an article entitled 'Human Ecology', notes the 'competition' between various population groups of an urban area, the 'dominance' of some groups, the 'invasion' of a natural area by a competing group and the consequent 'succession' of a new group to the position of dominance. According to Park, this competition is restrained, unlike within that in the plant world, by conventions, institutions and laws. Park, R. Human Ecology in R.E. Park et al. (eds), The City, Chicago: University of Chicago Press, 1925.
specific character of the zones change over time due to the on-going processes of invasion and succession.

Burgess' model is essentially concerned with portraying the processes of urban expansion in terms of extension, succession and concentration. He proposes a typical pattern for American cities based on Chicago's pattern of locational differentiation into 'natural' economic and cultural areas. Nevertheless, Burgess himself recognizes that the model is a purely conceptual one and that disturbing influences, such as topography and the disposition of lines of communication, tend to distort the theoretically concentric circles when applied to real towns.

Moreover the model seems to carry a series of underlying assumptions involving both contextual factors and value orientations. Examples of the former are the assumptions of an homogeneous economic base within the city of mixed commercial and industrial activities and also the existence of an efficient transportation system which is equally rapid in every direction at the same cost. These assumptions set the limits of the model. If on the one hand they allow for a deterministic model, on the other hand they render Burgess' theory only a partial description of the urban structure. As examples of value orientations the model assumes that profit maximization is the motive underlying land acquisition and, correspondingly, of the value placed by businesses on a central location due to greater accessibility to the entire city. Other assumption is the social value placed on residential location at the urban periphery, which seems to stem from the value placed on open space and larger houses with gardens, and the lack of institutional constraints, giving room for an economic competition with relatively little institutional intervention. These assumptions may mask the effect of cultural values and institutional arrangements related to land use distribution.

In summary, the contribution of Burgess's concentric zone theory lies in its provision of a generalized spatial diagram allowing for further empirical verification and refinement in different socio economic and
physical contexts although such a diagram does not give a complete answer to the challenge of providing a framework for the identification of relationships between land use distribution and more specific spatial determinants coming from the morphological dimension of the city.

Different from Burgess, in that he deals with both residential and non-residential location patterns, Hoyt's sector theory (1939) develops a model which is primarily concerned with land use patterns resulting from residential development.¹ The basic principle of this theory is that different income groups are segregated into urban 'sectors' or 'wedges' rather than distributed concentrically around the central area. The empirical basis for Hoyt's theory is a study of 140 American cities for which block data were gathered on population and housing stock characteristics. The model relies on the assumption that average block rent is representative of all other housing variables: 'Since the average rent of dwelling units in a block reflects the characteristics of the block which can and cannot be measured, patterns of rent may be fully relied upon to serve as a guide to the structure of residential neighbourhoods.'²

Hoyt's model suggests that the high-rent or high-cost residential areas can be found in distinct sectors within a city with rents decreasing gradually in all directions from these sectors: 'The rent area in American cities tend to conform to a pattern of sectors rather than of concentric circles. The highest rent areas of a city tend to be located in one or more sectors of the city. There is a gradation of rentals downward from these high rental areas in all directions. Intermediate rental areas, or those ranking next to the highest rental areas, adjoin the high rent area on one or more sides, and tend to be located in the same sectors as the high rental areas. Low rent areas occupy other entire sectors of the city from the centre to the periphery.'³ He also concludes that there is no 'geometric pattern' representing the location of high and low rent

---

² Ibid. p. 72.  
³ Ibid. p. 76.
sectors which is applicable to all cities, i.e. each urban centre has a
pattern of rent areas that is to a certain extent unique. No two cities
have high rent areas of the same size or shape or in the same location
with respect to the centre of the city. Topography, rapidity of urban
growth, location of industries and transportation lines, the movement of
the leaders of society, all produce different rental patterns.

In common with Burgess's theory, Hoyt also assumes the existence of a
single business centre. Nevertheless this seem to be their only point in
common. Hoyt's observation that there is no upward gradation of rents
from the central area to the urban fringe in all directions seems to be of
particular significance. He shows high rent areas as occupying only part
of the outer circumference, with some cities having low rent sectors
extending from the centre to the periphery. This clearly refutes
Burgess's placement of the 'better' residential areas in a concentric
circle at the farthest distance from the centre, assuming that these
residential areas are associated with relatively higher rents. Hoyt's
conclusion apply directly to Chicago, the city on which Burgess had based
his concentric zone theory. With this respect Hoyt shows Chicago's 1934
periphery to include sections with rents of $10-19.99, as well rents of $ 50 and over.

In summary, Hoyt has provided a description of residential land use
patterns and urban growth tendencies which contrasts rather sharply
with the concentric zone theory relative to the location of different
residential rent areas. Hoyt provides evidence on the direction of growth,
as well as the location of particular rent areas with respect to each
other and to the central area at particular points in time. He also
attempts to identify factors influencing the location of higher-priced
residential areas and, following Hurd, notes that these areas determine
the subsequent location of lower rent districts. Nevertheless Hoyt's
theory lacks an analytical framework integrating the factors identified
as impacting the structure of the city. The relationship among social,
economic and institutional factors is not clearly delineated, and the
influence of non-residential land uses on residential location and growth patterns is unclear. The lack of integration may stem from the partial nature of Hoyt's work, since he focuses solely on housing characteristics in general and only represented by rental values.

While the theories proposed by Hurd, Burgess and Hoyt are based upon the assumption that the growth of towns tends to occur around one single central area, the model proposed by Harris and Ullman (1945) suggests that an urban area may originally have more than one centre around which growth occurs.¹ In fact both Burgess and Hoyt had recognized the formation of sub-business centres, although these centres had not been explicitly incorporated into their spatial models. In contrast, for Harris and Ullman the patterns of land use within a city result from growth around several nuclei. Moreover, these nuclei need not be 'business' centres.

Harris and Ullman suggest that four factors affect the emergence of distinct nuclei within the city: the interdependency of certain types of activities, requiring physical proximity to specialized facilities such as transportation networks or services; the natural clustering tendency of certain types of activities which enhances profitability; the clustering of activities having no particular affinity for each other, but which are nuisances to other uses; the inability of certain activities to afford the high rents or land costs in certain areas of the city. These authors suggest that these factors are likely to operate in combination during the process of nucleation.

Although the original central area is still regarded by these authors as a rather universal nucleus, they postulate that other nuclei will emerge with similar importance in the form of industrial or wholesaling centres, major retail centres, educational centres, suburban centres, or satellite communities. Such land uses as a factory area or a retail

district may themselves serve as nuclei attracting additional growth. Other districts constituting urban nuclei may result from individual structures or land uses such as railroad stations, beaches and so on. Another form of nucleus is often provided by residential districts segregated by class, with high-class districts in desirable locations lacking environmental nuisances and low-class districts located near factories and railroad districts.

In view of its incipient degree of elaboration the multiple nuclei concept cannot justifiably be called a theory, rather Harris and Ullman have just developed an hypothesis which depicts more accurately the complex reality of contemporary urban land use patterns and allows room for a wide range of subsequent investigation.

This is also the case with Berry (1963) in his study of Chicago. Berry recognizes a multiple nuclei organization with a four level classification of centres. From the more locally oriented to the more global, these centres are: isolated convenience stores and streetcorner developments, neighbourhood business centres, community business centres and regional shopping centres. Barry suggests these centres tend to distribute themselves according to a pattern of catchment areas, i.e. these centres display location patterns that conform to the geographic distribution of consumers. Each is located centrally with respect to the maximum number of consumers it can serve.

Berry's differentiation in the patterns of location of these centres is mostly based upon the income of the population. He points out that there are marked differences in the hierarchy of centres between the higher and the lower income areas of the city. In higher income areas all four hierarchical levels are present, signifying the wider variety of shopping trips generated by higher income households and the greater distances travelled by families with more funds available to them. Lower income

---

areas, on the other hand, have neither major regional centres nor community centres. Shopping in the lower income areas is characterized by greater local orientation. Since incomes are lower there is inadequate support for the more specialized shopping stores that distinguish major regional from smaller shopping centres. Neither is there support for the greater range of convenience goods establishments that differentiate community centres from the smaller area convenience goods centres.

Despite his efforts at classification Berry eventually acknowledges the high degree of complexity that is often observed in land use distribution patterns. He observes that commercial uses often tend to interweave randomly and also disregarding the aspects of size and degree of specialization of the different centres. He also observes that higher order centres in many cases perform lower order functions, thus their lower order goods have somewhat larger trade areas than centres which are exclusively of that lower level. The opposite happens when a large commercial enterprise, belonging to the regional or even to the metropolitan scale, comes to be located in lower scale centre. In summary, Berry's contribution is particularly relevant both for its analysis of more complex patterns of mixed uses and moreover for its description of the changes in centre-periphery relationship, thus providing rather consistent evidence of the multiple-nuclei pattern observed in Chicago.¹

Transportation Cost and Land Use

The fundamental concept behind the studies to be reviewed in this section is that urban systems can be understood through the mechanism of an economic market composed of producers and consumers working

¹ With this respect Berry points out: '... only fifty years ago the central business district provided almost all the goods and services demanded by the residents of Chicago. Since 1910 a complex array of outlying business centres and commercial ribbons has developed to serve these residents. The 1953 Census of Business reported that all but 14.6 per cent of Chicago's retail transactions were completed outside the CBD in that year.' Ibid. p. 19.
within a system of perfect competition. The performance of these actors, producers and consumers, is explained as a consequence of their seeking to minimise their costs. The linking of the economic theory with spatial distribution is set up through the concept of transport cost, i.e. travel or transport cost is the variable that introduces the spatial dimension into these urban theories.

Von Thunen (1826) presents the earliest attempt to develop this kind of location theory. However his concern was to explain the location of types of agriculture the basic principles of his model were subsequently adapted to explain urban land use patterns. Von Thunen puts forward a very simple model of the world, consisting of one town and its surrounding region. All the agricultural products are sold inside this single centre. Thus the isolated state is 'featureless plain' with transport costs that increase radially from the centre of the town.

Von Thunen is concerned to explain, first what type of crop will be cultivated at different distances from the town centre and, second, the rent the producer will pay to the landlord to use a particular location. The theory evolves into both a locational model and a rent model for according to the distances from the centre particular crops will outbid others. Thus the pattern of location of crops will be concentric, i.e. the most intensive use of land will be near the centre and the rent or land values will decrease outwards. The pattern of crops in the hinterland will be located in direct relation to the frequency of communications required.

Based on perceived transportation savings at various locations, different land users will bid for land, thereby allocating it efficiently according to the criteria of profit maximization. The same proposition will be applied by authors to be further reviewed to urban situations where the crop types are replaced by urban land uses. Hurd's theory already presented,

however more centred on the role of land values than on transportation costs, evolves into a similar configuration of concentric zones.

Weber (1909), following the line of transport cost minimization, develops a theory for industrial location.\(^1\) His problem is to explain the location of an industry, like Von Thunen, in a featureless plain. The model implies that for an industry to be located two factors are to be considered, the location of the raw material and the location of the market where the firm is supposed to sell its output. In summary, if the transport costs from the sources of raw material to the industry and of the finished product to the market are known, the optimum location for the industry can be found.\(^2\)

Losch (1954) proposes a theory according to which the location of services, again in a theoretical featureless plain, is a consequence of the size of the consumer market related to that activity.\(^3\) The model assumes that there is a minimum population needed to support a service and that the number of consumers related to this service determines the size of the market area of that service. If all the consumers are distributed homogeneously, the spacing of the services will also be homogeneously distributed. Based upon this assumption the model proposes a classification of centres into hierarchical groups according to the type of service and the size of the market area.

Following a process of perfect competition the distribution of services will eventually perform a pattern of ‘nested hexagons’.\(^4\) In fact such a

---


\(^2\) Two sources of raw material are considered in the model, constituting with the market the classical Weber triangle.

\(^3\) Lösch, A. *The Economics of Location*, New Haven: Yale University Press 1954.

\(^4\) This pattern is inherited from Christaller’s Central Place theory which suggests similar configuration for the location of settlements at the regional scale. Christaller, W. *The Central Places of Southern Germany*, Prentice Hall: E. Cliffs 1933. The concept of catchment area proposed by Berry seems to have roots in these earlier configurations.
pattern of hexagons seems to be just an ideal geometric accommodation of circular market areas in the theoretical featureless plain, i.e. for the hexagonal pattern there will be no areas left at the interstices between hexagons as it would be at the interstices between circles if the pattern were to be presented as circular. As an economic interpretation for this spatial distribution the model suggests that if the population is distributed homogeneously throughout the plain there will be an increase in the demand for particular goods near to the centre in view of the decrease in transport cost. Conversely the demand curve will drop away with the increase of distance from the centre.

The work of Wingo (1961) provides perhaps the most systematic and rigorous statement of urban systems in the framework of transport cost analysis.¹ The central problem of this research is to achieve an equilibrium between the distribution of households of particular rent-paying abilities and sites with a particular structure of rents. With his attention mainly directed towards residential development Wingo develops a concept of transportation demand related to the distances between home and work. Assuming journey to work as 'the technological link between labour force and production process', he defines demand for movement as the total employment of an urban area multiplied by the frequency of work, i.e. the number of trips required to support the production process. The concept of space is embedded into one main unit of measurement, the cost of transportation based on the time spent in movement between points and the 'out of pocket' costs for these movements expressed in money equivalents for distance and number of trips.

The model achieves a location equilibrium between distribution of households and structure of rents by substituting transportation costs for space costs. On the supply side he utilizes transport costs to establish the distribution of household sites at varying position rents. On

the demand side the rents households are willing to pay are based on a 'class utility concept', which holds that the greater the unit rent the fewer the units of space consumed. This view of space use clearly leads to the notion of density, for the smaller the quantity of space consumed in the more accessible locations the higher the density. Thus the spatial distribution of these densities in the urban area involves a density gradient concept with the slope falling off from the centre of the city to the outskirts. Eventually to get at the characteristics of demand in the spatial context, Wingo constructs a demand schedule to determine the point at which prices and densities are in equilibrium.

Following the Von Thunian concentric concept, Alonso (1964) proposes a location model based upon the bid rent function. Compared to Wingo his model uses the market mechanism in a somewhat different way in order to distribute space users to urban land. Instead of developing a demand function he uses 'bid price curves' which in interaction with the price structure of land are used as a basis for distributing economic and residential uses. The model suggests that starting from the city centre land is 'put up for bid', and on the basis of these curves the bid for the most central site is compared to the next preferred alternative, with this preferred alternative being the combination of price and location for that particular use. According to this logic on the basis of the steepest bid price curve the highest bidder takes the most central site available and so on.

The models proposed by Wingo and Alonso seem to be the most developed which have been presented so far. The conceptual system is rigourously stated and the internal logic of these models is observed throughout. Nevertheless if we depart from their internal logic towards an account of the spatial organization of real cities these models suffer from the same limitations observed in all models reviewed in this section. The most outstanding of these limitations, let alone the avoidance in dealing

with the urban form, seems to be the reliance on the existence of a single focal point for measuring accessibility. This rigid assumption seems to be used in order to enable a mathematical formulation of urban location decisions and land use patterns. By assuming the concentric zone concept as an underlying pattern these models can ignore not only the locational interdependencies among economic activities but also the correlated effects of these interactions on residential patterns and vice-versa.

Recent attempts of modelling the relationship between land use distribution and transportation cost have not advanced towards the inclusion of configurational characteristics given by an intra-urban scale and have to a large extent followed the concepts put forward by the classic works of Alonso and Wingo.2

**Attraction or Gravitation Models**

The models so far presented have dealt systematically with the actions of individuals or groups as social actors; the producer and the landlord for Von Thunen, the industrialist for Weber, residential groups for Alonso and so on. The next approach to be presented, in contrast to the previous one, looks at the urban phenomena in aggregate. It is no longer important to appreciate the motivations behind the actions of individuals, instead the interest is focused on the behaviour of the mass, i.e. the aggregate of individual actions.

The fundamental assumption underlying this approach is the concept of attraction or gravitation, directly derived from the physical sciences, i.e. the concept of physical gravitation as an analogue to explain social attraction. The origins of this approach seem to come from studies of social-physics developed during the eighteenth century by utopians like

---

2 This is the case of de la Barra, T. Integrated land use and transport modelling, Cambridge University Press, 1989.
Saint-Simon and Fourier, however the widely known contribution in the
field comes from Carey (1858) with his derivation of the gravity model
for the social sciences: 'gravitation is here in human society as
everywhere else in the material world, in the direct ratio of the mass of
cities and inverse ratio of the distance'.

The general formulation of the gravitational models can be intuitively
grasped. Take as an example some type of interaction such as the traffic
flows between cities. If we assume as an hypothesis that travel is
instantaneous and costless, one could expect a high probability that the
traffic flows between pairs of cities would be proportional to their size,
i.e. to their mass, simply because distance imposes a cost, an effort, and
therefore the probability of travel decreases with the increase of the
distance. From this principle of interaction are derived the locational
models based upon gravitation, i.e. if the distribution of the origins is
known one may be able to predict the location of the destinations based
on some kind of attraction function. A number of models including
different urban functions have been developed from this same idea:
migration, transport, residential, retail, etc. The basic formulation is
systematically repeated; if the location of employment is given, the
location of residence can be predicted based on the concept of distance
plus some kind of attraction, or if the location of consumers is given, the
location of services can be predicted and so on. The development of the
urban models based on the concept of attraction has been extensively
reviewed by Carrothers (1956) and Batty (1972). This review will
present in short some examples of this concept applied to retail location
and residential location.

The model developed by Reilly (1931) is the first retail model based on
gravitation. He formulated a law of retail attraction according to which

---

2 Carrothers, G. An Historical Review of the Gravity and Potential Concepts of
   Batty, M. Recent Developments in Land Use Modelling, Urban Studies, Vol.9 1972,
   pp. 151-77.
two centres attract trade from an intermediate place, approximately in
direct proportion to the size of the centre and in an inverse proportion to
the square of the distance from the centre. The model is initially
concerned with the measurement of flows of people between origins and
destinations. From that is set up the delineation of potential market
areas which give rise to the prediction of the adequate location for a
given retail centre. In short, the model expects to predict the potential
of a particular zone to attract consumers. Huff (1962) has developed an
extension of the same approach for a pattern of multiple retail centres.1

Starting from a similar basic concept Artle (1959) suggests the use of
an income model for estimating the characteristics of the distribution of
retail establishments in Stockholm.2 Artle’s work proposes a probability
model to pinpoint the clustering of establishments as they become
distributed in retail areas. In this kind of application of the gravity
model, income is used in the numerator, with the usual time or distance
measure in the denominator. Thus this formulation carries the
assumption that the income of people living in any particular zone has a
potential influence on all other zones, but with this influence declining
with the increase of distance. Based upon a forecast of the aggregate
income potential in each zone and viewing this income in terms of
possible future demand, Artle suggests that this model can be used to
distribute to sections of the metropolitan area a total number of retail
establishments of appropriate types.3 The characteristics of these
appropriate types are previously estimated from an ‘input–output’ study.

Hansen (1959) proposes a gravity model for the prediction of residential
development.4 He uses the concept of accessibility as an organizing
concept for distributing to specific sections of the metropolitan area a

---

1 Huff, D. Determination of Intra–Urban Retail Trade Areas, Los Angeles, University of California 1962.
given aggregate estimate of residential growth. His basic concept
describes the distribution of new population to zones according to their
respective 'development potentials' relative to those of all other zones
in the metropolitan area. To estimate a zone's development potential,
Hansen establishes what he calls a 'development ratio', which is
operationally defined as a function of accessibility to employment. In his
formulation of the accessibility function he uses the gravity model. He
stated that the accessibility at point A to employment in area B is
directly proportional to the size of employment in area B and inversely
proportional to a function of the distance separating point A from area B
(travel time). Applying this relationship to all employment zones a
composite measure of accessibility is obtained. Having devised a means
of estimating a zone's accessibility to employment and from this its
development ratio, Hansen proceeds to distribute household population to
the metropolitan area, taking into account the increase in residential
population in each area, the total increase in residential population for
the entire metropolitan area and the total amount of land available for
development. The model proposed by Hansen comes to be the base of a
number of subsequent studies. A similar concept is used by Lowry (1964)
in his model of metropolis.¹ Extensions of the same idea have been used
by Batty (1969) and Echenique et al. (1969), not as a potential model but
dealing with actual trips between work and residence.²

Models based upon the gravitational theory were found useful in the
description of land use patterns in small urban areas, however the model
has proved weak when dealing with metropolitan areas where the central
city is an area of declining population with only the outlying suburbs
receiving growth. Moreover, although gravitational models have been

² Batty, M. *The Impact of a New Town: An Application of the Garin-Lowry Model*,
   Echenique, M., Crowther, D. and Lindsay, W. *A Spatial Model of Urban Stock and
quite successful in describing different aspects of urban reality, the fact that remain is that these models are not really explaining that much. Instead they seem to be just making the outcome consistent with the information input, i.e., the models tend to depart from measures of accessibility in order to explain patterns of land use distribution, although, we suggest, the measures of accessibility are in themselves an outcome of the way the problem is formulated, they are not the reason why the pattern of use occur in that specific way.1 Apart from that the fine-grain variations of land use pattern at the street scale, which is the object of the current study, is hardly manageable by using the models presented above where one point (or one 'node') might correspond to a large urban area or even a whole town when the model is applied at the regional scale.

Human Interaction Theories

Another branch of the literature on land use is the one concerned with human behaviour or patterns of human interaction as a determinant factor for the explanation of the distribution of activities. Following this line Webber (1964) utilizes interaction as the basic organizing concept of his theoretical system.2 He observes urban communities in two related perspectives, i.e., two aspects of human interaction which he suggests must be taken into account in the urban studies. A first type of interaction occurs in systems which tend to have a locus in particular urban areas at a particular time, while a second type refers to systems which have no specific spatial boundaries but may be region-wide, nation-wide, or world-wide at any particular moment in time.3 To give some differentiation in the spatial meaning of these two kinds of activity systems, Webber has suggested the term place community for

---

1 The example provided by Hansen is classic with this respect, since the measure of accessibility is in itself a function of distance plus employment size.
3 Ibid. p. 146.
the first kind of system and non place community for the second. Webber is concerned with modern transportation and communications having the effect of stretching distances. He notes that individuals, firms, organizations and institutions more and more have contacts, conduct transactions and maintain communications on a global basis, thus their ties may extend to a variety of non place communities. To distinguish them from the urban place, he calls these nonplace communities urban realms.

In both the place and non place view of the urban community, Webber emphasizes his view of the city as a 'dynamic system in action'. This dynamic feature is traced through 'linkages' which he defines as 'dependency ties' relating individuals, groups, firms, etc. He terms these 'the invisible relations that bring various interdependent business establishments, households, voluntary groups and personal friends into working associations with each other - into operation systems'.¹ His spatial counterpart for this aspatial view of linkages involves three related perspectives. First is a view of the city in terms of spatial patterns of human interactions, i.e. flow of communications people, goods, and so on. Second is a view of the physical form of the city, i.e. the space adapted for various human activities and the pattern to networks of communication and channels of transportation. Third is a view of the city as a configuration of activity locations, i.e. the spatial distribution of various types of activities by economic functions, social roles, etc. This three-component perspective of urban spatial structure is further developed into a descriptive classification scheme. Six dimensions of each component (human interactions, physical plant and activity locations) are suggested: size of the phenomena, tendency toward concentration in concentric forms, tendency toward concentration in subcenters, degree of 'pile-up' or concentration per unit, relative spatial 'togetherness' of similar phenomena and, finally, relative degrees of mixture of unlike phenomena.

¹ Ibid. p.95.
In summary, Webber's work is more of an exploration of the spatial and nonspatial aspects of interaction and communication in urban systems. This dichotomy seems to be useful in that it firmly drives a wedge between the spatial and nonspatial components of locational decision-making. On the other hand, the ways in which the classification system presented above will be used in the behavioural approach he favours for the analysis of interaction systems is not clearly stated. The classification scheme suggests the types of measurements required for describing the dimensions of spatial structure. Nevertheless, the use of this classification system as the basis for a behavioural model of urban spatial structure is not spelled out in terms of the analytical means of translating description into a system of interrelationships between the identified dimensions of spatial structure. This extension of this theory into an operative model will necessarily require the clarification of these aspects.

The Natural Zoning Approach

The ideas to be presented in this section do not develop into a theoretical model as is the case of most of the works so far presented. Instead, the relevance of these studies within this review and for this thesis is found in some hypotheses they introduce and it is precisely these hypotheses that are in many respects coincident with the aims of the current research. These studies are concerned with describing in one way or another the character of functional diversity so often found in unplanned settlements, the ways in which different uses tend to spontaneously emerge and mix in naturally evolved urban areas and moreover, the notion of 'natural zoning' as a way of explaining this mixture of uses often observed in traditional towns. The natural zoning hypothesis will be discussed from the standpoint of two different perspectives. The first is a more behavioural approach where the work of Jacobs (1962) will be utilized as a benchmark. The second is the work of
Siegan (1973) where the natural zoning hypothesis is approached from a more economic point of view.

The study of diversity in urban systems is a central theme in the research of Jane Jacobs. She investigates a sample of urban areas in different American cities in terms of the relationships between community behaviour and the physical environment these communities live in. Her sample includes both modern planned developments and traditional evolved urban areas. With respect of modern developments Jacobs develops a harsh criticism of the functional simplification of 'orthodox' planning theory that 'is deeply committed to the ideas of supposedly cozy, inward-turned city neighbourhoods, ideally composed of 7000 persons, a unit supposedly of sufficient size to populate an elementary school and to support convenience shopping and a community centre'.

Jacobs is particularly concerned with the physically homogeneous character of residential neighbourhoods, often constituted by a series of 'units' built all at once. These places, she suggests, have been handicapped in every way, so far as generating diversity is concerned: 'It seems that one cannot blame their poor staying power and stagnation entirely on their most obvious misfortune: being built all at once. Nevertheless, this is one of the handicaps of such neighbourhoods, and unfortunately its effects can persist long after the buildings have become aged'. Jacobs notices that neighbourhoods built up all at once change little physically over the years as a rule: 'The neighbourhood shows a strange inability to update itself, enliven itself, repair itself, or to be sought after, out of choice, by a new generation. It is dead. Actually it was dead from birth'. Monotonous spatial configurations are also a target for Jacob's criticism. She suggests that these 'monotonous'

---
2 Ibid. p.115.
3 Ibid. p.117.
4 Ibid. p.118.
configurations might have been thought of by the designers as a sort of order 'however dull'. But spatially it unfortunately carries within it a deep disorder, the disorder of conveying no direction: 'in places stamped with the monotonity and repetition of sameness, you move but in moving you seem to have gotten nowhere. North is the same as south, or east as west. It takes differences, many differences, cropping up in different directions to keep people oriented. Scenes of thoroughgoing sameness lack these natural announcements of direction and movement, or are scantily furnished with them, and so they are deeply confusing.'

In turning the analysis towards traditionally evolved urban areas Jacobs observes that the concept of neighbourhood, in the modernist sense of the term, once applied to big cities has any meaning at all, that city people are mobile; 'pick' and 'choose' from the entire city for everything from a job, a dentist recreation, or friends, to shops and entertainment: 'And whatever city neighbourhoods may be, or may not be, their qualities cannot work at cross-purposes to thoroughgoing city mobility and fluidity of use, without economically weakening the city of which they are a part.' Moreover Jacobs' observations suggest that to understand cities, we have to deal outright with combinations or mixtures of uses, not separate uses, as the essential phenomena.

Starting from a more behaviouristic perspective, Jacobs does not go directly into the spatial factors affecting the distribution of land uses, although eventually she will arrive at that. Jacobs initially maintains

---

1 The case limit of 'neighbourhoods built at once' is set up by the organization of 'residential units' in the orthodox Bauhaus urbanism, where the distribution of housing blocks is reduced to a juxtaposition of functions on a site in the most homogeneous manner as possible, preferably hiding differences, even those suggested by topography. A strong ideological purpose is detected by Lefebvre in the spatial homogeneity, lack of contrasts and 'places' found in so many proposals of the early modern movement: '... urban democracy would imply (for the early modernists) both in an equality of places and in an equality of participation in the global interchanges, while the centrality of the traditional city would be a source of hierarchy and in consequence of inequality'. In Lefebvre, H. La revolucion urbana, Alianza Editorial, Madrid, 1969, p. 131.

2 Ibid. p.119.
3 Ibid. p.143.
4 Ibid. p.143.
that a mixture of uses, if it is to be sufficiently complex to sustain city safety, public contact and cross-use, needs and enormous diversity of ingredients. Her analysis of a 'neighbourhood like' area in New York shows that the lack of commercial choices as well as places of cultural interest is closely related to the physical character of the environment: 'We can see how fatal is its monotony. The missing diversity, convenience, interest and vitality do not spring forth because the area needs their benefits. Anybody who started a retail enterprise here, for example, would be stupid, he could not make a living. The place is an economic desert'. In other words, the physical character of the place does not suit for the location of any economic activity. Different from the modern developments, she suggests that traditionally evolved cities are natural generators of diversity and prolific incubators of new enterprises and ideas of all kinds. Moreover, traditional cities are the natural economic homes of immense numbers and ranges of small enterprises.

At this point Jacobs' discourse seem to be very much committed with a sort of urban economic democracy, based upon the physical character of the traditional city which for her is related to the problem of scale which she explains through the morphological notion of grain; variations of grain with an special emphasis on the small grain. Jacobs maintains that the benefits cities offer to smallness are just as marked in retail trade, cultural facilities and entertainment. This is because city populations are large enough to support a wide range of variety and choice in these things. On the other hand, suburbs are natural homes for huge supermarkets. Jacobs makes sure that smallness and diversity are not synonyms. For her the diversity of city enterprises includes all degrees of size, but great variety does mean a high proportion of small elements. A lively city scene is lively largely by virtue of its enormous collection of small elements.

1 Ibid. p.145.
Furthermore physical factors are systematically pointed out by Jacobs as determinant for the achievement of diversity. She suggests that commercial diversity is in itself, immensely important for cities, socially as well as economically. But more than this, wherever we find a city district with an exuberant variety and plenty in its commerce, we are apt to find that it contains other kinds of diversity also, including variety of cultural opportunities, variety of scenes, and a treat variety in its population and other users. She suggests that this is more than coincidence, that the same physical and economic conditions that generate diverse commerce are intimately related to the production, or the presence, of other kinds of city variety. Three physical conditions are pointed out by Jacobs as the generators of functional diversity in an urban area. Firstly, she suggests, that the area must alternate primary uses and secondary uses. Primary uses are considered those which, in themselves, bring people to a specific place because they are ‘anchorages’. Secondary uses are the enterprises that grow in response to the presence of primary uses, to serve the people the primary uses draw. She maintains that ‘every city primary use, whether it comes in monumental and special guise or not, needs its intimate matrix of profane city to work to best advantage’.

In the second requirement for diversity, Jacobs states that most blocks of an urban area must be short, i.e. streets and opportunities to turn corners must be frequent. Here she goes deeper into the problem of the space and urban morphology. She describes the long blocks of West Manhattan and concludes that ‘if these long east-west blocks had an extra street cut across them, not a sterile promenade of the kind in

---

1 The advocacy of mixed use and high density is also part of Alexander’s ‘Pattern Language’. Alexander attacks separation and zoning for fragmenting life and decomposing society, in an argument which is coincident to that of Jacobs: ‘When people have their own homes among shops, workplaces, schools, services, the university, these places are enhanced by the vitality that is natural to their homes. It is only where houses are mixed in between the other functions, in twos and threes, in rows and tiny clusters, that the personal quality of the households and house-building activities gives energy to the workshops and offices and services’. In Alexander, C. A Pattern Language, Oxford University Press, New York 1977.

which super-block projects abound, but a street containing buildings along, activities would automatically grow at the spots viable: places for buying, eating, seeing things, getting a drink'. In this case Jacobs assumes explicitly that the increase in the spatial permeability of an urban area would increase its functional diversity. This seem to be not necessarily the case, or at least, not a general statement. This issue is to be dealt with in the empirical part of this research where a range of effects of spatial permeability (or density of public space) in the location of different land uses will be identified.

As the third generator of diversity, Jacobs suggests that an urban area must mingle buildings that vary in age and condition, including a good proportion of old ones so that they vary in the economic yield they must produce. This mingling also must be fairly 'close grained'.

In summary Jacobs' study is relevant for its acuteness in picking up behavioural aspects of urban life closely associated with both the spatial character of towns and with the problem of land use distribution. The lack of precision when dealing with spatial issues is already expected in view of the more sociologically oriented character of the research. Nevertheless Jacobs' study arrives at some conclusions that are quite relevant as statement of hypothesis for further verification on subsequent studies more concerned with the morphology of the urban space as is the case of this thesis. Jacobs assumes that mixtures of uses and frequency of streets are the most effective factors in helping to generate diversity 'only because of the way they perform'. Indeed it is precisely 'the way they perform' that must be explained. The problem she introduces, however she has not evolved, is precisely the difficulty in the assessment or measurement of spatial performances, a character that her descriptions just superficially deal with. Nevertheless there is one fundamental notion put forward by Jacobs, i.e. that the intricate minglings of different uses in traditional cities are not a form of chaos. On the contrary, they represent a complex and highly developed form of

---

1 Ibid. p.175.
order. The question that eventually remains, which is central in the development of the current research, is how this complex order of mingled uses works in relation the spatio-morphological character of the city.

Representing the more economic dimension of the 'natural zoning hypothesis' the work of Siegan (1973) is focused with the study of patterns of land use distribution in Houston.\(^1\) Based upon a large sample of negotiations and agreements between local authority and community members, Siegan attempts to demonstrate that the market can be used effectively to solve problems which it is commonly thought can only be handled by zoning ordinances. His study's central hypothesis states that there is inherent in the market place a planning mechanism that tends to separate and allocate different activities according to economic requirements related to strategic locations in an urban system.

The observations carried out in Houston, a city that has grown without any zoning legislation, suggest not only that market demands are closely associated to the locational or spatial character of the different parts of the city but also that the different activities - commerces, industries, single family houses, etc.- tend to 'organize' or accommodate themselves in a satisfactory way, according to their particular economic character and related spatial requirements, without the use of any zoning ordinance. The author maintains, on the basis of his field research, that the real estate market does not operate chaotically or haphazardly: 'the market is quite rational and orderly... An illustration of this is the location of different uses. Economic forces are highly effective in causing uses to locate separately.'\(^2\) However Siegan does not refer explicitly to spatial factors in the morphological sense of the term, his 'location factor' is systematically related to particularities observed in the physical character of the different parts of the city.

---

2 ibid. p.73.
In dealing with the single family residential use Siegan concludes that 'it might be thought that the continued existence of the single family home was once presumed on peril and that, were it not for zoning, the single-family subdivision might be by now something of the past. The Houston experience, however, does not bear this out; the single family residence is hardly in jeopardy there. It would appear that on the average, and notwithstanding the termination of restrictions in many places, homes have had steady and substantial appreciation in value over the years'. With respect of the distribution of commercial and service activities, Siegan acknowledges that the 'different scales of the city', from the more public to the more private, tend to establish a sort of natural hierarchy in terms of type and size of the different activities. This refers not only to extreme cases like larger shops that tend to locate in the major streets or avenues and to the local commerces and services more linked to the residential areas that tend to be more segregated - though also strategically located with relation to its immediate surroundings - but also to a continuous variation of intensity in the occupation of land by different economic uses in agreement to the market demands. Such a continuous variation permeates, in a complex way, the different parts of the city.

In dealing with industrial location, Siegan detects a wide range of situations where industries locate inside the city, without conflicting, even in some cases mixing with residential areas. His observations suggests that heavy industries tend to segregate themselves especially for their requirements of proximity to large scale transportation facilities, water sources and other reasons related to the character of its operation. The case of Houston shows that most industries would prefer avoiding homes they might possibly offend with noise, odour, smoke, heavy traffic or perhaps even with late or early working hours. Industry has found complaining owners or tenants to be costly and time-consuming, and productive of a bad image with resulting injury to sales. He concludes that heavy industry may now be equally as anxious to avoid

1 ibid. p. 50.
homeowners as homeowners are to avoid industry. On the other hand he also points out a number of different cases where particular types of industries are adequately integrated with residential surroundings. It all depends on the operational character of the plant, which eventually comes to be too much specific to be covered by a general zoning ordinance.

In summary, the work of Siegan departing from a harsh criticism on zoning procedures concludes that economic forces tend to make for a separation of uses even without any zoning; business uses will tend to locate in certain places, residential in others, and industrial in still others; these uses will mix naturally according to economic locational demands: 'A nonzoned city is a cosmopolitan collection of property uses. The standard is supply and demand, and if there is economic justification for the use, it is likely to be forthcoming. Zoning restricts the supply of some uses, and thereby prevents some demands from being satisfied.\footnote{Ibid. p.76.}

The studies developed by Jacobs and Siegan, despite their efforts in describing in an objective basis the ingredients of functional diversity, lack an objective description of the physico-spatial factors that are attached to this character of functional diversity so often observed in the naturally evolved urban areas they have dealt with. Similar search is part of the objectives of this investigation whose hypothesis, as initially expressed, suggests that the spatial properties of the urban spaces at an intra-city scale or, more specifically, the syntactic configuration of the urban grid has something to say in respect of the way in which uses are 'naturally' distributed in the urban field. For both Jacobs and Siegan the emphases on problems of distribution undermine the importance of urban morphology, i.e. the criticism of 'modernism' has been limited to a rejection of its programmatic aims, mostly of zoning, rather than extended into the development of effective descriptive theories of the urban space. As it has been noticed by Peponis, in relation to the work of Jacobs, 'the principles of dense occupation and mixed use
still remain in search of their architectural counterpart'. It is precisely the description of a morphological counterpart for the paradigm of functional diversity that is pursued by this investigation. It is likely that an accurate and systematic description of the relationships between configurational characteristics of the urban space and land use patterns can provide not only one possible way of assessing an 'architectural counterpart' for the principles described by these authors but also a valuable instrument for the understanding of what are the spatio-morphological rules that underlie what might be called the 'natural zoning paradigm'.

Does Space Matter?
A Review of the Literature on Urban Morphology

From this section on the focus of the discussion shifts towards the literature concerned with the description of the urban form. Different from the urban land use studies yet presented, where the physical dimension of towns has been regarded or translated in terms of socio-economic variables - land market, transport costs, patterns of attraction or interaction - the studies to be now presented are concerned with the description of the physical artifact, the concrete physical form of towns. These works are mostly focused in the description as an end in itself, i.e. description as a way of understanding the laws of the object rather than as one more aspect of socially or economically oriented studies. The objective of reviewing this body of literature is to provide a background against which to set up the distinct character and descriptive power of the syntactic analysis of the urban space; the analytic tool to be applied during the empirical part of this current research.

A range of forms of grouping the literature concerned with the descriptive techniques of urban systems have been proposed. Gebauer

---

(1983) proposes three groups according to the work's predominant theoretical approach: perceptualist, behavioural and urban morphological. Hanson (1989) proposes three groups: formal descriptions, descriptive techniques within the field of urban history and morphological geography and finally the studies based upon a typological approaches. The different forms by which the literature is approached is naturally a consequence of the particular concerns and theoretical frameworks of each research. In the example above, the way Gebauer groups the literature mirrors the concern of her study with relations between morphology and imageability, while in Hanson the literature is more centred on the relationships between morphology and history.

For the purposes of the current research, whose central concern is the configuration of street grid in its different scales, the literature to be reviewed is divided in two groups: the first includes the works that are concerned with the built form, that is to say the local scale of the urban block or groups of blocks; the second includes studies where the description of grid configuration is the focus. Yet the last group is the one particularly relevant for the purposes of the current research, a discussion on the works concerned with the scale of the urban block will be useful for clarifying the different ways the unavoidable presence of the street grid is considered in these studies. The concern of some of them with the description of spatial continuity will naturally evolve towards the introduction of the syntactic description of the urban space to be carried out in chapter two.

Built Form as a central concern

A range of urban studies developed at the Cambridge Land Use and Built form school are focused on the study of the built form, understood here

---

2 Hanson, J. Order and Structure: A morphological history of the City of London, op.cit.
as the urban block or groups of blocks. This is the case of Martin (1972) who attempts to model relationships between building density and geometric variations of the urban block. Martin's aim is to show that an apparently monotonous grid can generate a rich variety of built forms:

What has been described is a process. It is now possible to extract some principles. Artificial grids of various kinds have been laid down. The choice of grid allows different patterns of living to develop and different choices to be elaborated. The grid, unlike the fixed visual image, can accept and respond to growth and change. It can be developed unimaginatively and monotonously or with great freedom.

Utilizing a theoretical regular grid as a background, Martin proceeds a series of tests concerning changes in a number of characteristics of the urban block such as size and shape of the built forms, plot ratio, height, legislative controls, etc. The grid is kept as a neutral background capable of absorbing a variety of geometrical changes both in the volumetric and in the planimetric characteristics of the block. These morphological changes are coupled with enlargements in the scale of the street grid, i.e. with the increasing the size of urban blocks by the omission of some streets. Martin is systematically centred on the problem of the degree of overcrowding the urban blocks carry and how similar amounts of floor space can be accommodated in different volumetries, thus changing the amount of area available for open space: '... if the size of the road net were to be enlarged by omitting some of the cross streets, a new building form is possible. Exactly the same amount of floor space that was contained in the towers can be arranged in another form. If this floor space is placed in buildings around the edges of our enlarged grid, then the same quantity of floor space that was contained in the 21 storey towers needs now only 7 storey buildings. And large open spaces are left at the centre.'

2 ibid. p. 15.
3 ibid. p. 21.
Both the focus and the background of Martin's study is in many ways different from the objectives of the current research. First, Martin is not concerned in quantifying and classifying the changes produced in the street grid as a result of varying the block geometry, i.e. the spatial properties of the grid itself, which is the main focus of the current study. Second, Martin regards uses or function exclusively as a property of buildings and not of streets while the current research is concerned precisely with the potential the street grid has in affecting land use distribution.

The possibility that different types of grids, i.e. different geometrical and topological arrangements can in themselves generate different distributions of uses is not taken into account. This holds true for the effects of the spatial interaction between adjacent grids, that is what actually happens in the real world. These issues automatically raise the problem of describing the global dimension of the street grid which is a central concern for the current study, i.e. the interaction of different geometries and topologies, and the relationship of such more global patterns with its parts, the local scale. Martin's descriptions, though useful for the description of urban blocks, have nothing to contribute to this sort of investigation.

Kruger (1979) is also concerned with the study of urban areas focusing on morphological changes in the urban block. He studies the town of Reading, from the stand-point of the different morphological characteristics assumed by the built form. These characteristics are: party-wall structure of the buildings (terraced, detached, semidetached, back to back), adjacency of the building interior to surrounding open spaces through external walls, permeability between the interior of buildings and public space, etc. In order to measure these characteristics, Kruger develops a series of measures, most of them concerned with the description of the building arrays, the way he refers to groups of

---

buildings inside each block. Blocks are referred to as *urban constellations*. These measures include perimeter (mean number of external walls per building), compactness (mean number of external walls per building array), a shape measure (ratio of external walls to party walls per array) and a connectivity measure (number of party walls per building array).

The performance of these measures is utilized as a way of setting up differences in the morphology of different parts of Reading. The notion of adjacency, which is common to the different measures, provides consistency for Kruger analysis. Nevertheless this same notion of adjacency seems to be insufficient to describe the urban grid in the terms required by the current research, i.e. a global representation. And this happens simply because the character of spatial continuity of the street grid cannot be described in terms of adjacency. In fact Kruger offers a node map as way of representing the street grid (his built-form galaxy). Based upon this type of representation Kruger considers the street grid as a system of nodes, one at the intersection between each two streets, and reduces it to an hypothetical rectangular grid. As a consequence the actual layout of the street grid, which is the main concern of the current research, is missing.

While the studies developed by Martin and Kruger provide a synchronic description, the works of Conzen (1960) and Brown (1985) are concerned with the historical development of the urban block. Conzen develops a system of description where the individual plot is the fundamental unit of analysis. He studies the morphological cycles which take place at the level of the plot. His approach is evolutionary. Starting from the first set up of plot boundaries and street line, the study covers a series of intermediate stages of occupation, eventually arriving at the point where the density of buildings on the plot reaches saturation. These

---

evolutionary cycle is supposed to happen both by changes restricted to the interior of the block (redevelopment cycle) and by changes that also alter the layout of the street grid (augmentative cycle).

For the definition of his areas of study Conzen carries out the disaggregation of the town plan in its constituent elements he calls *plan units*, which eventually correspond to sub-areas of a larger urban area. Such a problem of setting up objective criteria for dividing large urban areas in smaller sub-areas is one to be dealt with during the empirical part of the current study. The process utilized for Conzen for doing so has already been a target for Carter's criticism by the argument that the method 'is essentially subjective and completely reliant upon individual interpretation. Conzen defines a 'plan division' as 'a geographical group of morphogenetic plan units' and a 'plan unit' as 'any part of a town plan representing an individualised combination of streets, plots and buildings distinct form its neighbours, unique in its site circumstances, and endowed with a measure of morphological unity'. But individualised, distinct, unique and unity are all terms which demand specification'.

In general the method of description of the urban form proposed by Conzen cannot, for different reasons, answer the questions posed by the current study. First, because of its strict concern with the scale of the urban block. Second because Conzen is not concerned with the use of land in terms of the activities developed inside the plot, but in terms of the evolution of the built forms. And finally, because when he deals with the the more global scale of the town, i.e. for defining the characteristics of his plan units his criteria becomes rather vague and subjective to be applied to the case of Porto Alegre - the town to be investigated during the current research - where only a few of the areas to be studied present morphological characteristics so distinctive to allow a straight visual differentiation.

---

Another research focused in the morphology of the urban block is developed by Brown (1985). The ultimate aim of the research is to explain the mechanisms by which London grew up. He concentrates on the description of the principles of arrangement of buildings and plots within typical medieval urban blocks in London. The model simulates computer generated patterns of growth inside the urban block. Brown suggests that these patterns perform as shape grammars: 'rules were sought which, separately, could be interpreted as corresponding to real historical actions - the establishment of property boundaries, the maintenance of light, access, etc.' These computer generated shape grammars simulate both the performance of different possibilities of building plot aggregation and also the emergence of public pathways inside the urban block.

However the concerns of the current research are rather distinct from the focus of Brown's study, the analysis of public pathways inside the urban block will emerge too in different parts of the current research. The difference is that for Brown the breakthroughs - the way he calls for these pathways - are a local phenomena which result from the development of building plots while for the current research these same pathways are just a part - the most local scale - of a more global entity we shall call the urban space.

In general the works described during this section have dealt with the urban grid as a by product of the arrangement of urban blocks. It is precisely in this way that the approaches reviewed above are distinct from the concern of this investigation where the spatial configuration of the urban grid is in itself the object of interest. This does not mean that the description of the constituent parts of the urban block is not part of this investigation. On the contrary it is precisely one particular way of describing the association between urban block and spatial grid that will allow for the measurement of the relationships between grid configuration and land use distribution. That is to say instead of dealing

1 Brown, F. and Johnson, J., op. cit., pp 277-400.
with the arrangement of uses inside each urban block the descriptions to be utilized during this investigation will focus upon the relationships between the pattern of land use, as given by each urban block, and the spatial configuration of the grid as a whole.¹

The urban form as a spatial continuum

In this section the focus shifts from works aimed at the description of the urban block towards the works concerned with the description of urban spatial continuity, that is to say works where the representation of the urban grid as a whole is attempted in one way or another. This section does not attempt to provide another classification for the small set of spatial descriptions to be reviewed in what follows. It would probably end up by being rather idiosyncratic. Nevertheless the sequence adopted ends up by dividing this review in two different groups, one more committed with the description of the general configuration of the street grid and other more committed with reducing the urban space to a typology of morphological elements. Yet the works to be presented are not intended to follow a chronological order, eventually a sort of chronology will spontaneously emerge.

The methods of description to be discussed evolve from general representations such as the figure/ground map towards more complex descriptions which, as it will be shown, eventually pave the way for the introduction of the methodology of syntactic analysis. More than discussing extensively the work of different authors this section is concerned with detecting and discussing how the issues the current study is concerned - description of spatial properties, the role of spatial continuity, relationships between local and global scales, etc. - emerge, in fragments, in the work of different authors.

¹ The procedure for measuring land use distribution to be utilized during this investigation is fully explained in chapter two of this thesis.
The most commonly invoked general description of the spatial continuity of the urban grid has been given by treating the built/unbuilt elements of the urban phenomenon as figure and ground. This method is already part of history through the Nolli map of Rome. Nolli’s representation (1748) goes further from the built/unbuilt distinction by showing the major interior spaces of public buildings as extensions of the public open space. Camillo Sitte (1899) takes the Nolli’s description one step further. Sitte’s work is a catalographic coverage of examples of classical, medieval and baroque spatial organization. In the three cases one can find the same fundamentals which are inherent in the connection of their elements. Space is continuous and buildings have meaning only insofar as they are related to each other. For Sitte, ‘the modern disease of isolated construction is to be condemned’.1 The work of Sitte is throughout a radical criticism on the abstract city planning theories proposed by the early modernism, that, he points out, ‘fails to take concrete spatial experience into account’.2

Sitte’s representation is a development of Nolli’s plan in which the solids were shaded in two ways, distinguishing both public buildings and the more ordinary fabric of the city. Sitte thus compromises the fundamental figure/ground relationship in order to convey information about buildings of a certain category of use and meaning. He elaborates a model of spatial organization based on the systematic analysis, ‘in a purely artistic and technical manner’, of the ‘compositional elements which come into play in the pre-industrial city and evolve from an innate, instinctive aesthetic sense’.3 The main features of Sitte’s spatial model are ‘continuity in constructed elements, enclosure, diversity, asymmetry, irregularity and connecting elements which are significant in themselves’.

---

2 ibid. p.53.
3 ibid. p. 4.
In general Sitte is concerned with the local scale of the urban space. In fact he deliberately avoids the analysis of the global scale of the street grid by the argument that the properties of the street network *could only be comprehended sensorily in their entirety* and hence lacked all aesthetic interest.¹ This seems to be contradictory since he assumes that function is just a direct consequence of the positional character of the building inside the city. He actually seems to design buildings and elaborate forms primarily for the purpose of arranging the urban space and scarcely considers their intended use. Thus despite Sitte's concentration in the local scale, the functional hypothesis he raises seems to be germane with the object of investigation of the current study, in the sense that a sort of natural zoning is supposed to underlie his distribution of land uses.

Similar analytical device is used by Habraken, though, in this case, the categories of built and unbuilt space are complemented by the *thematic* and *nonthematic* distinction that is applied to buildings, though not to the urban spaces.² Thematic is applied to describe the building types most recurrent in an area of study. If the area is residential the dominant theme will tend to be a dwelling type. If the area is predominantly commercial the theme will be shops and so on. The non-thematic are the exceptional buildings, i.e. the building types that contradict the recurrent trend. The mapping consequently has a similar appearance to that of Sitte. However, Habraken's distinction of thematic and nonthematic morphological elements provides a descriptive advance over Sitte's social distinction of public and private buildings.

Another description of the urban space derived from Nolli's figure/ground representation is proposed by Peterson (1979). He considers as the first and most general feature to be considered in order to describe the

¹ ibid. p. 229. With respect to Sitte's lack of concern with the global scale of the city, Rossi comments: '...Sitte's lesson contains a gross misconception in that it reduces the city as a work of art to one artistic episode having more or less legibility rather than to a concrete, overall experience.' Rossi, A. *The Architecture of the City*, op.cit. p. 35.
morphology of the different areas will be the texture of the urban fabric. Texture, he suggests, is the basic matrix material of the city. It is characterized by the combined pattern of streets, squares and blocks whose variations range in a continuum of typological orders from gridded to random. Peterson suggests that texture can be described according to morphological characteristics such as degree of regularity, proportion of solid to void and density. Degree of regularity is given by the scale and repetitiveness observed on the frequency and types of streets and blocks: 'It has grain and directionality, depending on relative street widths and orientation.' Proportion of solid to void depicts the amount of open spaces with relation to the amount of built form, while density concerns the scale of the urban blocks. Peterson holds that the modern, or anti-space, city texture does not provide as many variables and is limited to frequency and rhythm. Peterson proposes three types of texture with varying degrees of regularity, scale and proportion of solid to void. One contains no blocks but an assembly of large buildings, another is a transformed block system and the third is a random pattern overlaid with regular lines.

Peterson's descriptive system seems to be a useful tool for differentiating conspicuously distinct morphological patterns, whose differences can be visually detected from a figure/ground map. Nevertheless the three variables of texture would be certainly useless to differentiate more subtle morphological differences in more similar urban systems. At any rate one of the descriptions of grid configuration to be presented in chapter four of this thesis provides an attempt of comparing the cases to be studied from the standpoint of their 'proportion between solids and voids' as it is proposed by Peterson.

Ellis (1978), develops a two folded typology for describing the urban space which involves a global description for the street grid and a local

---

2 ibid. p. 77.
description for the street space. The global description of the street grid also unfolds into two basic types. The first is a traditional one with its streets in a system of differentiated open spaces and a contemporary one with its streets in a system of undifferentiated open space. Ellis calls the traditional pattern a structure of spaces, because street space seems to have been carved out of a solid building mass so that it is the shape and character of this carving which defines the urban blocks. The representation of the structure of spaces is again derived from Nolli figure/ground map. In contrast modern spatial configurations are termed a structure of solids, since they tend to be built up from free-standing pavilions spread in a landscape and it is the shape of the buildings that dominate the surrounding open space. In his local representation Ellis also calls for two sub-types: the continuous development, how he terms through streets, and the elongated courtyard which he applies for cul-de-sacs.

Furthermore Ellis shifts the argument towards the problem of the functional dimension of urban systems: 'The walls owe a responsibility to the formation of those rooms. The interior functional considerations of buildings can be coordinated to allow them to perform the function of creating exterior city space.' The walls are the walls of the urban block while the rooms are the open spaces that constitute the street grid. The idea is parallel, if not coincident to the model proposed by Sitte, in the sense that the purpose of each building is regarded as something that tends to naturally emerge from the spatial character of each particular urban situation. This proposition, yet dealing with local properties of urban systems, is particularly relevant in the context of the current

2 ibid. p. 114.
3 Ellis' concept of 'traditional city' approximates the description of the pre-industrial city presented by Choay (1969). Both describe traditional urban settlements as a complex arrangement of more or less contiguous buildings, which seem to form the spaces between them. Choay adds that such a configuration, 'has resulted from growth by infill rather than by expansion, reflecting such factors as their need to remain small and compact for efficient communication'. Choay, F. The Modern City: Planning in the Nineteenth Century, Braziller, New York 1969, p. 7.
4 ibid. p. 130.
research since it raises again the hypothesis of the *natural zoning* of traditional settlements, this time from the morphological standpoint.

Ellis addresses a particular relevance to the positional properties of some streets which 'tend to produce relative differentiation in the surrounding street system. This structuring function tends to increase a sense of place in the organisation of cities in that it helps to structure them into wholes, it tends to reduce the likelihood of random, limitless organisation'.¹ The statement introduces the notion of sub-areas in urban systems associated with the notion of street hierarchy, as a way of structuring urban areas. Special streets are said to be special by virtue of their width, length or monumentality. Ellis notion of special street is a local one, which is defined in terms of the local qualities of particular streets. Nevertheless the argument does not link his global description of the street grid to these local characteristics.

The principles of this *new localism* that proposes the revival of the street at the local level ² coupled with the denial of the global scale of the city, are well stated in the work of Caliandro (1978), a survey on American street patterns.³ Caliandro’s research focuses on the problems and potentials for maintaining a cohesive pedestrian oriented city. His basic interest is to develop a 'classification of street-oriented or non-street oriented settings, a question of whether buildings depend directly on the street for accessibility and internal spatial organisation'.⁴ Caliandro describes the urban space in terms of a range of variables such as land use (residential, commercial, institutional, mixed), built form (detached, row, apartment, tower, etc.), circulation (pedestrian and vehicular) activity setting (as individual, group or private space) and public-private use boundary (the presence or absence of secondary property boundaries to isolate unusable exterior space). These properties

² The expression 'new localism' is utilized by Peponis, op cit., in order to describe 'late modern' tendencies in urban design, which concentrate in the study of local patterns. In Peponis, J. *Space, Culture and Urban Design in Late Modernism and After*, op cit.
⁴ ibid. p. 151.
are represented into maps and further compared in terms of quantities. The method of comparison seems to be carried out rather by visual observation than by a more accurate measurement.

While dealing with the description of these local properties Caliandro's descriptive method seems to be quite effective. On the other hand, when the problem of spatial articulation with the surrounding areas is approached the analysis becomes contradictory, too restricted to the local scale and a series of value judgements seems to be implied. Yet Caliandro explicitly acknowledges the role of a larger physical context in creating a 'recognizable and identifiable order of streets and sustain a certain level of pedestrian street activity' his analysis of Willow Place, just one example, reveals his difficulties in describing these spatial factors he is so keen to identify, i.e. spatial factors that affect the relationships between the local characteristics of streets and their surroundings: 'The success of Willow Place as an urban residential place and street is contingent upon a congruence between the physical configuration and the activity choices - reinforced by a strong sense of enclosure, continuity with the adjacent building fabric, limited length, an identity within its immediate context, a clear dependence upon adjacent commercial and institutional facilities and virtually no through vehicular traffic'. The list of qualities stated above provides a recipe for integrating an urban area and its surroundings. Integration is achieved by means of increasing continuity with the adjacent building fabric. Although continuity must also be coupled with certain limits in street length. That is to say, spatial continuity coupled with a certain degree of enclosure and spatial fragmentation.

The point is worth to pursue for it raises two questions that are to be investigated during the current study. The first concerns the extent to which a more global spatial interaction between street patterns is dependent on the length of their streets. Apparently, if one intends to favour the spatial interaction, it seems that the adequate spatial

---

1 ibid. p.160.
strategy is to favour the increase in the length of the streets and not the opposite. The second question refers to the investigation on patterns of mixed use in areas with high residential density. With respect of the functional dimension Cailandro's model proposes a congruence between the physical configuration and the activity choices, which not only excludes the allocation of commercial and institutional facilities in the area but also puts a positive value in the clear dependence upon adjacent facilities. The list of characteristics discussed above, yet reinforced by the no through vehicular traffic axiom, makes Cailandro's model despite its façade of apology of the traditional street a rather segregationist one.

Krier (1978) reduces the description of the urban space to a limited vocabulary: streets and squares. The distinction, despite its apparent axiomatic character, is ambiguous. In real cities, only the paradigmatic cases allow for a definition based upon shape. A simultaneously wide and short street is difficult to differentiate from a narrow square and vice-versa. Krier is therefore compelled to specify the elements of his vocabulary, and as a consequence his two basic types evolve into a wide range of categories, which arise from the adaptation of the original elements to different geometries, modulating factors, and so on.

Krier's work sets up another branch of the localism detected in Cailandro's proposition, yet his local character is more perceived from his design proposals than from his discourse. Krier's urban theory is in fact explicitly sensitive to the structuring role of the global properties of the city and moreover with the role of these same properties in the process of design: 'any planning innovation in a city must be governed by the logic of the whole and in design terms must offer a formal response to pre-existing spatial conditions'. Krier goes on to indicate that 'streets in cities rarely operate as an autonomous isolated space, as in the case of villages built along a single path. Streets are to be perceived

---

1 Krier, R. Urban Space, op.cit.
2 Ibid. p. 88.
as part of a global network. Our historic towns have made us familiar with the inexhaustible diversity of spatial relationships produced by such a complex layout.¹

Nevertheless these theoretical assumptions are not converted into design practice in Krier’s urban design proposals. The reconstruction of Stuttgart city centre is a case study where the typological model is tested. The spatial configuration of the city in a more global scale is hardly taken into account in the design proposals. Almost as a rule, many axial steps are necessary to reach a proposed scheme from the outside surroundings, that is to say the schemes are quite deep in relation to the global scale. They are not perceived as part of a global network as Krier suggests. The result is a sort of translation of the neighbourhood unit principles - pedestrian/vehicular separation, self contained quarters with local communities and corresponding local facilities and so on - into a morphological repertoire mostly retrieved from the urban tradition of the nineteenth century.

The functional complexity and the globality of the contemporary city is denied in the same way as it is denied in the modern utopias. This localist dimension of Krier’s work has already been discussed by Peponis: ‘Krier’s informal classicism, where urban axes hit buildings slightly off centre, where the frontal view of major buildings does not catch the main line of approach and where building elements are allowed to interrupt major lines of sight in order to give oblique views, is probably a classicism of spatial fragmentation, for all its visual coherence’.²

In summary, the methodology of spatial description proposed by Krier can hardly be applied to answer the questions proposed by the current study. Apart from being too idiosyncratic - despite the apparent simplicity of the street/square distinction - Krier’s typology is totally concerned with the local scale of the urban space, that is to say, he deals with local

¹ ibid. p. 89.
² Peponis, J. Space, Culture and Urban Design in Late Modernism and After, op cit. p. 6.
examples independently of the relationships these urban elements evolve among themselves giving rise to the global configuration of the city.

In contrast to the cumbersome typology proposed by Krier, Alexander (1965) proposes a description of the urban space based upon the distinction between natural cities and artificial cities, that in his case are the traditional and modern planned cities. Alexander's distinction is initially functional, yet it soon evolves into a spatial proposition. He initially suggests that unplanned cities are characterised by the overlap of catchment areas of different facilities and areas routinely covered by inhabitants in their everyday life. He defines these patterns of overlap by comparing them with the zoned distribution of planned cities where, he suggests, a 'tree-like hierarchy makes the different parts of the settlement disconnected or fully encompassed by units of higher order'.

The concept of set is central for the specification of Alexander's theory: 'A set, in general terms is composed of elements which co-operate or work together; in terms of urban studies a set is a spatio-temporal integration of diverse elements like a drugstore, newsrack, traffic light, bystanders and customers'. The concept of set is the basis for the distinction between tree and semi-lattice patterns: a collection of sets forms a semi-lattice if and only if, when two overlapping sets belong to the collection, then the set of elements common to both also belongs to the collection. ... a collection of sets forms a tree if and only if, for any two sets that belong to a collection, either one is wholly contained in the other, or else are wholly disjoint.

Yet Alexander's collection of sets is given a spatial structure, this structure is diagrammatic and abstract. It strictly prescribes that if the boundaries of the spatio-temporal entities overlap then the city forms a semi-lattice. On the contrary if these entities are nested, a tree-like

---

1 Alexander, C. A city is not a tree, in Architectural Forum № 122, April/May 1965.
2 ibid. p. 47.
3 ibid. p. 49.
4 ibid. p. 49-50.
structure exists. There is no commitment with the pattern of the urban grid where these sets may be located and related together. Alexander makes the functional comparison his strong point. He suggests that the *semi-lattice* pattern of unplanned cities produces a complex pattern of use where local facilities belonging to one area are also used by inhabitants of other areas. At the same time unplanned urban areas depend on other parts of the city to satisfy the requirements of their own inhabitants. Alexander argues that, following an opposite direction, modern town planners tend to propose self contained *tree-like* urban patterns with their own facilities from which they are also separated.

Alexander uses a variety of cases - that range from Chandigarh to Hilberseimer's proposals to Berlin - for exemplifying his *tree-like* diagram in different cases. Nevertheless when confronted with the necessity of clarifying the morphological counterpart of his *semi-lattice* activity diagrams Alexander overtly quits from entering into the analysis of the complexity of the unplanned cities: 'I must confess that I cannot yet show you plans or sketches. It is not enough merely to make a demonstration of overlap - the overlap must be the right overlap. This is doubly important, because it is so tempting to make plans in which overlap occurs for its own sake. This is essentially what high density 'life-filled' city plans of recent years do. But overlap alone does not give structure. It can also give chaos'.

From this point on the description departs from the field of the urban studies and dives into the fine arts and Alexander is rescued by a painting of Simon Nicholson which is supposed to explain the notion of *activity overlapping*. In general, the contribution of Alexander to the description of the urban space remains more as an hypothesis than as a

---

1 ibid. p. 55.
2 This difficulty in describing the morphology of traditional urban systems tend, in the work of different authors, to be followed by a sort of artistic escapism. The same happens when the Smithsons are confronted with the necessity of explaining the notion of *urban tension* in unplanned cities. In this case they use a painting by Paolozzi as an example of *structural tension* in the same way as Alexander is helped by Nicholson. In Smithson, A. and P. Urban Structuring, Studio Yista, London 1987, p. 21.
fully stated model. The lack of a morphological counterpart for his patterns of overlap and, in consequence, the unclear relation of these same patterns to the urban grid sets up the limits of his theory as a methodological tool of analysis.

Following a more perceptualist approach, Lynch (1960) develops a typology of the urban space whose aim is to provide a description of the overall form of the city as it is perceived by its inhabitants. Lynch's model is based in five types: paths, edges, nodes, district and landmark. The definition of these concepts mixes spatial, functional, aesthetic and symbolic criteria. While paths, edges and nodes are clear spatial concepts, for the definition of districts Lynch enters into considerations of functional, social and aesthetic nature. And the concept of landmark is mostly based in the symbolic dimension.

This lack of common ground of reference is double sided. If on the one hand it enriches the content of each of these concepts, on the other hand it prevents the use of these same concepts as a way proceeding with comparative analysis. Apart from that the concepts of path and edge are rather superimposed ones. Actually the concept of edge seems to be more a specification for a more general concept of path. Both the accumulation of different urban dimensions (spatial, functional, social composition, symbolic, etc.) inside the same concept and the conceptual superimpositions seem to derive from the method of analysis utilized by Lynch, a methodology that relies on interpretations of form - responses of samples of residents - rather than on objective descriptions.

These aspects make the descriptive method proposed by Lynch unappropriated for describing the phenomena and answering the questions formulated by the current study. Nevertheless the contribution of Lynch for this thesis comes precisely from its capacity in capturing, from a perceptual point of view, a series of spatial characteristics and

---

2 Similar mixture of spatial, functional and symbolic contents is observed in Rossi's theory of monuments. Rossi, A. The Architecture of the City, op.cit. p. 57.
properties such as the axial organisation of the city, spatial continuity, the notion of depth, the dialectics between local and global scales and sub-area division, whose objective description will be dealt with during the empirical part of this study. Moreover his consideration of the urban system as a pattern of spatial relationships among different spatial elements is also germane to this thesis.

Lynch shows that for most people interviewed paths are the predominant city elements, yet their importance varies according to the degree of familiarity with the city. Individuals who knew the city better had usually mastered part of the path structure: 'these people thought very much in terms of paths and their interrelationships'. Lynch goes on to approach, from the perceptual point of view, the topological description of an urban system through the axial map: 'paths may also be imaged, not as a specific pattern of certain individual elements, but rather as a network which explains the typical relationships between all paths in the set without identifying any particular path'.

The argument is extended towards the ways spatial continuity affects both the intelligibility of the city and the distribution of uses. Lynch suggests that the fundamental characteristic that define the perception of spatial continuity is the continuity of the actual track, i.e. that the bed of the pavement go through. His observations suggest that the continuity of other characteristics is less important. The results of his inquiry show that paths which simply have a satisfactory degree of track continuity were systematically selected as the dependable ones: '... they can be followed even by the stranger', Lynch suggests. He also relates this character of spatial continuity to the distribution of land uses, by the argument that when track continuity is interrupted - as in his example of Washington Street at Dock Square - people have difficulty in sensing a continuation of the same path. Washington street has its bed of

1 Lynch, K. *The Image of the city*, op.cit., p. 49.
2 ibid. p. 48.
3 ibid., p. 95.
pavement interrupted in Dock Square, yet it continues after it. Lynch points out that the interruption in this case is followed by a sudden change in the use of buildings. The example can be also interpreted as one where the increase of depth is related to variations in the land use pattern.¹

The notion of depth in urban systems is more clearly identified in Lynch's observations on unaligned paths. He observes that many streets tend to 'gain intimacy as they shift course, though the shift can be also taken as a cause for confusion.'² His analysis of different areas of Boston suggests that, in view of the misalignment of the area, people were uncertain of which ways to use in order to arrive at particular destinations. Their view of the outside destinations was blocked, and the paths failed to tie to outside paths. Lynch's misalignment describes precisely the increase in the depth of a system, in view of the increase of the amount of axial steps to be followed in order to reach a particular destination. With this respect Lynch prescribes: 'Lines of motion should have a clarity of direction. The human computer is disturbed by long successions of turnings, or by gradual, ambiguous curves which in the end produce major directional shifts.'³

The argument is also extended towards the role of paths in structuring the global scale of the city: 'Paths, the network of habitual or potential lines of movement through the urban complex, are the most potent means by which the whole can be ordered.'⁴ Lynch associates the spatial characteristics of different areas of Boston to the pattern of distribution of land uses. His observations suggest that the concentration of a special use or activity along a street tend to give it prominence in the minds of the inhabitants and moreover, that this

¹ The concept of depth will be presented and discussed further in this chapter, during the presentation of the methodology of syntactic analysis. For the moment it is enough to say that the concept of depth describe the extent to which it is necessary to pass through a number of intervening spaces in order to reach a certain space or a set of spaces.
² ibid. p. 96.
³ ibid. p. 96.
⁴ ibid. p. 46.
prominence is increased by 'the visual exposure of the path itself or the visual exposure from the path to other parts of the city'. The argument suggests the role of some urban spaces in producing the overlapping of the local and the global scales of the city, and mostly how the perception of how far one can see and how far one can walk is a determinant factor for that. Eventually Lynch suggests, following the perceptual approach of his thesis, that 'there is a pleasant feeling of relationship to be gained simply from standing on a street which continues to the heart of the city, however far'.

The problem of defining sub-areas inside the city is also approached by Lynch in his notion of district: 'districts are the medium to large sections of the city, conceived of as having two dimensional extent, which the observer mentally enters inside of and which are recognizable as having some common, identifying character'. He observes the identifying character of different districts in terms of having 'a distinct and recurrent street pattern'. As the effective physical element for defining this 'thematic continuity' he proposes the concept of texture. The concept is spatially defined. Lynch considers that 'a large number of paths may be seen as a global network, when repeating relationships are sufficiently regular and predictable'. The definition shows traces of Conzen's plan unit, yet for Conzen's physical descriptions a vague spatial definition is less acceptable than in Lynch, for the explicit perceptualist approach of his work.

In a subsequent work Lynch shifts his focus towards the development of a typology of the urban grids based upon relationships between their

1 ibid. p. 51.
2 In syntactic terms the characteristic of 'how far one can see and how far one can go' is the basic requirement for the axial description of the urban space.
3 Lynch, K. The Image of the city, op. cit., p. 52.
4 ibid. p. 47.
5 ibid. p. 47.
6 ibid. p. 47.
formal and functional characters. Lynch suggests that 'the intrinsic formal character of each of these patterns has certain functional implications, such as rigidity or flexibility, dispersed or concentrated communication, specialisation or repetition of parts. Other characteristics appear only when applied to a particular situation. These patterns once applied can be judged on many counts, but most likely two will be crucial: the accessibility provided between units, which is the basic functioning of the whole and the sense of form and organisation that will be conferred on the final design, which is fundamental to its aesthetic quality.'

Furthermore this general classification is subdivided, as an attempt to capture the relationships between each pattern and the different elements they are composed. This subdivision generates a wide range of sub-types which makes Lynch's proposition less a theory of possible city forms and more a catalogue of different parts of cities. The use of Lynch's typology as an analytic tool is rather prevented by such an idiosyncratic character. Besides that the model carries a sort of hierarchical organization, which dismisses the fact that most urban components belong simultaneously to different scales of spatial organization, from the more local to the more global.

The contribution from Lynch is less relevant for the typology he proposes than for his insights, in a further study, with respect of the need for the development of graph descriptions of the urban space. The lack in urban theory of a specific and accurate description of the spatial features is his target. He maintains that 'the study of cities has no powerful basic language of its own and that it borrows the devices of geography and architecture, but these are only partly useful. If a language particular to

---

1 Lynch, K. The Pattern of the Metropolis, in Blowers et al., Urban Change and Conflict, op. cit.
2 Ibid. p. 34.
As cities develop, it is likely that it will be a graphical one, since graphics are superior to words for describing complex spatial patterns. The prescription offers some hints which lead towards a representation of the urban space that is parallel, if not coincident, to the way proposed by the syntactic methodology.

Lynch relies on the objective fact that 'a spatial pattern can be seen as a network, which itself has a form and a connectedness.' He maintains that a network description is clearly appropriate to describe these features, since 'graphic diagrams would be the prime ways of conveying these shapes.' He further suggests that 'mathematics is steadily becoming more important for doing so, particularly by means of topology, since many of the important spatial relations in settlements are nonmetrical... graph theory is useful in analyzing route networks and the networks of interaction.' Lynch's statement clearly indicates the necessity of urban studies to be dealt with as an experimental science, where graphic representations tend to work better than words as instruments for more precise descriptions.

Lynch is particularly concerned with the gap between spatial descriptions and the representations of land use distribution. He criticizes the standardized planning procedures that have systematically dealt with patterns of land use distribution without taking into account the spatial properties of the urban systems: 'The familiar land use map is a constant subliminal pitch, urging us to consider spatial patterns in this map-pattern mode.' Lynch acknowledges the necessity of linking a network representation of the urban spaces to the representation of land use distribution. His concern is focused on the problem of measurement of accessibility, in topological terms: 'we might map the degree of access, at any point, to the activities at other points of a settlement and

---

1 ibid. p. 351.
2 ibid. p. 357.
3 ibid. p. 357.
4 ibid. p. 357.
5 ibid. p. 356.
so short out a long circuit of street networks...⁴ Lynch, at this point, anticipates the central proposition of the current research, that is to say, the analysis of patterns of land use distribution from the standpoint of urban morphology.

The perceived effects of spatial configuration on space use is also the concern of Schumacher (1978), who points out some clearly syntactic oriented views on the interrelationships between urban components.² He suggests that 'configurations in which the dwelling unit is isolated by extensive and underused spatial elements (path, lobby, elevator, corridor) occurring in the route from street to dwelling increase the incidence of disorientation... A high degree of privateness for the dwelling unit may also enforce remoteness from the world outside'³

Furthermore Shumacher's perception on the effects of depth, stated above, transcend the residential use. On the relationship between shops and street in the towers of the Sixth Avenue in New York, Schumacher states: 'ground level land uses are relatively private and relate to the buildings, but not to the street. While the street is called commercial on the land use maps, the type of activity housed at ground level (elevators, lobbies and banks) does not sponsor street activity... In Madison Avenue, by contrast, the land use distribution, which places shops at street level, is conducive to street related activity.'⁴ In this case Shumacher is keen to acknowledge the importance of constitution, i.e. the direct relationship between entrance door and public realm, the effects of lack of constitution in generating depth between land uses and urban space and moreover the repercussions of that in street use.⁵

---

¹ ibid. p. 358.
³ ibid. p. 134.
⁵ Constitution is the syntactic concept for describing the relationship between public and private realms through entrance doors.
Eventually Schumacher, in dealing with the street to street relationship, offers an attempt for describing the syntactic dimension of urban space. His model, inherits much of the Alexander’s proposition yet discussed, though it evolves into a morphological explanation of the semi-lattice pattern. In contrast to the tree-like configurations he states that in traditional settlements ‘streets are related in a contiguous, hierarchical relationship and as such, streets enhance or inhibit contextual continuity ... This hierarchy can be represented by a spiral diagram which permits each of the direct relations of house to street, house to neighbourhood, and house to district to be easily cognizable.’

Shumacher’s diagram, however a reduction of the spatial complexity of actual urban systems, is an advance with relation to the unclear notion of semi-lattice proposed by Alexander. Moreover the contribution of Shumacher’s work is less important for his spatial model, than for his insights on the role of spatial relationships as an essential element in street pedestrian use and understanding of the public urban environment: ‘the quality of getting there is central to the existence and quality of there... A choice system of understood multiple routes to multiple goals is apparently essential’.

Anderson (1978) takes the network-type description of the urban space, suggested by Lynch, one step further and proposes the representation of the street grid as a pattern of ebbs and flows he will call space of public claim and corresponds to all space which is permeably or visually accessible to everyone in the streets. Such public space is loaded by two other functional distinctions. These are the space of private or domestic claim and the space of occupational claim (work). Some concepts as well some descriptive methods utilized by Anderson are in many senses germane to the descriptions to be found in the current research.

---

1 ibid. p. 146.
2 ibid. p. 135.
Anderson proposes a method for describing the spatial continuity of the urban fabric. He suggests the translation of the urban plan into graphs that may be analysed topologically. These graphs, 'by retaining their metric and topographical reference may also be analyzed metrically or statistically'. It is a linear street map, a graph generated by tracing centre lines of streets and projecting them to their meeting points. Anderson suggests that this method will not only allow the comparison of different graphs, but also the storage of different types of information, such as 'the designations of types of accessibility, ownership structure, land use distribution...'. Anderson also anticipates that such graphs may permit systematic and comparative descriptions of the transformational rules that relate one pattern of spatial organization to another. Both his proposal of loading the axial lines with socio-economic information and also the possibility of proceeding comparative descriptions based upon topological properties of the street grid are methodological procedures that are systematically utilized during the empirical part of the current research.

Yet Anderson's base graphs resemble in a first look Hillier and Hanson's axial map, this is not the case. Both are linear representations of the structure of public spaces of a city, as lines corresponding to the street grid. Although there is one fundamental difference. While for Anderson the correspondence between line and street is a direct one, i.e. street $x$ is represented by line $x$, for Hillier and Hanson each street of a system is decomposed in a pattern of axialities, i.e. a decomposition of this same structure into its axialities. In the case of a curvilinear street the base graph will describe with a line the very contour of the street, while the axial map will decompose the curve into the smallest amount of axial segments which are capable to cover the same path. It is precise this translation of the actual plan into a diagram of axialities that generates the description and the measurement of the syntactical properties of an urban area, to be further discussed.

---

1 ibid. p. 284.  
2 ibid. p. 284.
More than acknowledging the potential of the graphic analysis as an instrument for identifying the topological differences between urban areas, Anderson suggests that a graph description also allow an exploration of what he takes to be an important factor in understanding urban structure: the order of streets. Order in his case has nothing to do with Hanson's concept, to be further discussed. Anderson's concept is hierarchical, order expresses an increase or a decrease in the degree of importance a street has. Nevertheless the concept is vague, it includes the morphological character of the urban space yet it seems to be more concerned with function: 'it is relatively easy to describe an order of streets which would be quite generally accepted in itself and in its implications for the activity and significance of the various streets'. Yet the main question remains as to what accounts for this order.

As possible ways of defining an order of streets Anderson deals with a series of urban properties such as geometry, continuity, width, number of parcels accessed, intensity of circulation, etc. In fact he does not develop a procedure for measuring more objectively these properties, especially the ones like continuity and intensity of circulation that are related to the global organization of the city. However, the proposition is relevant both for its emphases on the potential of graph analysis in allowing 'systematic and comparative descriptions of the transformational rules that relate one pattern of organization to another' and moreover for the link Anderson sets up between space and society through the base graph: 'a description of a network is already the record of social decisions'.

From the works presented above the contributions of Lynch and Anderson seem to be the ones more related and probably influential to the type of spatial description this thesis is concerned. Lynch besides presenting a

---
1 Hanson, J. Order and Structure in urban space: a morphological history of the City of London, op.cit. pp. 89-115.
3 ibid. p. 271.
number of precise insights on the syntactic dimension of the urban space, from the perceptual stand-point, acknowledges the subjectivity of his approach and anticipates the need in the urban studies for the development of descriptive techniques concerned with the spatial network of the street grid. Anderson takes Lynch proposition one step further and introduces the base graph. Yet he does not develop a system of measurement, the description he introduces is in fact a less developed version of the axial map.

By contrast the review of the more typologically oriented descriptions has shown that for most of the literature discussed nothing is said about the configurational properties of cities at a global scale, i.e. 'that quality of being spatially integrated on a global scale without compromising the differentiation and distinct character of their parts'.\(^1\) The attempt of reducing the spatial complexity of urban systems to a typology have either ended up by being too reduced or too cumbersome as to become more a catalogue than a model with an internal theoretical logic.\(^2\) Eventually the problem of classifying the urban space has inevitably led different authors to the impossibility of describing not only the endless variety of spatial configurations but moreover how the different elements of the spatial continuum relate to the each other throughout the urban grid. This is precisely the phenomenon the syntactic method to be discussed during the next chapter aims to describe.

Notes on chapter one

As a whole the literature reviewed during this chapter has shown that urban land use and urban morphology have been dealt with as rather autonomous fields of study in relation to the each other. On the one hand the spatial variable considered in land use studies is either restricted to

\(^1\) Peponis, J. Space, Culture and Urban Design in Late Modernism and After, op cit. p.15.

\(^2\) The work of Krier seems to be a classic example of this last group.
the demarcation of zones in the urban field or translated into time-cost variables. The problem of identifying the effects of the actual spatial configuration of the urban phenomenon upon the patterns of land use distribution has not been taken a relevant issue in urban land use studies. That is to say the problem of whether or not land use distribution is somehow affected by spatio-morphological factors is in effect a blank page in the literature.

On the other hand the literature concerned with the description of the morphological character of towns has done little to clarify this same issue. Within these studies land use has been dealt with as a catalographic record within paradigmatic situations instead of as a feature whose performance might have broader (or global) spatial implications.¹ More than that the literature concerned with morphology has done little to describe the potentially endless variety of grid configurations observed in actual cities. Different from that the review of selected work presented in this chapter has shown a systematic effort by different authors of reducing the 'natural' spatio-morphological variety of towns to a limited range of 'types'.

It is precisely in this gap observed in the urban culture that this study aims to be inserted. That is to say, as an instrument for the assessment of the configurational character of urban areas and moreover as an instrument for describing land use distribution from the standpoint of spatio-morphology or, in other words, from the standpoint of the configuration of the urban grid. The clarification of the instruments to be utilized for that purpose and their theoretical background comprise the subsequent steps of this study to be put forward in the next chapter.

¹ The works of Caliandro (Street form and use, op.cit.) and Anderson (Ecological model of the urban environment, op.cit.) are examples of that.
Chapter 2
Grid Configuration and Land Use: Methodology of Analysis

This chapter introduces the methodology of analysis and the cases to be investigated. It starts by presenting the method of syntactic description of the urban grid; a range of concepts and measurements which comprise the analytical framework to be utilized in order to accomplish with the aims of this research, namely the description of grid configuration in Porto Alegre and in a subsequent step the investigation of the extent to which the range of descriptions to be provided are associated with the patterns of land use distribution in the same areas.1 The presentation of the methodology of syntactic analysis will be paralleled by a discussion of other network or 'graph' representations of the physical environment.2

This is followed by the presentation of the areas of Porto Alegre that will be examined and the criteria applied for their selection. The presentation of the areas to be given at this stage is not a detailed spatio-morphological description, but just an overall view of visually observable features directly given by the cartographic material. The detailed spatial description of each area is the specific object of chapters three and four where a complete syntactic analysis of each area is carried out.

A subsequent step will introduce the descriptive techniques concerned with the description of land use distribution. The techniques to be presented are distinct from traditional land use representations in the sense that they aim to describe as precisely as possible the distribution

---

1 Some more specific and complex procedures related to the decomposition of the urban grid will be dealt with during chapter three in the light of examples provided by the cases to be examined.

2 The idea of carrying out with this discussion at this stage, and not during the review of literature presented in chapter one, is to show that although some systems of measurement are common to syntax and other types of network analysis, the concern of the syntactic description with the shape properties of the street grid sets up both a quantitative and a qualitative difference if compared with other network descriptions.
of uses in relation to the street grid itself and not as an areal dimension as it is done in conventional land use studies and masterplanning. A brief review of literature concerned with problems of land use classification was also included here (and not in chapter one as it could be expected) as a way of discussing and justifying the classification system to be proposed in the light of some paradigmatic works that have been carried out in the field. These tooling up sections are followed by an overall view on the organization of data and its processing procedure. The final part of this chapter provides an outline of the statistical tests that will be utilized during the analysis.

Urban systems as axial systems: A syntactic approach for describing the urban space

The descriptive theory proposed by Hillier and Hanson is an attempt to describe and measure the continuous variation in the spatial continuity of the urban grid by means of a set of non-arbitrary elements. The syntactic description carries the dual objective of both representing and quantifying the urban grid. The method aims to identify the irreducible elements and relations in grid configuration and, moreover, to describe these spatial structures by using particular synthetic notations. The syntactic descriptive theory differs from the preceding theories in two simple, yet essential, respects. First, space is described in terms of abstract properties of topological nature rather than in terms of geometric regularities. Second, space is described as a relational pattern which can be explored and understood without being directly visible in its entirety.

The syntactic description of urban grids is based upon the analysis of cartographic material which generates numerical information and allows not only the comparison of the syntactic properties of urban spaces

1 The syntactic methodology of urban settlements is fully stated in the Chapter 3 of Hillier, B. and Hanson, J. The Social Logic of Space, op. cit.
The numbers in the axial map at the bottom show the connectivity of each line.

Smaller town in the Ver Region of France (Geller-Hiller and Henson).
within an urban area but also the comparison between the configurations of different urban areas. The representation of the continuous spatiality of urban systems, through a specific and adequate notation, is the key element which opens the possibilities for the investigation of the relational properties of the urban space.

The ideography proposed by the syntactic method of analysis introduces the axial representation of the urban spatial continuity. According to the method, the open space structure of the settlement is translated into an axial map, which is constituted of the fewest number of straight lines that pass through its open space. Each line carries two properties: visibility - how far one can see - and permeability - how far one can walk. An axial line can only be drawn between two points when there is a direct sight line and also a line of unimpeded access. As a consequence the axial map is an accurate record of the least set of longest and straightest lines of sight and access which covers the public system of open space of a city (Fig. 2.01). Therefore, as it is observed by Hanson, an axial map is not the same as a street map: 'Where two or more streets are aligned in such a way that a long line of sight and access can be drawn which crosses both, then this is drawn even though it compresses the two named streets into one axial line. Where, on the other hand, a street curves so that it is not possible to see and go all the way along it directly, this too is reflected in the transcription' that is the street in this case will be decomposed into its axial segments.¹

The axial map can be constructed both manually or by computer using an algorithm which decomposes the geometric configuration of the street grid into its axial segments. In any case the same construction rules apply. Hanson recommends: 'each axial line will be drawn by aligning a straight-edge along the back of the building line and moving it until the longest possible straight line is arrived at which is end-stopped, however obliquely, by building facades. Where two axial lines overlap'

¹ Hanson, J. Order and Structure in urban space: a morphological history of the City of London, op. cit. p. 85.
and run together, both are drawn and where these intersect with a third to create and an apparent 'island' this is disregarded.¹ These trivial islands which happen entirely within the open space structure are shaded in order to differentiate from the axial lines that surround urban blocks. This is shown in the axial map at the bottom in Fig. 2.01.

In a subsequent step, once the street plan is decomposed into its axial lines, each of these lines is numbered. The axial map is then translated into a numeric matrix which describes all the connectivities between lines. A line is connected when it crosses or intersects another. The representation of the urban grid as a pattern of connections, will propitiate and facilitate the description of each space according to its position in the system. The connectivity matrix, which is derived from the axial map, is the basis for deriving a range of measurements of different properties of the street grid.

The research so far carried out utilizing the axial map as an analytic tool has been much focused on modelling patterns of pedestrian movement. Nevertheless, as Hillier puts forward, the syntactic methodology has a broader spectrum of interest: 'space syntax techniques were not originally aimed at modelling movement but at understanding the morphological logic of urban grids' ² The modelling of pedestrian movement is, for Hillier, 'literally a by-product of a research programme with different aims'.³ In any case the understanding of the axiality of an urban system as movement lines, either vehicular or pedestrian, seems to be essential for the understanding of the syntactical approach.

The research on axiality has shown that 'the way in which an urban area structures a pattern of pedestrian occupancy and movement is largely a function of how it organizes a pattern of direct lines of unimpeded movement which are also sight lines', that is to say, a function of the

¹ Hanson, J., op.cit., p. 85.
² Hillier et al. Natural movement: or, configuration and attraction in urban pedestrian movement, Unit for Architectural Studies, Bartlett School, 1989, p. 6.
³ ibid. p. 6.
axial organization of the area.\textsuperscript{1} Understood in this way the axial map is closely related to the way individuals see and understand the pattern of space of an urban area. Thus the axial map, as it has been noticed by Hanson, in covering 'the essential visual and access information field of a pedestrian user, is a recovery of a 'real' property of urban space.'\textsuperscript{2}

Syntactic research on pedestrian movement has also suggested that the shorter axial lines tend to be quieter back spaces, while the longer lines are the busiest ones: 'straight lines minimise distance, so long straight lines are likely to be on more distance-minimising routes than shorter, broken-up lines. It is not surprising, then, that where more broken-up lines are concentrated, one will tend to find fewer people, while one will tend to find correspondingly more along longer lines.'\textsuperscript{3} This statement carries in fact an oversimplification of the problem, for these experiments have also revealed that the length of an axis is only partly responsible for the movement it carries. A more subtle property to be further introduced, defined as integration, seems to play the a more effective role for the vitality of urban systems.

Two important properties emerge from the axially of the urban systems. The first is its capacity of giving rise to a 'successive awareness of a system of spaces from a multiplicity of points within that system.'\textsuperscript{4} Hillier regards the axially of urban systems as the means of linking the local scale to the global and achieving a compression of scales, the sense of being in a local identifiable place and part of a much larger global system, at the same time and by the same spatial means.\textsuperscript{5} The second property is its double nature: instrumental and symbolic. In this way, Hillier makes a distinction between an instrumental axially, which is

\begin{flushleft}
\textsuperscript{1} Hillier, B. et al, \textit{Coin Street: an applied study in syntactic analysis}, Unit for Architectural Studies, Bartlett School, 1985, p. 3.
\textsuperscript{2} Hanson, J., op.cit. p. 85.
\textsuperscript{4} Hillier, B., \textit{Axis as Symbol}, Unit for Architectural Studies, Bartlett School, 1983.
\textsuperscript{5} An argument that seems to be coincident with Lynch’s perception of the global scale of the city.
\end{flushleft}
associated with situations where the exigencies of everyday production and distribution are the dominant requirements, and a symbolic axiality, which is associated with 'situations where the requirements of social reproduction dominates over the needs of production'.

The current study aims to extend the research on the axiality of urban systems, so far more focused on the modelling of patterns of pedestrian movement, towards the performance of land use distribution when compared with syntactic descriptions. The central hypothesis of the current investigation is that if the distribution of land uses is systematically related to the axial properties of the street grid, we can infer that these properties play themselves an influential part in the functional distribution of an urban area, that is to say, the axial organization is in itself a powerful predictor for the location of different land uses. This research intends to demonstrate that the analysis of settlements based upon the information of the axial map not only provides rigorous descriptions which allows objective terms for the comparison of urban forms, but also, can demonstrate how different urban patterns tend to be associated in their form and structure to different land use distributions. Such embodiment is in itself a part of the morphic language of the urban space.

**Measuring networks**

Before presenting and discussing the syntactic measures that will be utilized in the empirical part of the current study, it will be clarifying for comparative purposes to provide a brief account on *network representations* of the physical environment. The reason for discussing this type of representation at this point is that some syntactic

---

1 ibid., p. 6. This representational capacity of the structure of open spaces of a city has also been noticed by Aymonino, and related to functional diversity: 'the monument, as a point of reference and synthesis of different meanings, has been replaced in contemporary cities by the system of routes, as the place of total representation and multiplicity of uses of the urban form'. In Aymonino, C. *El significado de las ciudades*, Blume Ed., Barcelona, 1970, p.41.
Fig. 2.02  A transcription of a road lay out from Hagget and Chorley

Fig. 1.2. Reduction of a map of a transport network (A) to a graph (B).

Fig. 1.3. Alternative topologic forms for the graph mapped in Fig. 1.2.
measurements, as it will be seen, are derived from network descriptions, not only in the field of urban geography but also in the field of sociometry. The idea is to show that although some systems of measurement are common to syntax and network analysis, the concern of the axial description with the shape properties of the street grid sets up both a quantitative and a qualitative difference if compared with network descriptions.

Network descriptions of urban systems have been in most, if not in all, cases adaptations of proceedings traditionally used either by regional planning or by urban geography. The network of streets is in these studies reduced to a node map. The work of Hagget and Chorley (1969) illustrates this descriptive approach. Fig. 2.02 shows how these authors reduce the map of a road network to a graph. Each road intersection is represented as a node and each road as a connection between nodes. The actual form, or shape, of the road is deliberately not taken into account: 'there is no concern with the length or orientation of lines nor whether they are curved or straight.'

The lack of concern of the mapping procedure described above with shape properties, sets up a fundamental restriction for its use as an instrument for describing the fine structure of the street grid. The comparison with the syntactic description is clarifying. As Hanson notices, 'in architecture, the shape properties of the design are more important than in geography, and were the road layout to have been a designed one then the difference between the relatively straight sections of road and the highly articulated parts would have been intended, perhaps as a reflection of different kinds of use. In syntax the

---


2 Hagget and Chorley, op.cit. p. 5.
nodes and their intersections are directed towards capturing this spatial articulation as well as the property of intersection'.

It is not intended to present here a discussion on the theoretical and operational implications of node and axial representations. This has been proceeded recently elsewhere. Nevertheless it is noteworthy that the studies concerned with the comparison between these modes of representation acknowledge that the simultaneous description of spatial articulation and intersection makes the axial representation a more accurate description of the spatial dimension of the street grid. As Hanson notices, the axial description allows 'the articulation of a road to read as a spatial discontinuity of equal importance to an intersection', and moreover allows 'the continuation of a line of sight and access across an intersection to read as a spatial continuity. This seems to capture more accurately than a conventional node map the spatial properties which are of specific interest to the design and use of street space'. Nevertheless it is not only the fact that network analysis is not concerned with the length or orientation of the routes or whether the routes are actually straight or curved that differentiates it from the syntactic analysis, since these aspects could be included into the analysis of a network. The difference seems to be a rather conceptual one, for network analysis is basically concerned with the study of locations or flows instead of the actual spatial configuration of urban systems. A precise account of the functional character (quantitative parameters) of these elements is what counts for an accurate network description of a given system.

1 Hanson, J. Order and Structure in urban space: a morphological history of the City of London, op. cit. p. 59-60.
2 The relationships between the axial and node representations is fully discussed in Kruger, M. On Node and Axial Grid Maps: Distance Measures and related Topics, UAS, Bartlett School 1989. A comparative study between node and axial representations for orthogonal and radial grids is also provided by Hanson, J. Order and Structure in urban space: a morphological history of the City of London, op. cit. p. 94-97. See also Hillier et al. Natural movement: or, configuration and attraction in urban pedestrian movement, op. cit. p. 9.
3 Hanson, J., op.cit., p. 61.
4 The typology of network components proposed by Lenzi for Reading is an example. He proposes eight categories of nodes (intersections) according to a rather mixed criteria that
The morphological dimension is considered only when the performance of a system is supposed to be affected by such a factor. This is the case of the study of highways or railways in a regional or national scale. It is this more functionally oriented character that makes the network studies developed by urban geography a useful descriptive tool to represent systems belonging to a regional scale, where flows of different types can be more clearly identified or, when applied to an intra-city scale, to the specificity of transportation flows. Different from that the axial representation proposed by the syntactic analysis is by definition concerned with the spatio-morphology at an intra-city scale. The description is spatial. The axial network is by definition a spatial network, where the actual shape properties of an urban area are described.

This seems to suggest that the geographic concept of location is too coarse for describing, in spatial terms, the functional complexity of intra-urban scales, where spaces and activities are closely juxtaposed, mixed and sometimes even spatially superimposed. Besides that the networks concept of flow can hardly be applied to the description of a street. This does not prevent the axial representation from being seen in terms of locations and flows. The axial lines in real cities are actually loaded by locations, i.e. location of different activities along itself, yet it is flow at the same time. The street is locus - is location - although it is a channel as well. The concept of axial line puts together these static and dynamic properties of the street. The syntactic definition of axiality based upon how far one can go and how far one can see, is in fact a synthesis of form and function at the scale of the public spaces of a city. It is architectural when describing visibility, yet at the same time it keeps the flow character when describing accessibility. This dual

---

includes the amount of links connected to the node, the presence or absence of traffic lights and the physical configuration (roundabouts, multi-level crossings, etc.). For the links (segments of streets), Lenzi proposes a hierarchy related to the width of the road, which is based on the 'national classification of road categories'. This classification includes a range of road types from the by-passing town motorways down to the local access roads. Lenzi, G. Urban Systems: a study of a road network, op. cit., p. 12.
character of the axial description is what allows for its use as a morphological base in relation to which the correlated performances of different socio-economic variables can be observed. It is precisely in this way that patterns of land use distribution will be described and analysed during the empirical part of the current research.

Measuring the configuration of the street grid

This section introduces a range of ways of measuring spatial axiality in urban systems. Some of these measures have been previously utilized in the description of networks, or as it is referred to above, for measuring node representations of communication systems. Nevertheless, from the operative standpoint, all the measurements to be utilized in this study are originally syntactic, in the sense that despite some procedural similarities with networks description, all the measurements in this study will be derived from the axial map. For instance, in standard network analysis connectivity is measured in terms of the number of nodes in the network while in syntactic terms the connectivity of a street means the amount of intersections observed in each axial segment of that street. The syntactic concept of connectivity, as it is stated by Hillier and Hanson, differs from connectivity in network analysis in that it is closer to the description of the actual configuration of the street grid. Needless to say that the axial description of urban systems expressed in the axial map is perhaps the most effective contribution of syntactic analysis to the field.

Most of the measurements to be utilized have been and are currently being tested in the Unit for Architectural Studies of the Bartlett School. This is the case of the measurements for integration, connectivity, and

1 The term communication systems is, in this case, a generalization provided in order to describe such different phenomena as physical flows in, for example, transportation studies up to networks of human communication in sociometry.
2 That is Hagget and Chorley's $V$ number, i.e. the number of vertices in the network. In Hagget P. and Chorley, R. Network Analysis in Geography op.cit. p. 32.
choice and intelligibility. Nevertheless some measurements to be introduced are being utilized for the first time, as instruments of urban analysis, during the current research. This is the case of both the length of each individual axial segment and also the average length of the axial segments belonging to a specific part of the grid. Other measurements to be introduced include the density of axial lines per area as a way of measuring the distinct degrees of axial fragmentation of different parts of the grid; an axial version of Borchert’s classical measure of density of intersections per area\(^1\) and an axial version of Horton’s measurement of drainage density which for the purposes of the current research will be translated in terms of the total length of the axial segments relativised to the area of the system of interest.\(^2\)

The first order measurements—integration, choice, connectivity and axial length—describe urban grids both in terms of the axial properties belonging to each one of the axial segments of the system and also in terms of the mean value of the measurement for the area of interest.\(^3\) That is to say while the first order measurements are referred to the syntactic identity of each axial line within an urban area, their mean values—inside the area of interest—will be utilized as a way of describing the syntactic identity of the area as a whole and moreover to compare different areas from the stand-point of these parameters. For instance, each axial segment belonging to an urban system has its own connectivity value which corresponds to the number of intersections it carries. At the same time the system which this axial segment is a part has a mean connectivity value which is the arithmetic mean of the intersections of all axial segments inside the system. Different urban areas can be then compared in terms of their mean connectivity. The density measurements referred to above are included amongst the group


\(^3\) The criteria for the definition of the boundaries of each area is defined at the outset of chapter three.
of parameters which aim to describe the syntactic identity of whole areas.

The order in which the measurements will be presented does not imply in that some of them are more important of more accurate as descriptive tools than others. Each measurement describes a particular feature of the urban grid and moreover all these measurements can be regarded as products of *ongoing* research, in a field that is new and much open to propositions.

The measurement of integration is based upon the notion of depth in urban systems. Depth exists where it is necessary to pass through a number of intervening spaces - that is to say, a number of axial segments - in order to reach a certain space or a set of spaces. Depth can be seen and experienced from any given point inside or outside a system of spaces. Shallowness is the opposite way of referring to the same property. The term is in fact applicable for describing small depths and indicates the extent to which the route between spaces is more direct.

From the notion of depth comes the measure of integration. Every route - i.e. axial segments of routes - in an urban grid will be a certain number of axial steps away from every other line in this system. By repeating this procedure for every axial line we will find that the totals - the number of axial steps that interconnect an axial line to the whole system - for each line are different, often considerably so. The measurement of integration is obtained by assigning a depth value to each space - to each axial line - according to how many axial steps it is away from every other space in the grid, thus providing a global index of relative integration (or segregation) for that line.

---

1 Yet the consistency observed in the correlations between the measurement of *Integration* and patterns of movement of people has rendered this measure a spacial status inside the syntactic research. This is acknowledged both in Hillier et al in *Natural movement: or, configuration and attraction in urban pedestrian movement*, op. cit. p.10 and also in Hanson, J. *Order and Structure in urban space: a morphological history of the City of London*, op. cit. p. 85.
The numerical value for integration is a number varying about 1 with lower values indicating spaces from which the system is shallow - spaces which tend to integrate the system - and higher values for spaces which tend to be more segregated in the system. The formula for the calculation of integration is \(2(MD - 1)/K - 2\) where MD is the mean depth or mean number of spaces away of all the other spaces in the system from the selected space, and K is the total number of spaces in the system. A correcting factor is then applied to eliminate the empirical effects of size.

Each axial line belonging to an urban grid has its own integration value which is the mean of all depths between itself and all the other lines of the system. This characteristic makes integration a global measurement. Global in the sense that it describes a local element, i.e. the axial line, from the standpoint of its global properties, that is to say, from the standpoint of its interaction with all other lines of the system. Besides the integration value of each axial line, each system - groups of axial lines composing an urban grid - will have its mean integration value which is the mean of the integration values of all its lines. In other words the Integration measure of a system will be the mean depth or shallowness of all spaces within it. Integration values are rank ordered from the most integrated to the most segregated axial line within a system. In this sense, as Hanson notices, integration is a measurement of spatial hierarchy.

---

1 The mathematical description of algorithm utilized for calculating Integration is fully presented in Hillier, B. and Hanson, J. *The Social Logic of Space*, op. cit., p. 108-109.

2 There are two possibilities for relativising the system. Hillier and Hanson suggest that this can be done by comparing the actual Integration value arisen from the axial map to the Integration value calculated for the root, i.e. the space at the bottom, of a diamond shaped pattern (the diamond distribution gives an even spread of spaces above and below the mean). In Hillier, B. and Hanson, J. *The Social Logic of Space*, op. cit., p. 111. In a later study Kruger has suggested another way of looking at the same question, that is to relativise the system with respect to the node map of a regular orthogonal grid, set on one of its corners. In Kruger, M. *On Node and Axial Grid Maps: Distance Measures and related Topics*, UAS, Bartlett School 1989, p.29.

3 Hanson, J. *op. cit. p. 85.*
Both the most integrated and the most segregated spaces can be highlighted in the axial map. The most integrating lines of an area, i.e. the lowest values in the integration rank, provide a distinctive pattern. It is called the integration core.¹ The integration core of an urban system can be either composed by contiguous axial lines or be fragmented throughout the area, all depending of the configuration of the grid. The shape of the integration core as well the way it spreads – the order of integration – can be used as ways of describing urban grids. One of the techniques this research intends to utilize is precisely the description of different urban areas in terms of the shape and spread of their integration core, and moreover to verify whether any relationship between these configurational properties and the distribution of land uses emerge. The conjecture is that the configuration of the core defines what are the spaces from which the whole system is more directly accessible and more easily controllable, and thus these variations in accessibility should have effects in the way different uses are distributed in the area.

Another way of measuring the axially of the urban grid is in terms of the choice value of its axial lines. As with integration, choice is a global measurement since it also describes each axial line with relation to all others in the system. Although, instead of indicating depth, choice indicates the degree of accessibility – in terms of number of axial steps – that a space represents on all shortest routes from all spaces to all other spaces in a system: ‘the choice value of a space indexes how many of the most direct paths connecting each of all the possible pairs of other spaces, go through that particular space’.² An integrated space does not necessarily have a strong choice value. The syntactic character

¹ The percentage of lines that is selected in order to define the configuration of the integration core varies according to the size of the system. In large urban areas 5% is usually enough to provide a clear picture of the spatial pattern described by the most integrating lines. In smaller systems the percentage tends to increase, yet 10% can be regarded as a reasonable standard.

of a cul-de-sac provides a classic example in this respect. A cul-de-sac may be shallow within a pattern of connections, and so having a high integration value, but since it does not lead anywhere it has a low choice value. The choice value will be calculated by taking all axially shortest paths from all spaces to all other spaces and then computing the proportion of shortest paths in the system which pass through every constituent axial line.¹

Like integration, choice measurements can be rank ordered from the space which carries the greatest proportion of shortest routes to those that carry the least. Syntactic studies so far carried out have shown that choice cores tend to be more spread than Integration cores and are also more likely to pick up the global structure of the area.² In view of this capacity of describing the global structure of the urban grid, the configuration of the choice core - the highest choice values of an urban system - has often been used as a parameter for defining the spatial boundaries of urban areas.³

The procedure for measuring the degree of choice an axial line represents among all other lines in an urban system, has already been utilized in the study of networks of human communication. Bavelas (1948) anticipates the topological notion of choice with his concept of point centrality in communication systems based upon the structural property of betweenness: 'A point in a communication network is central to the extent that it falls on the shortest path between pairs of other points'.⁴ Freeman (1977) utilizes similar conceptualization to state that 'a point is considered to be central to the degree that it falls between other

¹ The mathematical description of algorithm utilized for calculating choice is fully developed and presented in Spatial Configuration and Use Density, Report to the Science and Engineering Research Council, UAS, Bartlett School, Mar 1986, Appendix 2.
³ This is done in Peponis, J. The Spatial Core of Urban Culture, op. cit. The performance of high value choice lines as a parameter for boundary definition is assessed during the chapter three of this thesis.
⁴ Bavelas, A. A mathematical model for group structure in Applied Anthropology, № 7 1948, p. 27.
points on their shortest or geodesic communication paths. A point falling between two others can facilitate or block their communication.¹

As with "all syntactic measurements, the concept of centrality is topologic, not geometric. A high degree of centrality is, according to the definition of these authors, the syntactic equivalent to a high choice value. Identical procedure is also utilized by Hagget and Chorley (1969) in order to measure shortest path matrixes: 'The shortest path between two nodes in a network is measured topologically by the number of intervening links to be traversed...the shortest path matrix may be used to compare the relative accessibility of nodes within the network.'² Nevertheless, despite the operational similarities the syntactic measurement of choice is conceptually different from the shortest path measurements referred to above, in that it is a spatially oriented parameter derived from the axial map.

Different from Integration and Choice, that are global parameters the measurements of connectivity and axial length are local descriptions. Connectivity, as it has already been said, is literally the number of axial lines which intersect with each line in the system, or more straightforward, how many spaces are one axial step away from a space.³ Length, again it is relevant to stress, is not the length of the street, but the metric length of each axial segment of the urban grid represented in the axial map.

The syntactic measurement of the intelligibility of an urban system, as proposed by Hillier et al. (1986), is the correlation between its connectivity and its integration value: '... the correlation between local and global properties might be a mathematical way of expressing the intelligibility of a system, in the sense of how well the properties of the system as a whole can be understood from its parts. Analytic studies

¹ Freeman, L. A set of measures of centrality based on betweenness, op.cit., p. 36.
³ One 'space' within the context of the current research is equivalent to one axial line.
show that in many types of urban systems this correlation is strong, whereas in others, including many modern environments described as labyrinthine, it is weak. Since on this definition intelligibility seems to be a static property of systems it might be conjectured that the intelligibility of a system, mathematically rather than psychologically defined, might be given by the correlation between connectivity and integration.¹

In theory it can be said that if a space is well connected locally and well integrated globally, then local information is a good guide to global information, i.e. if this is the case the system of interest is well intelligible. Hanson conjectures on the sociological potential of this measurement: ‘Intelligibility expresses the extent to which the axial information which is available to an individual moving through a particular space about how it relates to its neighbours locally, also gives reliable information about the large-scale, global structure of the grid. The conjecture is that integration leads to intelligibility and intelligibility leads to a stronger movement interface between inhabitants and strangers.’²

As it has already been proposed, a set of measurements will be utilized in order to describe not the syntactic identity of individual axial lines — as the measurements proposed above — but what might be called the syntactic identity of specific parts of the grid. Some of these are the mean values, inside the area of interest, of measurements already presented — mean values for integration, choice, connectivity and length. Others are based upon either the number of axial lines or the number of connections (or links) within a specific part of the grid relativised to the area of the system.³ These are the ‘density’ measurements referred to above. These measurements will be fully explained and tested out in

¹ In Spatial Configuration and Use Density, op.cit. p. 6.
² Hanson, J. Order and Structure in urban space: a morphological history of the City of London, op. cit. p. 88.
³ Within the context of the current research the term ‘system’ will refer to a specific part of the street grid.
real situations during chapter four when the comparative analysis of the syntactic identity of distinct parts of the urban grid is proceeded.

One last way of assessing the configuration of the urban grid will be in terms of the amount of order and structure, in syntactic terms, they carry. The syntactic definition of these concepts, order and structure, has been attempted in recent study by Hanson (1989) which examines the syntactic features and the growth process of perfect orthogonal, radial grids and sheaves of randomly generated axial lines. Some of her findings on the syntactic configuration of perfect grids may prove to be a useful benchmark for comparison with the irregular urban grids which form the bulk of this thesis, where the relationship between order and structure is less clear cut.

Hanson observes that in perfect orthogonal grids all axial lines have the same connectivity, i.e. half of the total number of lines in the system, the same integration value and the same intelligibility (zero). This feature is recurrent and independent from the size of the system. From that Hanson raises the hypothesis, based upon the observation of a large theoretical sample, that perfect orthogonal grids lack structure despite their conspicuous visual order. Hanson reads the lack of syntactic intelligibility as a lack of information content in the distribution of values, since all lines are syntactically the same: 'Despite the degree of order which is apparent in the orthogonal grid, formally speaking, it is syntactically unstructured. The computer working on the basis of a connectivity matrix and interrogating a perfect grid as a system of connectivities rather than as a visual pattern, cannot distinguish between the components which make it up. This captures something of

---

1 Hanson, J. Order and Structure in urban space: a morphological history of the City of London, op. cit.
2 In fact the mean integration value of perfect orthogonal grids falls insofar the grid increases in size, yet inside each case the integration value is the same for all lines, i.e. a plot of integration distribution is flat.
the experiential reality of gridiron plans: moving about in them, orientation is difficult since each part of the grid is the same as all others.¹

Hanson then compares the syntactic configuration of perfect orthogonal grids to 'piles of sticks' — the sets of randomly generated axial lines. These are generated by randomly mixing radial and orthogonal tendencies. From this comparison emerges Hanson's syntactic concept of structure, based upon the variation in the distribution of integration values according to the position of each line of the pile within the configuration as a whole: 'This is unlike the previous case of the perfect grid, where all values were identical. These differences from one component in the configuration to another give a pile of random lines structure, although by definition the pile lacks visual order since it is arrived at randomly. If a plot is taken of intelligibility then there is an almost perfect correlation. A pile of random lines, it seems is perfectly disordered but perfectly structured, the opposite of the perfect regular grid.'²

Hanson's order/structure distinction is relevant within the theoretical formulation of the current study. Besides, the cases to be examined can shed some light on the implications of the order/structure distinction to the arrangement of land uses. The urban grids that constitute the bulk of this thesis are neither perfect grids nor piles of sticks. They are rather a complex interaction, and sometimes superimposition, of more regular, more deformed and more labyrinthine-like urban patterns. Nevertheless, if one considers that the topological distance from real urban grids to a theoretically perfect grid 'is precisely what they lose in order but gain in structure', as Hanson suggests, then the different syntactic measurements can be understood as different ways of describing the more ordered or more structured character of each pattern.

¹ Hanson, J. Order and Structure in urban space, op. cit., p. 94.
² ibid. p. 100.
Whether or not this more ordered or more structured character of urban grids is meaningful in terms of the arrangement of land uses is in effect coincident with the central question of the current research. An hypothesis naturally emerges. If the amount of order and structure invested in an urban grid is in effect related to its intelligibility, if more ordered layouts are in fact less intelligible from their inside than when observed from outside (or from above), if syntactic structure actually creates both overall and local differences which make real urban grids intelligible, then the distribution of human activities, and their corresponding land uses, may be in one way or another related to the more ordered or more structured character of the grid, as described in syntactic terms. These issues will be fully discussed during the analytic chapters.

Finally it is worth to mention that the last section of this chapter will present the database containing the organization of all the measurements described above - both the ones referred to each one of the axial lines within a system and also the ones referred to mean values and 'densities' observed for the different systems.

On Selecting the Areas of Study

The empirical part of this thesis will examine a sample of grid configurations taken from the city of Porto Alegre, a 1 500 000 inhabitants state capital in the south of Brazil. The simultaneity and interaction of a large variety of 'types' of urban grids inside the same city make of Porto Alegre a case where this research seems to have fertile grounds for development. The configuration of the street grid of Porto Alegre carries in itself examples of baroque urbanism, garden city developments, modern housing estates and self-produced settlements, all interacting spatially inside the same city. This 'morphological

---

1 in the sense of the correlation between integration and connectivity.
patchwork' seems to make of Porto Alegre a paradigm of the contemporary city (Fig 2.03).

The grid configuration set up during the first phase of its urbanization can be considered what is currently called the typical 'traditional city', assimilating the features of the European City of the eighteenth and nineteenth centuries where a clear hierarchy of public spaces is revealed through the width and axiality of the main avenues inherited from the baroque urbanism. At the interstices of this spatial structure different types of grid configuration, some more regular some more deformed, take place. This is the recurrent pattern of urbanization up to 1920. In the third decade of this century the pattern of urbanization begin to change. New developments following the garden city tendency emerged in Europe at the time (Letchworth, Hampstead Suburb) add a new 'type' of configuration to the urban grid. The street system becomes more curvilinear and the 'griddy' pattern in these areas is replaced by what might be called a more 'maze-like' or 'labyrinthine' configuration. The resulting spatial form becomes a sort of continuum patchwork where different types of 'maze' and different types of grid interact.¹

In the fifties the era of the large housing estate begin. Two other spatial configurations are added to the existing ones. In the first the estate is embedded into the pre-existing street system and adds to it a smaller scale system of public spaces. In the second the estate is more isolated and introduces its own system of public spaces, or simply open spaces, which includes in most cases the whole area not occupied by buildings. A fourth type of urbanization is added to the ones referred to above when in the mid-fifties the disruption of the rural economy brought about an intense migration flow towards the cities in the south

¹ This is further exemplified in larger scale maps given in Figs. 2.06, 2.07 and 2.08. At any rate the distinction made here between a more 'griddy' area and a more 'maze-like' area is straight-forward just for the limiting cases, that is to say if a grid nearly orthogonal and a conspicuously curvilinear pattern are compared. Although for the purposes of an overall view - on the diversity of configurations offered by the city of Porto Alegre - to be provided at this introductory stage such a distinction seems to be enough. In effect the precise clarification of such complex descriptive issues will only be possible when the syntactic character of the selected sample of urban grids is described in further chapters.
of Brazil. At this time, in parallel to the advent of modern housing estate, Porto Alegre started to develop a large number of shanty-towns (Vilas Populares), the unplanned urbanization produced by the migrants. The Vilas Populares started with the occupation of peripheral areas of the city, but increasing social pressure precipitated the occupation of large areas, both public and private, inside the city.

Set alongside the variety of grid configurations another factor seems to favour the city of Porto Alegre as a suitable case study where the purpose of the current investigation can be fairly attained. The official land use legislation is relatively recent (1979) and, as a consequence, the current pattern of land use distribution is much more the product of a spontaneous process – evolved during the last two hundred years – than the effect of recent zoning ordinances. These conditions of spontaneous growth, both at the morphological and at the functional level, seem to make of the city of Porto Alegre a sort of 'laboratory' where the investigation of relationships between the spatial configuration of the urban grid and the distribution of land uses can be effectively observed and studied.

A sample of areas of Porto Alegre was selected for analysis. These areas were chosen according to a range of criteria that attempt to make the sample as little biased as possible, both in terms of its morphological composition and in terms of its chronology. The urbanization of Porto Alegre occurred from its original nucleus towards the periphery as in any radiocentric city, however here the occupation of the banks of Guaíba river has happened much earlier than the occupation of the interior land. In view of this characteristic the selected sample is concerned on the one hand with what might be called a diachronic criterion, which aims to show the morphological transformations that occurred during the historical development of the city, i.e. from its initial stage alongside the river embankment towards the successive developments of interior land. This criterion allows for the comparison of different grid configurations which closely follows the diversity of
Fig. 2.04 Two ‘sectors’ of urban growth
Fig. 2.05 The grid configuration of sector A.
Fig. 2.06 Fragment of sector A (west); orthogonal grid and its more deformed surroundings
Fig. 2.07: Fragment of sector A (east).

Fig. 2.08: Housing estates infilled in the street grid and the curvilinear 'garden city' pattern.
ways the problem of organizing the public spaces of the city was faced by designers and developers in different periods of its history.

On the other hand the sample is also concerned with what might be called a synchronic criterion which allows for the comparison of areas that were developed at the same time and carry morphological similarities however belonging to different parts of the city. In order to fulfil both the synchronic and the diachronic pre-requisites two different sectors of the urban grid were selected for analysis. This strategy allows for both diachronic comparisons, when each of these sectors is analysed in separate, and for synchronic comparisons when urban areas developed at the same time, though belonging to different parts of the city are compared (Fig. 2.04). As expected the more recent developments tend to be less consolidated both in terms of residential use and economic uses. In the attempt of minimizing these effects of age the sample has taken areas where the chronological gap between different developments is the smallest as possible.1

Another criterion observed in the selection of the sample was the coverage of the widest possible range of grid configurations among those available in the city of Porto Alegre. 'Sector A' - the northern of the two selected areas - includes at its west part two types of grids, one almost perfectly regular and another more deformed, yet also carrying 'lumps' of regularity (Fig. 2.05 and 2.06). The east part of sector A is more a patchwork pattern. It carries two maze-like configurations which might be labelled as the typical curvilinear 'garden city' pattern (Fig. 2.05 and 2.07). It also carries in its southeast corner a large area occupied by housing estates which follow a range of distinct spatial configurations, most of them infilled in the pre-existing grid (Fig. 2.08). These estates are in effect superimposed upon a continuous deformed grid that spreads throughout the middle of the area. These different patterns of urbanization are all juxtaposed performing the

1 The perimeters of the two urban 'sectors' to be examined during this investigation, as given in Fig. 2.04, were defined according to a set of spatial criteria which are fully explained at the outset of the syntactic analysis developed in chapter three.
Fig. 2.09 The grid configuration of sector B
interaction of what might be described as a continuous spatial patchwork.

The southern of the two selected areas - sector B - presents a diversity of grid configurations not so conspicuous as the previous case, yet all configurations referred to above are to some extent represented (Fig 2.09). The west part of sector B provides a fair example of a 'brickwork grid', i.e. a regular grid where some segments were rubbed out.1 The east part of sector B is, following the previous case, a large patchwork composed of distinct configurations. It is a regular grid in its north part. It becomes a deformed grid in the centre, an area where large housing estates and self produced settlements have made room for development inside the larger 'islands'.2 In the south west the grid configuration turns into a small maze-like pattern.3

The different grid configurations contained inside the two selected areas seem to carry most, if not all, the grid configurations available in Porto Alegre. It is conjectured here that the selection of a sample containing a wide variety of grid configurations may assist in the development of a typological model of some wider relevance. In effect the selected examples might be regarded as representative of most spatial patterns (or grid configurations) produced by western cities during the last two hundred years.

Besides, the sample distribution so divided in two sectors of urban growth allows for a systematic comparison between urban patterns developed at the same time and located in different parts of the city - the proposed the synchronic criteria - and as such the relationships

---

1 This 'type' is part of Hanson's classification of theoretical grids. In Hanson,J. Order and Structure in urban space, op. cit., p. 102.
2 The expression 'islands' is utilized in this thesis as another way of referring to the urban block.
3 A detailed description of the spatio-morphological characteristics of the different areas is part of the beginning of the analysis. The methodology for definition of boundaries also makes a separate section.
between grid configurations and land use distributions for different areas can be compared. The more regular grids from sector A, for example, can be matched with more regular grids from sector B, the same for more labyrinthine patterns and housing estates. This procedure aims to test out what is observed in one part of the city against others, in an attempt of finding how relevant each place's lessons might be outside its own special case.

One last criterion taken into account in the definition of the data was the reliability observed in the survey of land uses obtained from the Porto Alegre Planning Office. The last official inventory of land uses was carried out in 1978 in order to inform the masterplan worked out at that time. Small samples of different parts of the city were checked 'in situ' in order to verify the reliability of this material. The areas selected for this research are the ones where the results of these field observations most approximate the official survey. In a subsequent step the land use information for each of the selected areas was entirely updated, what in effect makes it a first hand inventory.

**Constitution as a land use measurement**

The main problem to be tackled in the attempt to relate the spatial configuration of the street grid to land use distribution is the identification of a common ground of interaction where these two distinct dimensions of a town can be explicitly and objectively related. Despite the fact that grid configuration is in objective terms a physical characteristic of the urban phenomenon, it is broadly accepted that the urban grid - and the urban space in general - carries a great deal of socio-cultural content, as the reviewed literature has pointed out. Moreover, research on urban axially and its syntactic properties has
revealed that a wide range of socio-cultural variables are significantly correlated with syntactical properties.¹

On the other hand, land use distribution has been mostly regarded as a socio-economic variable within the urban studies, though it also carries an explicit physical dimension. Different land uses - residential, commercial, industrial, etc. - are above and beyond socio-economic variables, precise human activities that occupy precise pieces of land within a town. These pieces of land, or plots or buildings are connected in one way or another to the public open spaces and also separated from them by the walls or fences that define the limits between public and private domains.

The assessment and measurement of the relationship between land use and spatial configuration becomes possible if one starts to think such a relationship in terms of the number of connections that public and private domains - buildings and public open spaces - have between each other along each one of the axial lines inside an urban area. This way of approaching the question coincides with the syntactic concept of 'constitution'. Constitution means the extent to which public and private domains are connected, i.e. the degree of permeability between public open space and built form. The measure of Constitution is given by the number of entrance doors which are directly connected to each axial segment of the urban grid. The measurement, once relativised to the length of each axial line, becomes a density measure, i.e. the linear density of constitution.

The concept was originally proposed by Hillier and Hanson: 'Since spatial structure is the result of the arrangement of buildings, and possibly other bounded areas such as gardens, parks, and the like, it can also be described in terms of how the houses, shops, public buildings and the like, are adjacent to it. When buildings are directly accessible to an axial

¹ A recent account on this point can be found in Hillier et al. Natural movement: or, configuration and attraction in urban pedestrian movement, op. cit.
Fig. 2.10 Fragment of sector A
Convex spaces, axial lines and constitutions
or convex space we say that the space is constituted by the buildings, but if the space is adjacent to buildings to which it is not directly permeable, we say it is unconstituted.¹ The concept of Constitution allows axial systems to be discussed from the standpoint of the buildings which define the system and, moreover, provides a spatial character to the relationship between activities 'within buildings' and the spatiality of the street grid. Once these assumptions are accepted and utilized as an operational instrument the problem of finding a common ground in order to correlate land use and grid configuration can be resolved through the qualification, in terms of land use, of each and every entrance door that is connected to an axial line. It is precisely in these terms - spatio-morphological terms - that the spatial distribution of land uses is approached by the current research.

Fig 2.10 shows a 'fragment' of the sector A and its representation in terms of convex spaces, axial lines and constitutions. The formal definition of 'convex space', as proposed by Hillier and Hanson, is that "no tangent drawn on the perimeter passes through the space at any point."² This representation shows that the constitutions that will be computed as belonging to each axial line are the constitutions of all the convex spaces that are traversed by the axial line of interest. Since the spatial configuration of the street grid is in itself a superimposition - or 'overlapping' - of distinct convex spaces, some constitutions will belong simultaneously to two or more axial lines.

The criterion seems to allow for a fair representation of this complex property of spatial overlapping in urban grids, i.e. not only the constitutions that follow the axial line in parallel are computed as belonging to the line, but all the constitutions that 'surround' the axis of interest. Fig 2.11 shows an enlargement where the convex spaces belonging to two distinct axial lines overlap (lines 53 and 54). The constitutions located inside the 'overlapping' are computed as belonging

¹ Hillier, B. and Hanson, J. *The Social Logic of Space*, op. cit., p. 92.
² ibid., p. 97.
Fig. 2.11 Convex superimposition
to both lines. The same happens at the intersection between lines 35 and 38. In this case two constitutions that parallel line 38 are also computed as belonging to line 35 since they are part of its convex space.

In all cases the boundaries of the convex spaces are considered as defined by the limit between public and private domains. Such a boundary coincides in some cases with the external wall of the building, i.e. when the façade is immediately adjacent to the street. In other cases when the building is positioned away from the alignment of the street the alignment itself is regarded as the boundary. The colours attached to each constitution represent different land uses categories (Fig 2.11).1

The concept of constitution besides depicting the way in which land uses are distributed throughout the street grid, describes a property that is specific of the public open space, and describes it spatially. It measures the intensity with which different uses are related to the axial line, i.e. the intensity of the relationship between activities 'within building' and the public open space. In this sense the constitution criterion seems to provide a reliable measurement for identifying the actual needs of spatial interaction between 'within' activities and the public realm.2 Defined in this way the measurement of constitution can be regarded as the final result and morphological counterpart for the sociological concept of 'location action' proposed by Chapin in his 'Urban Land Use Planning': 'The means by which interaction patterns become translated into structure-form outcomes is found in the location behaviour of households, firms, government and institutional entities. Location behaviour is viewed as a sequence of actions growing out of the needs and desires of day-to-day interaction . . . Location action is the instrumentality by which activity patterns are accommodated in the physical form'.3 The concept of constitution seems to offer a precise

1 The land use classification to be adopted is the object of the next section.
2 An assessment on the relationships between the measurements of 'constitution' and 'floor area' for the selected sample will be presented further in this chapter.
way of depicting different land uses in terms of these 'locational properties'. The concept of constitution comprises the notion of 'location as a quantity' which, in answering for the purposes of the current research, provides a 'quantity' that can be objectively matched with the syntactic description of the urban grid.¹ In this sense the current study can be regarded as an investigation on the 'locational' character of urban land use. Constitution, defined in this way, seems to provide a rather accurate criterion for measuring the 'frequency of location' of different uses throughout the street grid.

Following this 'locational' strategy the official land use data, obtained from the Porto Alegre Local Authority Planning Office, was taken to the field, i.e. to each of the selected areas. Each axial line was then described both in terms of the entrance doors attached to it and in terms of the land use (or activity) related to each entrance door, that is to say, each axial line was 'loaded' with 'qualified quantities of constitution' (Fig 2.11). Since this information is not available in standard land use maps the survey of constitutions had to be proceeded 'in situ' as a first hand inventory.² In other words the constitution of each axial line was described both in quantitative terms, i.e. the amount of entrance doors per axial line, and also in qualitative or functional terms, i.e. the use or activity corresponding to each and every constitution computed. This criterion of measuring land use in terms of 'qualified constitutions' seems to allow for an objective assessment of the importance of every building, independently of its size, for the constitution of the public space directly connected to it.

Besides, the observation of land uses through the constitution of each axial line seems to be an efficient tool for the assessment of the degree of importance that spatial relationships between the interior of

¹ The notion of 'location as a quantity', and especially the standard procedures of 'quantifying' location measurements, both in the field of geography and also in the urban studies, is fully stated and discussed in Lewis, P. Maps and Statistics, Methuen and Co. University Printing house, Cambridge 1977.

² This field work was carried out between February and April of 1988 with the help of staff provided by the Planning Office of the Porto Alegre Local Authority.
buildings and public open space have for each different land use category independently of the size of the building. Large scale buildings sometimes occupy an entire urban block but have a small number of entrance doors or even no entrance doors at all at some of its sides. This is the case of some industries or large department stores that have been surveyed. The blank walls of these buildings do not contribute for the constitution of the street, thus in spatio-morphological terms the effect of these uses upon the public character of the street grid is nil. The opposite happens to mixed buildings, sometimes small buildings, that present a variety of entrance doors corresponding to different uses at the ground level, for instance, a residential entrance, some shops and sometimes a public facility. The constitution criterion, as far as this study is concerned, seems to be an appropriate instrument for the identification of these 'fine grain' peculiarities that eventually are the essence of the functional dimension of each street of a town.

In a first view such a description based upon 'axial lines' and 'constitutions' seems to be just another version of the most general, and already standard, way of decomposing urban systems in terms of 'movement channels' and 'built forms'. In effect there are many versions of this sort of decomposition. Doxiadis, for example, terms these same elements as 'networks' and 'shells'. The Centre for Land Use and Built Form studies at the Cambridge University also make 'networks' and 'adapted spaces' its basic distinction. The operational aspects of this type of procedure is described in detail by Cheesman et al, in the 'Data Bank' for the LUBF studies on English New Towns. One aspect of their method is noteworthy: 'the coding and processing procedures for land use and road networks are considered separately'. The limits of this type

2 Lionel March et al., Models of Environment, Architectural Design, 41 May 1971, p. 271. In effect the concept of 'adapted space' will be further utilized in this research, though not as a way of quantifying the distribution of land uses, as in the LUBF studies, but as a way of assigning a physical character to each of the land use categories to be adopted in this study.
3 Cheesman, R.; Lindsay, W. and Porzecanski, M. New Towns: the data bank, its construction and organization, Land Use and Built Form Studies, University of Cambridge, Department of Architecture 1972.
of procedure are clearly identified by Anderson: 'Many of the bordering accessed spaces are in such dynamic interaction with the channels that neither the channel nor these adapted spaces can be understood if they are analytically sliced apart'.

It is precisely in this sense - well identified by Anderson - that the analysis of urban systems in terms of 'axial lines' and 'constitutions' differ from the propositions presented above. Since both axial lines and constitutions are spatial components of the street grid, an account on the configuration of the public open space based upon the identification of these categories seems to be an efficient way of describing urban spaces without 'slicing them apart'. Both the axial dimension of the street grid and the connections between building interiors and public open space are spatial characteristics of the same phenomenon, i.e. the morphology of the urban space. Apart from that the analytical procedure based upon axialities - how far one can see and how far one can go - and constitutions - degree of permeability between public and private domains, depicts a phenomenon which seems to correspond, as closely as possible, to the way in which the street grid is actually understood and used.

On land use classification

The problem of reducing the diversified and complex range of human activities into a manageable classificatory system has been the concern of a large body of literature within the urban studies. In effect these classification efforts have reflected the necessity of providing the activity of masterplanning with a consistent functional base whereupon zoning strategies could be proposed objectively and in a systematic way.

---

1 Anderson, S. Ecological Model of the Urban Environment, op.cit., p. 271.
2 An overall view of these works can be found in Sparks, R.M. The case for a uniform land use classification system, Journal of the American Institute of Planners, August 1958; and also in Rice, P. Land Use Classification: A review of contemporary British (G 25 RIC).
This section neither intend to review this literature nor to go into the complex discussion on the relationship between 'activity systems' and land use classification. Such a subject could probably be itself the object of another thesis.

Different from that the objective here is to put forward the land use classification that is adopted in the current research and moreover to justify our classificatory effort in terms of some paradigmatic works that have been carried out in the field. This is not an easy task especially for the high level of disaggregation observed in the works that could be taken as parameters. The masterplan of Porto Alegre, for example, presents a range of 533 different activities. These are grouped in 159 types of commercial activity, 212 types of services, 72 types of industries, 4 types of residence and 88 'special activities' - activities whose functional character does not fit inside the four main categories. A large number of exceptions to the rule, it must be acknowledged.

The work of Chapin (1965) can be regarded as providing a sort of 'standard' classification whereupon many masterplans, especially in the USA and UK, seem to have relied in order to derive their particular classification systems. Chapin proposes 79 different activities which are aggregated in three main activity groups - 'productive activities', 'residential activities' and 'general welfare activities'. The category of 'productive activities' includes activities of production and processing of goods (industries), storage (wholesale), distribution (retail) and services (management and related uses). 'Residential activities' includes different sorts of residential use, which Chapin differentiates in terms of their density - low, medium and high residential density. The 'general welfare' or 'institutional activities' group include those activities related to the 'development of the community' - activities of collective interest, such as schools, hospitals, community centres and institutional activities in general.

The work of Cooper, Lindsay and Taylor (1973) adopts an opposed strategy, i.e. a classification system with a low level of disaggregation. Their categories are: residential, industrial, offices, shops, public buildings and public open space. They justify the level of disaggregation adopted in terms of the objectives of their study: 'Although the level of detail on masterplans and in accompanying reports for each new town afforded a highly disaggregated land use coding system, the comparative nature of this study necessitates a more generalised classification'. The problem of deciding on the level of disaggregation of a classification system is also noticed by Chapin. He suggests that 'the degree of disaggregation of a classification system must be compatible with the objectives and analytical tools that will be applied in each specific case'. This seem to be the case of the analysis of new towns, carried out by Cooper, Lindsay and Taylor, where the nature of the study asked for a reduced classification system which would provide common grounds for a comparison between a large number of cases.

This is precisely the case of the current research where the comparison of a large sample of grid configurations will be compared, both in terms of their configurational properties and in terms of land use distribution. The land use survey obtained from the Porto Alegre Planning Office, as it has been referred to above, has a highly disaggregated coding system. The land use classification to be adopted in this study aims to reduce such a cumbersome classification into a manageable one yet without missing, as far as this is possible, the functional specificity of part of the street grid.

The classification to be adopted inherits part of the most basic distinctions proposed by Chapin. Two general categories are adopted -

1 Cooper, P.; Lindsay, W. and Taylor, E. New Towns: Analysis of Land uses, Land Use and Built Form Studies, University of Cambridge, Department of Architecture 1973.
2 ibid., p. 2.
productive activities and residential activities.1 The disaggregation of these basic 'activity' categories will be proceeded in terms of a range of 'adapted spaces' corresponding to each of the general categories. The concept of 'adapted space' is borrowed from Webber and allows for the assignment of a physical dimension to each land use category which otherwise would be reduced to strict 'activity' concepts.2 The concept of 'adapted space' yet retaining a physical dimension is not so specific as the notion of 'building type'. In fact it is more flexible so allowing for a range of activities to be regarded as 'related' to a certain kind of 'adapted space' yet without reducing such a physical character to a specific building typology. Doubleday (1974) assigns two characteristics to the concept of 'adapted space'.3 The first is its permanence of location. The second is its 'inability, to greater or lesser extents, to accommodate at changed intensities the activities for which they were designed or, alternatively, to accommodate different activities, without structural alteration'.4 A shop can be regarded as an 'adapted space', yet there is an endless number of possible shop configurations.

The concept of 'adapted space' allow us to reduce Chapin's 'productive activities' - which in his taxonomy includes 19 types of retail, 31 types of services and 25 types of processing activities - to three categories: 'shops', 'offices' and 'industries'. The concept of 'shop', understood as an adapted space, is specific enough to describe the activities that open doors to the public open space at the level of the pavement, yet at the same time general enough to include a large variety of activities which can range from different types of retail up to personal services, such as a barber shop, a repair service or even public facilities such as a post-office agency. All are from the 'adapted space' standpoint shops. The

1 The third of Chapin’s most general classification – his ‘institutional’ or ‘general welfare’ activities – is not to be dealt with during the current research. That is for the analysis of both ‘productive activities’ and ‘residential uses’ has already delivered a rich and complex output containing more information than this thesis could cover and in effect more than enough for carrying out, in a rather effective way, with the purpose of the current investigation.


3 Doubleday, C. Some characteristics of the built stock in Reading, Land Use and Built Form Studies, University of Cambridge, Department of Architecture 1974, p.9.

4 ibid. p. 3.
different 'shop' activities exemplified here are, according to the masterplan of Porto Alegre classified in three distinct functional categories yet all of them are in fact shops.¹

Similar synthesis has generated the categories of 'offices' and 'industries' which although comprising a wide range of possible activities tend to occupy a rather limited range of adapted spaces. The category of 'office buildings' includes according to the adapted space criterion not only the high rise building especially built for office purposes, but also houses adapted to office activity.² The industrial activity is also one that tend to recur in a sort of adapted space which might be said as a 'warehouse' type. Nevertheless there are also exceptional cases where houses are converted into industrial spaces, especially for small manufacture. The particular case of the large scale storage premise was put together with the industrial activity. This is because for most cases the distinction between wholesale and industrial activity was a difficult one to identify, not only because of the limits imposed by the adapted space criterion in this specific case, but mostly because in most industrial establishments surveyed, with the emphasis on economy of scale these firms are increasingly handling their own wholesale distribution and as such the distinction between wholesale and industry, from the point of view of the adapted space criterion, becomes irrelevant.

For the 'residential activity' four adapted spaces are considered: 'house', 'block of flats', 'mixed building' and 'housing estate'. 'House' is the adapted space equivalent to what Chapin refers as the 'low density residential establishment'. The classification proposed does not distinguish between the unifamiliar residence and houses converted into

¹ Restaurants and bars were also included under this same label.

² This case provides a clear example of the greater flexibility of the concept of 'adapted space' as compared with the concept of 'building type'.
flats. Block of Flats is the adapted space equivalent to the 'collective habitation' proposed by the masterplan or the 'high density residential establishment' proposed by Chapin. 'Mixed buildings' are those where the residential activity - either located in a 'house' or in a 'block of flats' - is coupled with a 'productive activity' - either 'shop', 'office' or 'industry' - within the same building. In this case the 'constitution' criterion allows for the identification of each of these uses, at least at the ground floor level. The inclusion of 'housing estate' as a specific category inside the residential activity has been proposed as a way of differentiating these more large scale developments from the blocks of flats or houses which were built as independent unities. These different modes of housing, as it will be seen during the analytical chapters, tend to perform in rather opposite directions with relation to the configuration of the street grid.

The classification system proposed above translates the functional character inherent to the 'activity' categories commonly utilized in urban planning studies into a morphologically oriented classification based upon the 'adopted space' each one of these 'activities' take place. If on the one hand there is a loss in terms of functional specificity, on the other hand the proposed categories retrieve, as far as this is possible, the physical character of the buildings that shelter each one of them. Moreover the level of disaggregation proposed here seems to provide a degree of descriptive accuracy compatible with the purpose of the current research in identifying regularities in the pattern of land use distribution from the standpoint of the configuration of the urban grid. That is to say the proposed level of disaggregation seems to be high enough for differentiating between those uses which recur in a more identifiable syntactic performance from those whose distribution tend to perform more randomly when matched with the configuration of the urban grid. At the same time the proposed level of disaggregation is low enough for allowing the clear identification of the syntactic performance

1 Although these 'converted houses' represent a high proportion of the houses in some of the areas of study such a distinction was not available from the survey obtained from the Porto Alegre Planning Office.
Fig. 2.13 Land use distribution in sector B

Activity Group | Adapted Space
--- | ---
Productive Activities | Shops
| Offices
| Industries
Residential Activities | Houses
| Blocks of Flats
| Mixed
| Housing Estates

North
of each one of the proposed categories, so preventing a superimposition of performances which would be most probably unavoidable in a more disaggregated taxonomy. At any rate further levels of disaggregation seem to be the natural development of future research on the relationships between land use and grid configuration.

In short, this is the land use classification that is adopted in the current research:

<table>
<thead>
<tr>
<th>Activity Group</th>
<th>Adapted Space</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productive Activities</td>
<td>Shops</td>
<td>SHP</td>
</tr>
<tr>
<td></td>
<td>Offices</td>
<td>OFC</td>
</tr>
<tr>
<td></td>
<td>Industries</td>
<td>IND</td>
</tr>
<tr>
<td>Residential Activities</td>
<td>Houses</td>
<td>HOU</td>
</tr>
<tr>
<td></td>
<td>Blocks of Flats</td>
<td>BFL</td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
<td>MIX</td>
</tr>
<tr>
<td></td>
<td>Housing Estates</td>
<td>HES</td>
</tr>
</tbody>
</table>

Figs. 2.12 and 2.13 show a representation of the distribution of the proposed set of land use categories in sectors A and B. The outstanding feature that emerges from the visual observation of these maps is the mixture of uses that is, to a large extent, evenly present in both sectors. Nevertheless the maps make it also clear that in specific parts of the grid both the mixture of uses and the concentration of specific uses tends to be more conspicuous than in others. This is the case of the west part of sector A for example where the grid becomes more orthogonal and where the mixture of colours and the density of the grain is higher than in other parts of that system (Fig. 2.12). The same might be said about the more orthogonal parts of sector B, one of them more a west other more at north in that system, yet in both cases the intensity of the
mixture has decreased (as compared with the west part of sector A) and the grain is also slightly coarsened (Fig. 2.13).

For other parts of the grid, by contrast, the intensity of the mixture is slowed and the pattern becomes more residential. In some of these cases the dominant residential adapted space is the house or single family dwelling (yellow in the maps). This is particularly clear in the eastern part of sector B (Fig. 2.13) and to some extent in the northeast part of sector A (Fig. 2.12). In other areas the predominant residential density is brought about by an increase in the concentration of blocks of flats (represented in orange) as in the deformed grid at the southwest part of sector A (Fig. 2.12) and the most western part of sector B as well (Fig. 2.13). Housing estates are more concentrated in specific spots such as the centre and the southeast part of sector A and the centre of sector B. At any rate the maps made it clear that the proposed set of 'productive activities' are somewhat present in all parts of the grid. This applies even to the parts where the residential use is predominant such as the cases referred to above. In effect the incidence of productive activities in the two areas of study is high enough to allow an status of mixed used urban areas for both 'sectors' of study.

Although these maps are not aimed at providing a precise description of the variations of land use from one part of the grid to another, they provide a fair representation of how rich and complex such variations are. The precise measurement of each land use category at the different parts of the grid is part of chapters five and six where land use distributions are fully described and subsequently compared with descriptions of grid configuration. At any rate the visual inspection of the maps presented here seem to make it clear the relevance of setting up objective criteria for defining which are the 'parts of the grid' that should be acknowledged for comparative purposes. That is to say the problem of the decomposition of the urban grid for comparative purposes emerges as an important issue not only for the comparison of distinct grid configurations but also for an assessment of how the pattern of land
| Fig. 2.14 Example of the controlling syntactic
and word measurements per axial line |
use varies from one part of the grid to another.\(^1\) Finally it is worth to mention that the maps given in Figs. 2.12 and 2.13 are accurate reproductions (yet coarsened to a smaller scale) of the actual land use maps whereupon the land use data to be utilized in subsequent chapters was taken from. The original maps are in a larger scale (1:1000) as the one given in Fig. 2.11 (p. 93) which has allowed for a precise measurement of the frequency of location of each land use category in relation to each particular axial line.

**On the organization of data and statistics**

The syntactic and land use measurements introduced during this chapter have been organized in two types of files for the purposes of carrying out with the empirical part of this thesis. The first of these files contains information referred to each axial line within each particular system or 'portion of the grid'.\(^2\) The axial line is in this case the reference for all the information. Each axial line will be described both in terms of its syntactic identity (the range of syntactic measurements already proposed) and in terms of its land use character as given by the 'qualified constitution' criterion already explained which allows for the description of the 'frequency of location' of each land use category for each particular axial line. In this case each file corresponds to one particular system.

**Fig. 2.14** presents an example. Each axial line is identified by a number in the reference column at left.\(^3\) Columns one to five contain the range of proposed syntactic properties - axial length, connectivity, integration and choice - as measured for each axial line.\(^4\) Columns six to

---

1. The problem of the decomposition of the urban grid for analytic purposes is part of chapter three of this thesis.
2. As it has already been said the decomposition of the urban grid in different 'systems' or 'local areas' is the object of chapter three of this thesis.
3. The file in the example corresponds to a system with 60 axial lines.
4. The table given by Fig. 2.14 presents two distinct values for integration. The first of these values (RRA) correspond to a measurement carried out inside the local area the line belongs.
c

o

•

0

o

0

9 0

«

v»
Ui
X
X
e

x

•v.
X

oi

•

n» 9
in
0
n-

e 0 X •
J
04 O K
r i X pi

tn 0
X 9
04 X in
G
O

tn
X

•

U 9
O
m fu »
in 0 X
tn
00

tn a
X
0

9

9

ro o

9

9

0 X •
no O
X

ro

O o

9
0
C
O5?

9 0
X

•

tn
0

•

tn
0

•

04 «
X
X

•

fw •
0
X

X p- 9
04
04 r i

9
o X
no Pj 04
ri ri ri

0
0
d

0
0

3

m o
p X
ri

X
ri

o

ri d
ro

9 tn
pri

no X
rX X o
ri
0 pi

9

9

X
X
ri

•

m 9
X O
0 X
ri 0

0
0
X

p- X
X X
0 e 3
Pi pi 0 r i X

9

9

e

•

X X
o a
0 X

m •
o
0

0
e
0

3

0 •
r»

9

ro 9
*? in

S

in

&

1
CP

e •
C
O
d
X

X
e
ri

•

X
o
ri

•

•
9
0

X
V X

ri

0
0
0

X 9 0
X
ro
ri
ri

I
«
e
•o

X

•
in

3
0

0

0
ro 0
0 in

•

•

0

X

9

•

o
0
0

9

9

0

Ife
0
0
e
•j

r*

X
e
X
x

in
X

?

e

0 •
X
G
O
X

m
0 O
n» tn
tn
X p*

«
X

X
X

VI
Ui
X
X

0

«

•

IM

•

4

ri

•

rv
X 8

X

S

3

a

in 9
n»
in
0

*
O 0
0 0

X
0

0

0 m fu 9
p»
x
0
in
s

|

s

2

in X
0 p

9

0

0 0 tn 9
X ro o
0 X 0
0

o

X

0

r- X
r» tn

3

J

O r» 9
ro X
ro 0
r*

X a 9
a C
O
in no
r- 0

0 a
e
pi e
n
0

? 0
d
0 X
X X

£

0

9

0

z

X N
tn n
in
<
S
I

9

0 X
X p* p

9 rw o
0
ro

9

9

9

9

0 X
no X
0
X

9

9

0
X X
0
C
Ono
e X
ro 04

X X
0
ri d
X X
o

9

tn 0
04 o
ri

o 9
X C
O

?

0

1
9 0

X ro
no

0
C
Os

0

9 0
e

n

0 •
p»
01

X X X ro 9
m tn 0 0
0
ri
3
K r» s

5

X
0

•

9

si si

C
O0

C
O•
X
0

9 n- •
X
i

9 0
•
00

X
in
pi 0
0

X O
Pi r i
X
ro
X r-

9

9 0
X
ri

•

0

X
in
X
0

e
in
ri

0 X ro 9
X X X
0
i
8

X
r»

9

0
X

9 X tn
4
C
O tn
X ri 0
o 0 X
X 0 ro

0
X
0

9

0

0
X 3
X d

04 o X
O 0 X
0 d 0
e 04 X

8

X

O
m3

•

C
O•
X

X 0 9 n
p- C
X 3
O
ri ri

0

•

f*
0

o X 9
in tn
ri ri

p- 9

X
0

9

X

£
9 X

•

in

9 0
X

X
e
\
o
t*
o
x

•
S
ri

e

0

a.
X

ri
x

M
in s
N 0

in
0

9

x
tn
ri
in

0
n
in
x

9

0 0
n
3 0
X X in

9

•
0
4

n
p m 0
tn
04

tn 0
X
to «
04 ro

0 9
0
d
ro

o
p

o

o
tn
to
to

0
X
0

9

0 0
00 X
pi 0
tn

9

rX
04
X
tn

9

04
p o
d
ro X

9

o 0
X 0

9

o
0

9

fu X X
X X 0 X 0

9

X

9

0
4

in

d
N

0 X
0 0
X ri

9

ro •
a

9

•
5

0

o

X 9
no

0
p

9

X r»
ri ri
ro

9 0
9
r*
Pi
ro

ro 9
x
ri

0

X 0

9

ro 9
<
*4

ro
0
0
X

0

X

9

0

ri r i
X X

R

0

0 0
X
0 0

X

g

0
e
md
X
a.
X

x

•

0
x

x P- 9
r»
e e
V
ri ri
4
9
9 e

fu
0 $
r i at
x X
in

9

0
0
X
X
C
O•
n
ri

x
x
x

ro 0
C
O
Pi 0

9

•
X
'•s,
X
X
X

Fig. 2.15 Example of rile containing syntactic
and land use measurements 'per system'

r
X
e
v

9
in in
0
<1
X in 00
M 04 ro

0

0 0 9
0 ro
04
04

o

0

0
ri
r»
p»

X
X
0

9

e
d

4

X
e
X

9 04
e X
r i Pi 5
X
9 X 0

ro
X
ri
X
X

9

X
0 0
d X
no

0

0

X X
0 0
tn X
d 0
no

tn
e
d
ro

e 0 0
o
X X
ro

ro 0
0 0
pi r i
no

rx
ri
ro

X

9

9

0

0
in

9

•

3 5
ro

e
X

9 0 9
tn

X 0
Pj X
d

9 e
e
ri

pX
9

X
d
X

o
o
d ri
0
P- P

0

d

p
9 e
X
d

9

9

9

0
X
a
d

9
3
0

9

p

9 n- 9 e

0
0
X V

9 0
d

9

X

$
9

0

e
ro

X

0

X 0 X
0 X
0 pi

9
3
o

0

9 0 0
»
X P
0
ri
X
04 C
O?
9

ro
d

9 C
O
O
m
d
o
X

04 X C
O9 X
0
5 r i pi

ri

£
X
ei
u.
«•
jo

e
2
o

•
a
v
x

9

0
*
V 0

0

e
e
e
u

X
f*
X

•

6
91
X
e
X
©
e
*5
5

X
X
ri

•

•

s

0
0

O 0
4 00 tn
09
0

9

r*
X x
ri V
r» 0

n 9
ro
ri

0

in o 0
0 ro
in X X

9

in
04 9 r- p» X 9
e x 0
ro
0
?
ro ro ro
V ri V
0

in

0
0

0
in

9 in tn 0
0 0 in

ss

9

?

ie s
rJ
X
s

x
$ rPi 0

9 X X
0
d 0

ri d

0

9

9

9

X o
0 0 0
X 0 0

0

9

9
0
z

0
9

9

p- X
ri 0
X
e
ri

9

9 X 0 04 X 0
X
CO ro
X
C
Ono 04

9

0 0 9 r* ro 9 0 04 ro
0 04 X 0
0 X
e ro
no ro
ro ro
ri ri

9 n*
X *

9

8 g X
$ f?
0 0
0
ro r- X X 0
ro ro

je

9 C
O04 9 0
e
X
X ri

9

9 X X
X 0
ri

9

X

9 0

3
fi

ri

ri

ri ri

9

r*
tn X

9 p*
0

9
X

9 0 X
tn in

9 no e
e
ri
X ?

9 X
X

9

N
X
X

r-

9

tn
0

9

iR
Pi r i
o

e

0

s

9

0

?
ri
9

9

3
ri
0

%
p»

9

ro
0

9

ro
0
X X

9

0
0

X

X O
m
tn *
d ri

9

0 r* 0
0 0
X
ri ri d

9

0
0

9

3
e

9
p

9

R
0
O

0

X
e
ri

p

tn 0 in
04 04 X

9 X
04

o
p

0
in 0

9 0

s

X 3

d
X

O 9
in P
^

in

1

0
1,
e
bb
X
X

s

•

^5
•

•

o

*;

X 0
04 X 0
tn
04 S 8

9

f* in fo 9
0 in X
tn 0

9
0 in
X X tn

0

tn

tn r- 9
X X
d
» p-

0 tn 9
00 r^ in

0

9 o
X 0
0 no
0
ro r i
o
?

9

tn
in

9

X X
0 tn

9

•

9

3

**

X 0
C
O9
r^ 0
m pi
o C
O4

9

X 04 9
X Pj

9

m X 0 e r» 9
X 0 X X Pj

9

9
e 0
e 0
X tn

9

c

e
0

s

ro
X 0

p

s

X 0
Pj in

9

e

9

X
0

9

0

?

9

ri
X

9

9
X
r^ p^
ri ri
X X

a
X

9

9

o
X

9

X X
0 0

9

•

9

m 9
0 O
X 0
ro
ri r i
i
i

5
C

9
3

2

s

ri

c

©

in
pj

•

•

•

in tn
X 0

0

9

r*

tn 0
X
r* pj Pj

9

in 0

9

0

0

X
in

9

0

9

p» 9
n-

0

0

9

ro X X
X X

9 0
X

e

o
X
u
■
v.
X
X
X

•
x
»n

X
X
X

x
in

X x tn 9
r* 0
0 ro
co
co
•
1
9
?

0

0

x
w

e
X
X
VI

o
tn
X
X

•

?

0

0

o 0
ro
t
t

?
ro
i

in tn 0
*n VI

9

ro 0
in 0
ro ro
1
i

0
*

0
P

9 0 C
O 9 •n 0
OC
in X in
0 X

•

e 0
X 0
C
Oro ro
1 « •

9

ro r*
*

9 04 r 0 0

9

tn e
0 n

9 X e

0

i

1

9
X
a? P; «5

0

o
0

•

ri ri

X 0
X X

9

9 X

0 ?
in X
ri ri
1 i

9 CO 9 0
*
9

X

04 9 X
tn X
X

ro
t
9 o 9
p-

9 0
X

9

0
r* X

9
0

9 ro rin 0

p* X X 9
0 ro X
no p
ri ri ri
»
i
i

e
X

9 ro X p- 9
n n r*

X
•*

9 X X
p
p

ri
i

9 X
0

©
©
o
w
9>
VI

x
0
X
VI

0
x
X
X

nn*
X
X

0
x
X X
v> 0

0
X n
X X
99 99

0

0
0
0 ro
X X
99 V)

X
ro
r0 0 0
99 X X

0
0

0
X
c 0
X 99

0
0
O
Q
X

n o
X X
0 0
X X

0
X
0
v»

X
0
ro
0
C

0
X 3
0 0
V
) X

r*
ro X
0
0 0
V
9X

X
0
a
m

X
0
a
X


twenty three give the measurements for the proposed categories of land use — and corresponding aggregates. This is done both in terms of the number of constitutions related to each category and also relativised to the length of each axial line so providing what may be regarded as the ‘density’ of each land use category inside each particular axial line.

The second type of file contains information referred to each and every system within the current sample. While the first file describes the syntactic and functional identities of each axial segment (within the system of interest) this second file describes the syntactic identity of the system as a whole. It contains information on the ‘average’ characteristics of each system both in terms of syntactic and land use measurements. Fig. 2.15 gives an example. In column one each system is given a code based upon the initials of the ‘sector’ it belongs plus the number of axial segments it carries. Columns two to twelve give the measurements for the range of proposed syntactic descriptions. Some of these as it has already been said are mean values of the first order measurements (mean integration values, mean connectivity and so on). Others describe a range of configurational characteristics based upon the number of axial lines or number of connections within each particular system. Columns thirteen to twenty three give the ‘mean density values’ inside each system for each one of the proposed land use categories.

The two files described above contain all numerical data that will be utilized in the analytical chapters of this investigation. They are the general files whereupon the information required in the discussion of

---

1 The code ‘SA’ stands for sector A, while ‘SB’ for sector B.

2 As it has already been referred, this particular set of measurements — axial fragmentation, tension, ringyness, density of intersections and figure-ground ratios — will be fully described in chapter four.

3 These ‘mean density values’ for the different land use categories will be fully discussed during chapters five and six.
each specific topic - and moreover in the statistical procedures that will support the core of this investigation - will be taken.

The statistical tests that will be utilized during the analytical chapters of this thesis can be regarded as 'standard' procedures which have been routinely applied in the research developed at the UAS of the Bartlett School. The use of statistics as a way of matching data of topological nature (syntactic measures) and quantity location measures (land use distribution) reflects an implicit acceptance that the description and understanding of physical phenomena can follow a path similar to that which led to the development of numerical laws in the physical sciences. Unless logical grounds for the falsity of such an assumption are produced there is good reason to explore the possibility of establishing such laws in the field of urban design by comparable proceedings.

Correlation analysis is the main statistical tool to be utilized during the current investigation as a modelling technique aiming to demonstrate the extent to which the performance of different measurements (or variables) are associated. This study does not assign, at any moment, a 'causal' relationship from grid configuration to land use distribution. The distribution of land uses in the urban field is certainly affected by a large number of factors, of both socio-political and economic natures, which are beyond the spatial scope of the current research. What the correlation analysis aims to show is that there are consistent 'regularities' in the association between certain patterns of land use distribution and the syntactic configuration of the street grid and, in this sense, the output given by a correlation analysis can provide the basis for the testing out of particular propositions which, we suggest, must be dealt with more in terms of 'likely' or 'unlikely' instead of 'true' or 'false propositions.

1 The works of Norcliffe, G., *Inferential Statistics for Geographers*, Hutchinson and Co., London 1977; and Lewis, P., *Maps and Statistics*, Methuen and Co. University Printing House, Cambridge 1977, were taken as guides both for the selection of the statistical tests and also in order to assess the accuracy and pertinence of the different procedures.
In order to test the normality assumption - as required for the correlation model - each measurement (or variable) had a histogram plotted and its frequency distribution inspected. Many of the variables to be dealt with during this investigation are skewed, i.e. a large proportion of observations is concentrated at one extreme of the distribution. For instance, the sample of axial lengths for the so called 'more labyrinthine systems' will deliver a concentration of observations in the lower tail of the distribution as a consequence of the large proportion of short axial lines inside those systems. In effect, as the empirical chapters of this thesis will show, the particular character of each part of the street grid seems to be in itself a key element in affecting the frequency distribution observed for one same variable as measured in different parts of the grid. The sample of densities of houses for example, is normally distributed in some systems and positively skewed in others. The same can be applied to syntactic measurements. The distribution of integration values for example is generally normal, although in the case of more regular grids (such as the west part of the SA sector) it will be positively skewed. This particular configuration (the regular grid) will present as expected a large number of observations concentrated inside the same band for a large proportion of the axial lines inside that part of the grid are strongly integrated.

After the inspection of the histograms, the distributions that have presented an 'explicit' positive skewness have been logtransformed and for most cases the normality pre-requisite has been fulfilled. In respect of the problem of transforming data Norcliffe suggests: 'Many of the frequency distributions used by geographers are known to be skewed with an attenuated upper tail. For instance city size and various forms of interaction over distance tend to have approximately lognormal frequency distributions. If transformation of these data to a normal form were not valid, than geographers would be faced with almost intractable

\[ 1 \text{ For some cases fairly moderate transformations will be achieved by taking the square root of each observation. Nevertheless when required, a more radical transformation is achieved by taking the logarithm of each observation.} \]
problems in applying parametric methods using these types of data'.¹ Eventually he concludes that 'since all measurement systems are arbitrary, transformed data are just as valid as untransformed data'.² The complex theoretical issues related to data transformation are not to be dealt with here.³ Nevertheless, a specific discussion will be pursued in cases where the effects of data transformation are regarded as affecting the significance of the results.

The correlation analysis will be supported by F-tests which based upon the comparison of the variances of each measurement involved in the correlation will assess its statistical significance. The standard adopted in statistical procedures currently developed at the UAS of the Bartlett School recommends $p=0.005$ as the upper limit for the 'acceptability' of a correlation coefficient. Yet this standard will be taken into account the pattern given by the distribution of points in the scatter diagrams will play an essential role in the assessment of the significance of the coefficients to be observed. The specific unfolding of these statistical tests, inside each particular situation, will be discussed in detail during the analytical chapters that follow.

Notes on chapter two

As a whole this chapter has established the techniques that will be applied for describing grid configuration, land use distribution and above all the relationship between these two dimensions of the urban phenomenon. An effort has also been made in order to make it explicit the theoretical background that underlie the proposed descriptive techniques. To put it in short, grid configuration will be measured by the properties of the axial map which will give measurements both at the

² ibid. p. 67. This problem is in effect a rather open discussion inside the field of statistic since, as Norcliffe put forward, there are statisticians who argue that transforming data to normalize the frequency curve is nothing more than 'fudging' the data to fit the model.
³ For an account on this discussion see Bartlett, M., The Use of Transformations, in Biometrics, No 3, 1947, pp. 39-52.
level of each axial line and at the level of different 'portions' of the urban grid, as given by the mean value of syntactic measurements observed for each 'portion'.

The same applies for land use measurements which will be taken both at the level of each axial line (constitutions per axial line) and at the level of the mean density observed for each land use category within different 'portions' of the grid as well. The measurement of constitution has been proposed as the parameter for measuring the performance of land use distribution in relation to the street grid. It has been suggested that the spatial nature of both descriptive parameters (axial lines and constitutions) provides an effective description for one significant aspect of reality - which might be identified as the public nature of the street grid - that has been absent both from the urban land use studies and from studies of urban morphology as well.

The problem of how to define the extension of the conjectured 'portions' of the urban grid within the proposed areas of study seems to be the natural development of this investigation. A clear evidence on the existence of these 'portions' has been given not only by intuition but especially by the visual observation of the grid configuration of both sectors A and B. From the spatio-morphological standpoint it is clear that grid configuration changes from one part of the grid to another. The same applies for land use distribution as the visual observation of the land use maps has also suggested. Different portions of the grid have rather distinct patterns of land use distribution. Each use seems to perform in a distinct way. Some uses or some particular mixtures of uses tend to dominate specific parts of the grid. In other words, both from the configurational and from the functional standpoint the decomposition of the street grid for analytic purposes seems to be a justified effort to be pursued. The exercise of decomposing the street grid in the areas of Porto Alegre that have been proposed as case studies for this investigation is precisely the object of the next chapter.
Chapter 3
The Decomposition of the Urban Grid

This chapter is devoted to the study of how the decomposition of the street grid for analytic purposes may be carried out. Configurational features of the two areas of study will be investigated in the search of indications which might allow for their spatial decomposition. This chapter evolves from the description of what might be called 'whole systems' - sectors A and B described as a whole - towards the description of their 'parts' or, to put it better, their description as parts.

The first issue to be tackled here is the problem of definition of boundaries according to which such a decomposition might be carried out. This includes both the outer boundaries of the two areas of study and, furthermore, the internal boundaries to be assigned to conjectured portions of the street grid or 'local areas'. The second issue to be dealt with here is the problem of how to assess, in spatial terms, the extent of the 'autonomy' or 'dependence' between different parts of the grid emerged out of a proposed set of spatial boundaries. This second issue entails the relevance of analysing (or measuring) 'portions' of the street grid either as 'autonomous' systems or, on the contrary, as systems that are 'dependent' or sensitive upon syntactic effects coming from larger surroundings. The definition of these 'degrees of autonomy' will end up by generating a range of possibilities of decomposing and grouping conjectured local areas.

This chapter is structured in the following way. In the first section a range of views coming from different authors on the problem of how to define boundaries in urban systems will be examined. This issue could have been dealt with during the review of literature presented in chapter one, although for its relevance as a reference in the argument to be developed in what follows it has been deliberately included as an introductory section to the analytical procedure.
The analysis in its initial stage focuses on the definition of the outer boundaries of the two areas of study. In effect these outer limits have already appeared in chapter two when sectors A and B were introduced, yet at that stage the criteria that was applied for defining that particular perimeter was not explicited. Two measurements will be utilized in order to carry out with this initial boundary definition. Both are spatial criteria, i.e. criteria given by spatio-morphological features of the street grid. The first of these criteria has been termed as \textit{ruptures in traverse permeability} and aims to detect particular routes where the \textit{spatial continuity} of the grid decreases or is literally interrupted as it happens in some cases.

The boundaries given by this first criterion will then be matched with boundaries given by the highest choice value lines observed in the two sectors. This second measurement is aimed at providing a syntactic counterpart for the boundaries defined by ruptures in traverse permeability. Both these measurements are fully explained later in this chapter. In the following step, having the outer boundaries of the two areas of study already defined, the measurements of traverse permeability and choice will then be utilized in order to prospect for internal boundaries, that is to say, spatial ruptures \textit{within} each of the two larger sectors of study.

This procedure will deliver a set of 'portions of the grid' or 'local areas' which will be taken as an initial reference according to which further 'decompositions' or 'groupings' will be carried out and tested. These tests aim to identify the degree of interdependence (in spatial terms) between the conjectured portions of the grid. In other words, the question that emerges at this stage is whether the selected areas of study perform as 'whole systems' or as two or more syntactically autonomous systems which, if this is the case, might be analysed as separate parts. Some portions of the grid might be actually separated from its surroundings by a boundary, while for other parts the boundary might perform as tying up or 'zipping' two or more unlike parts together.
The conjecture here is that the boundaries taken as a reference for the decomposition procedure do not necessarily provide in themselves an indication of local area formation, that is to say, when we look at boundaries we cannot assume they enclose syntactically autonomous local areas. Visual inspection of the grid configuration presented by the two areas of study - as given by Fig. 2.05 and 2.09 - suggests that some parts of the street grid tend to be more autonomous (or detached) in relation to their surrounding areas than others which seem to be more 'tied' to their surroundings or, in other words, more a part of a larger area than a local area in itself. 'Autonomy' and 'dependence' are understood here in the 'syntactic sense', that is to say in terms of variations in the way the urban spaces - as described by axial lines - are interconnected amongst themselves constituting what might be called the spatial continuity of the urban grid.

A range of syntactic measurements will be utilized in order to measure the extent of the autonomy of the conjectured 'portions of the grid'. These measurements are all based upon the pattern of syntactic integration observed for the two areas of study. The first of these measurements will be given by comparisons between integration cores measured for each whole system (sectors A and B measured as a whole) and the integration cores of each one of the conjectured 'local areas'. The second measurement will be given by comparisons between mean integration values observed for the conjectured local areas and the mean integration value observed for the whole systems. A third parameter is to added in order to assess the extent of the syntactic autonomy of each conjectured local area. It is given by the pattern described by integration as measured among spaces up to three axial steps away from each space. This has been termed 'radius three analysis'. These measurements have been previously utilized in syntactic studies for similar purposes.

Despite the strict syntactic sense in which both 'autonomy' and 'dependence' are assumed at this stage it is conjectured that variations
in the spatial continuity of the street grid might have strong effects in the way patterns of land use distribution are set up in urban areas. If this is the case the objective measurement of such variations in spatial continuity might be regarded as useful instruments for the identification of the spatial rules according to which land uses are distributed in the grid. The analytical procedure, structured as put forward above, will end up by providing a range of possibilities according to which the two areas of study might be decomposed. The decompositions and groupings emerged out of this analysis is the object of study of the following chapters, both from the configurational (chapter four) and from the land use standpoints (chapters five and six).

A range of views on the problem of boundaries

The difficulty with finding some criterion for decomposing the urban grid arises from the fact that there usually are several connections between any of its parts. Any attempt to define, in spatial terms, limits within urban areas as well as of decomposing a large urban area into smaller systems more locally defined is often frustrated by the difficulty of deciding objectively how to select the streets that must be considered as boundaries and, consequently, the number of different parts thus created and the sizes of these parts as well.

This problem of how to define the boundaries of local areas (as a part of larger urban areas) has already been dealt with in the literature, although a more rigorous method for doing so, at least from the spatial standpoint, has yet to be developed. A short review of what is known in this respect is worthwhile. Hillier (1989), in dealing with the King's Cross area in London, proposes a criterion of boundary definition based upon patterns of pedestrian movement: 'Syntactic analysis was carried out at two levels and in two modes: of the whole area (the 'large area'), and of a smaller area bounded by Camden Road, Caledonian Road, Euston Road and Eversholt Street. The idea of varying the scale of analysis is to
check for any analytic effect that might result from the choice of boundary. The scale of the smaller area is based on a rough estimate of the normal pedestrian catchment area for the site, and the larger area on a rough estimate of 'catchment area of catchment area'.

Hillier's proposition is useful if one thinks in terms of the syntactic analysis of one development site as in the case of King's Cross. He suggests that by embedding the site in a larger area, and this larger area in another still larger it is possible 'to displace any edge effect in the spatial analysis into the outer reaches of the larger system, away from the area of prime interest in the more immediate vicinity of the site'.

In other words what is achieved with the successive enlargement of the 'areas of embedding' is a dispersion of possible edge effects. Since Hillier is primarily committed in describing how the syntactic character of larger surroundings will affect one particular area - the King's Cross 'void' in this case - the placement of this site of prime interest at the centre of successively larger areas fulfil his analytic requirements so allowing for a more flexible definition of the boundaries of his larger systems based upon a rough estimate of the 'pedestrian catchment area'. The problem with applying this criterion to the definition of boundaries of the urban areas to be examined in this research is that there is no area of 'prime interest' to perform as a reference for successive enlargements. Different grid configurations are to be analysed, both in themselves and also interacting with adjacent areas and in a case like this the spatial boundaries of each area must be defined as objectively as possible since there is nowhere to 'displace the edge effects' if these effects are to happen.

The definition of urban boundaries in terms of catchment areas is also part of Alexander's work. He points out that the characteristics of a

1 Hillier et al. Natural movement: or, configuration and attraction in urban pedestrian movement, Unit for Architectural Studies, Bartlett School, 1989, p. 11.
2 ibid. p. 11.
3 Alexander, C. A Pattern Language, New York, Oxford University Press 1977. The concept seems to have been firstly introduced at the regional scale in the works of Christaller and Lösch, yet discussed in chapter one. The use of the idea at the urban scale seems to come
'stable' system of shops relies on the fact that 'each unit of the system (each shop) has a certain 'catch basin' composed by the population which it needs in order to survive. Units of any given type and size will be stable if they are evenly distributed, each one at the centre of a catch basin large enough to support it'.\(^1\) The idea is parallel, if not coincident with the catchment area as proposed by Hillier. In both cases the boundary is socially defined, for one by 'population needs' for the other by pedestrian movement. The fact that the spatial configuration of an urban area is in itself a limiting factor in the definition of these 'catchment areas' is not taken into account in neither case.

The 'catch basin model' works for Alexander as an alternative to the 'competition model' proposed by Siegan in his 'natural zoning' hypothesis already discussed.\(^2\) Alexander suggests that every time a shop opens it faces a problem of choice; it can either locate in a new area where there are no other competing businesses, or it can place itself exactly where all the other businesses are already in the hope of attracting customers away from them. His answer is that 'stores are much more likely to survive when they stand, without competition, in the middle of a catch basin which needs their services'. The ideal location will be met according to the following procedure: *Identify all other shops which offer the service you are interested in; locate them on the map. Identify and map the location of potential consumers (density and total number). Look for the biggest gap in the existing web of shops in those areas where there are potential consumers. Within the gap on the web of similar shops, locate your shop next to the largest cluster of other kinds of shops*.\(^3\)

---

\(^3\) Alexander, C. op.cit., p. 108.
For its linearity the concept of 'catch basin' as it is proposed by Alexander resembles more a 'tree like' functional distribution that the complexity of his 'semi-lattice'. It represents in effect precise the opposite of what is conjectured by the 'natural zoning paradigm' as it is proposed by Siegan. Both authors deal with the notion of competition yet the first as a negative value and the second as a positive one. The catch basin model seems to pre-suppose a homogeneous settlement, both spatially and socially yet real cities are heterogeneous from both points of view. This is what the work of Siegan is keen to demonstrate by pointing out that certain concentrations of shops are so located because the evidence given by years of 'locational experiments' recommends that location. In other words what Siegan observes is that the distribution of shops in unplanned cities takes place in agreement with natural catch basins which by comprising the advantages and disadvantages of a particular location are the opposite of the ideal catch basin proposed by Alexander. Siegan actually demonstrates that only in very specific kinds of business one can locate a shop both in the biggest gap on the web of similar shops and at the same time find a large cluster of other kinds of shops to locate his shop next to.

There is also the problem of identifying the 'potential consumer' in order to establish the boundaries of Alexander's catch basin. What is a potential consumer it might be argued. Only for a local shop (ordinary daily supply) could one consider the inhabitants of a certain perimeter around as potential consumers. For every other type of commerce or service a range of more complex criteria - such as income of the target population, mobility, degree of especialization of the activity, etc. - should be taken into account for the definition of potential consumers. As a consequence, the way in which the potential consumer enters into the criteria for defining the boundaries of a 'catchment area' becomes, for most cases, no more than an effort of abstraction. Indeed the ideological content underlying the catch basin model are promptly acknowledged by Alexander when he states that his proposal has an
'accent on the cooperation between people as an alternative for the competition for location'.

The difficulty in translating the functional concept of 'catchment area' or 'catch basin' into the language of spatial configuration is that if there is a correspondence between form and function at the urban scale it is not necessarily a linear one. And the notion of catchment area as it is proposed above is strictly functional, hardly related to actual spatial distributions. Moreover it embodies traces of a zoning organization where supply and demand are in direct correspondence and ignores the actual complexity coming from the functional dimension of 'naturally evolved' towns where users and activities interact locally and globally at the same time.

The problem of identifying urban boundaries is also dealt with by Ratcliff in his notion of 'tributary area'. He suggests that each use or function may be said to have a relationship with a special 'tributary area' within which are those activities and facilities which give meaning to the location of that use. Ratcliff's tributary areas are irregular in shape and are measured in terms of interest groups, purchasing power and population density. Ratcliff pays attention to the problem of the local and global scales of the city. He suggests that each retail type has an optimum size of establishment, which is related to the nature of the tributary area: 'The centrally located variety store has the whole community as its tributary area, while the neighbourhood grocery store has a tributary area that is a few blocks in extent and covers a few

---

2 From this point of view the concept of 'catchment area' comes to coincide with the concept of 'neighbourhood'. It is worthwhile to remind Jacob's words on this precise issue: '... city people are mobile; 'pick' and 'choose' from the entire city for everything from a job, a dentist recreation, or friends, to shops and entertainment. And whatever city neighborhoods may be, or may not be, their qualities cannot work at cross-purposes to thoroughgoing city mobility and fluidity of use, without economically weakening the city of which they are a part'. In Jacobs, J. The death and life in the great american cities, Jonathan Cape, London 1962, p. 143.
4 ibid. p. 374.
Fig. 3.01. The same regular grid divided in five distinct 'zones'; after the Masterplan of Porto Alegre.
hundred households'. The contribution of Ratcliff is particularly relevant and in effect distinct from the 'linear' concept of catchment area, for its acknowledgement of 'the superimposition of an infinite number of catchment areas in actual cities' a notion that in effect mirrors the 'semi-lattice' proposed by Alexander.

The way in which the activity of masterplanning approaches the problem of boundaries at an intra-city scale provides another contribution to this discussion. The masterplan of Porto Alegre for instance utilizes the criterion of dividing the city in 'territorial units' or 'zones' bounded by the 'main circulation system' - the longest and sometimes widest avenues of the area. Each territorial unit has a certain range of uses which are there allowed. That is to say certain uses are allowed to exist inside a set of precise boundaries in a one to one correspondence between 'area' and function. The selection of the range of uses that is prescribed for each zone is based upon what might be called an 'organizational' strategy that gives which activities 'suit' the different zones.

The problem with applying this kind of strategy in a study concerned with spatial configuration is that in many cases these long or wide avenues do not define major changes in the configuration of the street grid. Legal boundaries in these cases are not spatial boundaries. An example is provided by the area more at west of the SA sector where three main routes are proposed by the masterplan as dividing an 'almost perfect' regular grid in five distinct zones (Fig. 3.01 top). These main routes are in effect part of a continuous regular grid and from the point of view of the spatial continuity of the urban grid these avenues have neither effects of increasing continuity nor of 'breaking' with it (Fig. 3.01 bottom). In this particular case this investigation will proceed with the partition of the area in different ways - to be further explained - in order to check the extent of the 'syntactic autonomy' of each one of

---

1 ibid. p. 375.
these 'zones' and their corresponding functional autonomy, if this is the case.

The contribution given by Loumi (1988) brings back the problem of boundary definition to the domains of the syntactic dimension of the urban grid. In his study of traditional Algerian towns, Loumi has found that 'radius three analysis' illuminates the debate on the existence of autonomous urban quarters in these towns. Radius three analysis is carried out on the basis of measurements of syntactic integration taken among axial lines up to three steps away from each line in the system, instead of looking at the total depth distribution of all spaces, as it is done for 'standard' integration. In Loumi's study, the integration core does not take the form of a deformed wheel, the characteristic shape in European towns. Rather, it passes mainly around the perimeter of the towns. Penetration into the geometric centre of his towns is slight, and directed mainly towards the market places and the mosques. Integration, he suggests, is powerfully related to the construction of an interface between inhabitants and strangers at the periphery of the town, where the market and other facilities are concentrated, while at the same time rendering the residential areas segregated and impenetrable. Radius three integration, on the other hand, forms a more or less continuous core of spaces running right through the heart of the settlement. Loumi suggests that this measure picks out 'spatially distinct quarters' which are related to clan membership within the segregated residential areas, and links them together into a more or less continuous system of access. Loumi concludes that radius three integration in the Algerian context constructs an interface not between inhabitants and strangers, but among inhabitants.

Following the syntactic approach Peponis (1988) has also contributed in the discussion of the problem of boundaries in urban areas. He proposes that the configuration of the choice core - the highest choice value axial lines inside an urban system - might be used as a parameter for the

---

definition of the boundaries of more local areas, or sub-areas, inside larger urban areas.¹ In practical terms Peponis' proposition is that the urban grid may be 'cut along the consecutive lines of the highest possible choice value which, taken as a set, traverse it from one edge to another'.² The explanation for Peponis' proposition is straightforward. When a high choice value is assigned to an axial line this means, by definition, that a high number of connections between the possible pairs of axial lines go through that particular line. By cutting along the highest choice value lines, Peponis suggests, 'one is in fact cutting at the seams of connectedness of the layout. Where the choice core bifurcates we always cut so as to maximise the total choice value while minimising the total number of necessary cut-lines'.³ The conjecture here seems to be that the spatial configuration produced by the set of strongest choice lines of an urban system depicts its main structural lines, the ones without which the system, or the fabric, would loose its structure or its 'structural tension'.

Peponis goes forward by suggesting that this decomposition procedure does not provide in itself an indication of sub-area formation. That is to say, the identification of spatial boundaries does not necessarily imply that the parts emerged out of the decomposition are syntactically autonomous local areas. This coincides with the conjecture raised at the outset of this chapter that some parts of the grid might be dislocated or separated from its surroundings by a boundary, while for other parts the boundary might perform as tying up or 'zipping' two or more unlike parts together. To check for the formation of sub-areas Peponis proposes two questions. The first asks how far the integration cores of the parts coincide with the integration core of the grid as a whole. Peponis conjectures that the greater the coincidence the less distinct the sub-areas will be. The second question asks how far the mean integration value of the 'part' under scrutiny is greater than the mean integration

¹ Peponis, J. et al. The Spatial Core of Urban Culture, in Ekistics, Jan-Feb 1990, pp. 46.
² ibid. p. 49.
³ ibid. p. 49.
value of the 'larger area' it belongs. If the part is more integrated when analysed in itself than when embedded in the whole area then it appears to be more autonomous and then a sub-area or local area in itself.

Peponis proposes that these questions can be clarified in two ways. The first is by defining what proportion of the integration core of the conjectured local area - measured as detached from the larger area it is a part - also belongs to the 'global integration core', i.e. the core of the large area measured in its entirety. Peponis calls this measurement 'overlap'. He conjectures that the greater the overlap the less distinct are the parts. The second is defined by the ratio between the mean integration of a global area and the mean integration of the local areas that are part of it. This measurement he calls the 'definition' of each local area.

During the syntactic analysis to be carried out next in this chapter the procedure described above - as suggested by Peponis - will be utilized as one of the parameters for testing out the pertinence of the decomposition strategy to be proposed. In fact Peponis' proposition can only be applied inside areas whose 'larger boundaries' have been previously defined. Since Peponis has dealt with a sample of small towns his point of departure is the definition of the choice core (the highest choice value lines) for the whole town. That is to say the high value choice lines give the 'start up' boundaries which are further tested out by the criteria proposed above (overlaps and definitions). The 'large area' is the whole town and as a consequence he has no concern with the selection of what might be called 'the large area of embedding', which would necessarily be his initial step if he was to deal with a large city where the street grid often extends through the so called 'metropolitan region'.

This is precisely what happens in the case of Porto Alegre, the city this investigation is concerned. Porto Alegre is a large city, in fact part of a 'metropolitan region' which includes other thirteen towns, all virtually
interconnected, and for cases like this some objective criteria had to be found in order to define the boundaries of the 'whole systems' or 'large areas' to be studied. Since the approach of the current research with respect of the morphology of the city is entirely spatial, the boundaries of each area of study had necessarily to be defined according to objective spatial criteria.

**Defining spatial boundaries**

A range of observations and measurements were carried out to define objective spatial criteria for setting up the outer boundaries of the two areas of study. A rough location of the two areas of interest was known beforehand, since those are the areas of Porto Alegre where changes in grid configuration are more conspicuous, and as such those are the areas where the phenomenon to be dealt during this investigation is more clearly observable.

As a consequence, taking into consideration the parts of Porto Alegre that present a conspicuous variety of grid configurations, the first step of the spatial analysis is aimed at identifying specific 'parts' of the street grid where spatial continuity is explicitly 'interrupted' or 'fractured'. What counts as a 'rupture' must be defined. The 'spatial ruptures' to be considered vary for each situation yet they can be reduced to two cases. One is what might be called an 'artificial' rupture. This is the case of large public facilities which perform as 'barriers' in the spatial continuity of the street grid. An airport located at north of sector A and two large cemeteries one located virtually in the middle of sector A and the other in similar position in sector B are examples of the 'artificial' ruptures referred to above. This sort of rupture is regarded as 'artificial' for it is extrinsic to the nature of the grid. The street grid in fact 'disappears' in these situations being replaced by large 'voids'.

---

1 The fact that both sector A and sector B carry not only similar public facilities but moreover similar public facilities located in similar positions - more or less at the middle of both sectors - is accidental.
Table 3.01 'Traverse permeability' measurements for the south boundary of sector A.

<table>
<thead>
<tr>
<th>Route</th>
<th>Connections</th>
<th>Continuities</th>
<th>Interruptions</th>
<th>Traverse Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 R1</td>
<td>17</td>
<td>12</td>
<td>5</td>
<td>.70</td>
</tr>
<tr>
<td>2 R2</td>
<td>15</td>
<td>12</td>
<td>3</td>
<td>.80</td>
</tr>
<tr>
<td>3 R3</td>
<td>12</td>
<td>10</td>
<td>2</td>
<td>.83</td>
</tr>
<tr>
<td>4 R4</td>
<td>23</td>
<td>4</td>
<td>19</td>
<td>.17</td>
</tr>
<tr>
<td>5 R5</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>6 R6</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>7 R7</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>.66</td>
</tr>
</tbody>
</table>
The other case and certainly the most recurrent is when the street grid is continuous yet the 'permeability' in some 'sections' of the grid decreases sharply. The 'sections' referred to here are routes whose connectivity happens mostly to either of its sides or, in other words, situations where a particular route is strongly intersected, although not crossed (or scantily crossed) by other routes. Two axial steps are often required to 'enter' the adjacent system. Besides the number of routes that cross the conjectured 'section' is explicitly lower if compared with adjacent parallel routes. These ruptures might be termed 'natural ruptures' since they are intrinsic to the nature of the urban grid. Fig. 3.02 gives an example. Seven routes were selected as 'possible boundaries' for the south side of sector A. Fig. 3.03 depicts the variations in 'traverse permeability' observed for these selected routes (R1 to R7).

Table 3.01 shows the connectivity of each route, the amount of continuities, the amount of interruptions and the ratio between continuities and the total connectivity of each route. This ratio might be termed the measurement of 'traverse permeability' for each of the seven 'sections' of the grid selected to be examined. For comparative purposes the length of each of these sections must be at least roughly similar.1 The measurements vary between 0.70 and 0.83 from R1 to R3, decrease sharply to 0.17 in R4 and increase again to 1.00 for R5 and R6. R4 is the route where 'traverse permeability' comes to its lower value, i.e. the route where the ratio between the number of continuities and the number of intersections is the lowest. For three of the selected routes 'traverse permeability' is relatively high as it would be expected for 'standard' deformed grids (R1, R2 and R3). For R5 and R6 traverse permeability

---

1 Another way of measuring 'traverse permeability' might be the ratio between the number of crossings and the length of the 'conjectured boundaries'. The difficulty with applying this method is that, apart from the case of regular orthogonal grids, the spatial configuration of urban systems tends to be too diversified so preventing for most cases the selection of possible boundaries with identical lengths. Besides the ratio between crossings and interruptions seems to provide not only a more clear picture of the 'spatial discontinuities' but also a higher degree of length flexibility in the choice of possible boundaries.
reaches the maximum since these two routes are part of a 'perfect' orthogonal grid. Since all connections are also continuities the 'traverse permeability' value for these three routes is one.\footnote{The line chart given in Fig. 3.04 provides another description for the same phenomenon.} Thus according to the traverse permeability criterion R4 might be regarded as the route that works as a spatial boundary in the south side of sector A. In the situations where the spatial continuity of the street grid is totally interrupted - as for the airport referred to above - 'traverse permeability' is zero since all the connections of the route that edges the airport are counted as interruptions. Hence the measurement of traverse permeability varies between zero, for an 'explicit' rupture, and one, for a perfect regular grid where all connections can be regarded as spatial continuities.

Fig 3.05 presents a diagram where the spatial boundaries of sector A are defined by ruptures in traverse permeability. The area of the airport at north, the areas of a cemetery and a sports centre virtually in the middle of the system and also an urban void at southeast bring about explicit barriers for the spatial continuity of the street grid, yet in all cases the grid will be further reinstated.\footnote{Even in the case of the airport.} The north boundary of sector A is defined by a long east west route composed of two different streets almost aligned where three distinct situations occur. For the lower part of this section (in the figure) two large rectangular urban blocks bring about a conspicuous rupture in traverse permeability. Six out eleven streets that intersect that part of the north boundary are interruptions or discontinuities. In the adjacent areas the grid is to a large extent a pattern of spatial continuities, especially the portion of the grid within sector A where the configuration is conspicuously orthogonal and composed of rather regular blocks both in terms of size and shape. Further north comes the area of the airport where nineteen routes are interrupted and just three continuities are allowed. At the upper part of this north boundary of sector A the grid is again extended northwards beyond the proposed boundary. Nevertheless just one continuity is
allowed - between the small development at northeast of sector A and the part of the grid regarded as within sector A - out of the seven routes that intersect that part of the north boundary.

The east boundary of sector A shows another route where rupture in traverse permeability is clear. Here again four large rectangular blocks bring about a 'section' where just five routes are continuities out of the twenty three that are intersected. The portions of the grid adjacent to this eastern section are mostly composed of continuities. This applies both to the curvilinear configuration at northeast of the whole sector A and to the more griddy system at southeast.

The south boundary of sector A is - as with the north boundary - defined by a range of different types of rupture. A large urban void at southeast allows for just three continuities out of the eighteen routes that intersect that route. Following down this same south boundary the grid becomes continuous southwards although a strong rupture in traverse permeability takes place. In this case the rupture in traverse permeability is not brought about by an enlargement of adjacent urban blocks as with the east boundary. Despite the fact that the sizes of the blocks in that part of the grid are rather homogeneous (at least if compared with the variety of shapes and sizes given by the urban blocks at the east part of sector A) the selected route is described by a strong rupture in traverse permeability where just four out of twenty eight intersected routes are spatial continuities. Further down in the south boundary of sector A, again different sections emerge as possible boundaries and the comparative procedure had also to be applied. The selected route allows for just four continuities out of the fifteen routes that are intersected, which is well below the other possible boundaries taken for comparison. The west boundary of sector A is clearly defined

---

1 This boundary was given as an example where the traverse permeability of parallel routes are compared (Fig. 3.02).
2 This is the south boundary of the more orthogonal part of the whole sector A at west.
3 The traverse permeability of the selected route is 0.26 while for the other alternatives the values are 0.83 (ten continuities out of twelve intersections) and 0.71 (ten continuities out of fourteen intersections). These routes are highlighted with dots in Fig. 3.05.
by the route that edge the river yet two continuities are allowed to the
docks and embankment.

Fig 3.06 presents a diagram where the *spatial boundaries* of sector B
are, same as with sector A, defined by ruptures in traverse permeability.
The north boundary is all defined by a motorway which runs along both
sides of Ipiranga River. In this case the rupture in traverse permeability
is explicit. Just seven out of the fifty five intersected streets are
spatial continuities. The east boundary of sector B is defined partly by
an urban void and partly by a route where large rectangular blocks
emerge. In this case just three out of the eleven intersected streets are
continuities, yet a pattern of continuities is predominant in both
adjacent configurations.

The south boundary of sector B is defined by three distinct types of
spatial rupture. In the upper part of this edge a sequence of large urban
blocks with different shapes brings about a 'section' where just four out
of thirteen intersections are spatial continuities. Despite the more
labyrinthine morphology of this area a pattern of spatial continuity can
be observed in the part of grid regarded as *within* sector B, while from
the selected route southwards a more labyrinthine configuration emerges
and a pattern of discontinuities becomes predominant. Further down the
south boundary of sector B is set up by a large urban void that produces a
concavity in the overall shape of the area. In the lower part of the south
boundary two developments are connected by just one street. In this
case - the southwest boundary of sector B - just one spatial continuity
is allowed amongst the ten intersected routes. The west boundary of
sector B is again defined by the enlargement of blocks which brings
about a route where just three continuities are allowed out of sixteen
intersections.

Having defined the areas of Porto Alegre where changes in grid
configuration are conspicuous and having defined the outer boundaries of
these areas - according to the traverse permeability criterion - the
Fig. 3.07 Sector A: Ruptures in traverse permeability

Fig. 3.08 Sector B: Ruptures in traverse permeability
analysis has, in its subsequent step, identified spatial discontinuities inside both areas of study. The phenomenon identified here as 'ruptures in traverse permeability' takes place not only at the outer limits of both sectors but in their interior as well and, for most cases setting up spatial boundaries between distinct grid configurations. Fig. 3.07 and 3.08 show how this happens for both cases. In the west part of sector A, to give an example, the route that separates the more orthogonal part of the grid (A) from the more deformed (B) presents an outstanding decrease in traverse permeability (Fig. 3.07). The same applies for the east part of sector A where the more labyrinthine pattern at northeast (C) is kept apart from a deformed grid (D) by a route where traverse permeability is markedly low. These examples indicate that the comparative measurement of 'possible boundaries', as presented in table 3.01, is certainly not required in cases where visual observation shows clearly that in one route - and only in that particular route inside the area of interest - traverse permeability decreases strongly.

There also happens situations where the comparison between 'traverse permeability' measurements - as a way of testing out alternatives for a particular boundary - is difficult if not impossible. This is the case of boundaries which involve more labyrinthine systems - areas crowded of short axial lines - where the 'possible boundaries' tend to be axially fragmented routes. The example given above - the boundary between the two conjectured sub-areas at northeast in the sector A - is also clarifying in this respect. One of the areas (C) is what may be described as a 'maze-like' pattern all composed of curvilinear streets. The other (D) is a deformed grid mostly composed of short axial lines (Fig. 3.07). Since the comparison between 'possible boundaries' can only be carried out between 'sections' at least roughly parallel the procedure can hardly be applied here. Nevertheless despite the difficulty in setting up a rigourous comparative procedure, visual observation indicates that the sudden change in grid configuration - from a maze-like pattern to a deformed grid - is followed by a conspicuous decrease of traverse permeability right at the 'section' that defines the limits between
curvilinear and orthogonal patterns. In effect from the thirteen routes that intersect that 'section', only two are spatial continuities. The low measurement observed for 'traverse permeability' (0.15) comes to confirm what visual observation suggests.

It is certainly difficult, if not impossible, to set up an objective criterion with general applicability for defining spatial boundaries in urban areas. Urban grids tend to be complex wholes which alternate continuities and discontinuities throughout. Nevertheless if one thinks in terms of 'variations' in spatial continuity as a possible criterion, the strategy proposed here of watching the fall and the rise of 'traverse permeability' ends up by providing a rather consistent criterion. These boundaries set up in agreement with the 'traverse permeability' criterion are supposed to work as an 'start up' boundary proposition within the current investigation. In what follows these start up boundaries will be compared other boundary description; the performance of lines with the highest choice values in the two areas of study, to be presented and discussed in the next section.

The strategy of challenging conjectured boundaries - and the proposition of alternative boundaries as well - will recur throughout the current investigation in its pursuit of identifying spatial patterns in the distribution of the different categories of land use. It is conjectured here that for some uses a system might perform just as a 'part' inside a larger area while for other uses this same system might be regarded as a more 'autonomous' urban area in itself. In other words 'spatial boundaries' may have some significant relationship with 'use boundaries'. The way in which 'local boundaries' in urban areas are syntactically arranged has probably something to do with the way uses are distributed inside the area, although this same area may carry uses that are more globally oriented in their location and for whom the spatial boundaries would be others probably more extended so assimilating syntactic effects coming from the global scale.¹ In this sense the analytical

¹ This conjecture will be fully exemplified and tested out during chapters five and six.
procedure based upon the investigation of alternative boundaries for the
same area is in itself a way of identifying and studying the performance
of land use distribution from the spatial standpoint. The analytical
strategy focused in this direction is likely to provide the means of
identifying fragments of the complex 'functional overlapping' of
unplanned cities as noticed yet not described by Alexander in his 'semi-
lattice' model.

From the wholes to the parts

This section starts by comparing boundaries set up according to the
'traverse permeability' criterion with the configuration produced by the
axial lines that carry the highest choice values inside each area of study.
These lines, following Peponis' proposition, might be regarded as another
way of describing spatial boundaries inside urban areas and as such
another way of decomposing the urban grid for analytical purposes. The
resulting set of boundaries - after the observation of traverse
permeability and choice - is not to be assumed as a final and conclusive
evidence upon which the decomposition strategy to be adopted should rely.

Further tests based upon the configuration of integration cores will be
carried out. These tests will first identify the extent of the 'overlap'
between local cores and the core of the whole system, that is to say the
global core lines that are also part of the system (the conjectured local
area) under scrutiny. As it has been already referred, Peponis has
suggested that the greater the 'overlap' the less distinct are the parts. In
other words, when the overlap between local and global cores is
significant the system might be regarded more as 'a part of the whole'
than a syntactically autonomous system in itself. Despite the fact that
the measurement of 'core overlap' is given by a ratio between
measurements emerged out of percentages of the cores of interest, it is
assumed here that since the core percentages to be utilized will be the
ruptures in traverse permeability

Fig. 3.10 Sector A: 5% highest choive value lines
same for all cases throughout the current sample, the measurement of overlap might provide a reliable parameter for comparative purposes.

Three other measurements based upon the pattern of integration will be utilized in the attempt of measuring the extent of the syntactic autonomy referred to above. One is the 'definition' of each sub-area as given by the ratio between its the mean integration value - measured as a separate system - and the mean integration of the whole system of which it is a part. In this respect Peponis suggests that if the conjectured local area is more integrated when analysed in separate than the larger area it is a part then it might be regarded as a syntactically autonomous system in itself. The extent of such autonomies is what remains to be seen. Other measurement for describing the 'syntactic autonomy' of the proposed local areas is the 'difference' between the mean integration value observed for the sub-area measured as detached and the mean integration value observed for the same sub-area measured as a part of the whole system. It is conjectured in this respect that the greater the 'difference' the more autonomous the part will be in relation to the whole. The third measurement to be utilized in order to assess the extent of the autonomy of the conjectured sub-areas will be given by the pattern of integration measured among spaces up to three axial steps away from each space (radius three analysis). This measurement, since it is a local parameter hardly affected by changes in boundary, will be utilized as an independent measure, against which the results given by overlaps, definitions and differences will be compared. The set of measurements described above is supposed to perform as a configurational benchmark against which the decomposition of the current sample of urban grids will be systematically tested out.

Figs. 3.09 and 3.10 are axial representations of sector A. The first gives an axial description for the 'sections' of the grid where traverse permeability decreases. The second shows the sequences of highest choice value lines for the same system. The point to be discussed for
start is the extent to which the configuration produced by the choice core either confirms or contradicts the boundaries given by ruptures in traverse permeability. For descriptive purposes each conjectured sub-area is assigned a code which is given by the initials of the sector (SA in this case) plus the number of axial lines observed for that 'portion' of the street grid (Fig. 3.09).1

The boundaries given by the traverse permeability criterion, as it has already been noticed, are for most cases positioned at the interface between distinct patterns of urbanization or more specifically, at the interface between distinct grid configurations. In effect it could not be different from that since the lines that separate grids with different spatial configurations tend to be for most cases lines that are intersected yet not crossed by lines belonging to the adjacent systems. Fig. 3.09 shows that this stands for the boundary lines between SA60 and SA77 which are lines that separate an orthogonal grid from a more deformed grid. This also stands for the boundary lines between SA106 and SA72 which are lines that separate a more labyrinthine configuration from a 'pinwheel-like' grid.2 Nevertheless such a characteristic - distinctive grid configurations for adjacent systems - is not shared by all the identified traverse permeability boundaries. SA72 and SA71 for example are both deformed grids composed by rather similar axial lengths and block shapes, at least this is what visual observation suggests. Nevertheless the line that divides these two systems is an edge where a strong rupture in traverse permeability occurs.

The distribution given by the highest choice value lines may prove itself a particularly relevant tool at this initial stage of the analysis in the verification of the syntactic significance of the boundaries set up according to ruptures in traverse permeability. Fig. 3.10 shows the 5% highest choice value lines in sector A. The characteristic that immediately emerges from the configuration of the choice core is its

---

1 Boundary lines were counted as part of each sub-area.
2 As defined in Hanson's typology of grids. In Hanson, J., op.cit., p. 103.
spatial continuity. The highest value choice lines are sequences of axial lines of which the longest one - the longest sequence - traverse sector A in all its eastwest extension. From this long route a series of 'branches' emerge as sub-dividing the grid. Visual inspection makes it clear that the high value choice lines do not match entirely the boundaries defined according to the traverse permeability criterion.

Nevertheless when the two propositions are compared some interesting similarities emerge and most of the traverse permeability boundaries are at least partially confirmed by lines belonging to the choice core. SA60 - the more regular grid at east - has most of its contour defined by high value choice lines. SA77, the more deformed grid immediately above, is all but its south edge so defined. The same can be said for most cases yet some exceptions also occur. This is the case, for example, of the boundary between SA72 and SA106 where there is no more than a 'hint' of the choice core that perform as an edge indication. The lesson coming from this particular case seems to be relevant for clarifying why traverse permeability boundaries and the lines given by the choice core tend to coincide to a large extent. The conjecture here which arises from visual inspection is that both the length of the axial line and its position inside the system (or even the combination of both these factors) will bring about such a coincidence when it exists. Lines defined by ruptures in traverse permeability and high value choice lines tend to coincide as boundaries just when both these boundary descriptions are given by long axial lines. While the boundaries defined by ruptures in traverse permeability also include short axial lines, the boundaries defined by choice lines tend to be mostly composed of long axial lines.

This is not to say that all high value choice lines are long axial lines, yet most of them actually are. If this is the case it is likely that the measurement of choice - in view of its shortest path character - is to a

---

1 Compare the two descriptions in Fig.3.09 and 3.10.
large extent associated with the length of the axial lines.\(^1\) However as it has been suggested some exceptions occur, i.e. short lines that are both high value choice lines and traverse permeability boundaries. This is the case of the sequence of short axial lines eastwest oriented right at the centre of the whole system (Fig. 3.10). This particular set of lines is part of the choice core more for its position than for its length. At the same time this set of lines supports to all extent the traverse permeability criterion. On the other hand the boundary between SA106 and SA72, where traverse permeability and choice do not coincide, is a situation where neither the short length of the lines that compose the boundary nor their position inside the whole system justify a coincidence between the two boundary modes. Nevertheless it still seems to stand as an 'actual' boundary not only for the traverse permeability rupture as observed but especially for the conspicuous change in configuration if the two adjacent systems are compared. The south limits of SA77 and SA71 (Fig. 3.09) are also examples of boundaries composed by short axial lines deprived from the 'positional requirement' referred to above, i.e. they are topologically marginal in relation to the main shortest paths and here again ruptures in traverse permeability do not coincide with high value choice lines.

Despite the exceptions referred to above the comparison of the diagrams given in Fig. 3.09 and 3.10 suggests that traverse permeability boundaries and choice boundaries tend to coincide in situations where the length factor and the positional factor are superimposed and this counts for most of the cases inside sector A. The explanation for that seems to be straightforward. Since traverse permeability boundaries tend to be given by lines highly connected although not crossed, these same lines tend to perform at the same time as shortest paths between different parts of the whole system.

---

\(^1\) Further in this chapter the relationship between choice and length for the current sample of grid configurations will be examined (amongst the relationships between other syntactic measurements).
It is noteworthy that the choice core also includes axial lines that penetrate inside the local areas defined by ruptures in traverse permeability. Yet the coincidence between ruptures in traverse permeability and choice lines as observed for most cases has provided a rather consistent pattern for what might be called 'start up' boundaries, the presence of high value choice lines inside some of the conjectured local areas seems to provide some hints for further local area subdivisions. This is the case of the three high value choice lines that cross the interior of SA60 (Fig. 3.10).1 One of them — north south oriented — seems to divide the regular grid in two other smaller systems.2 This sub-division will be further tested. Nevertheless this cannot be taken as a rule since most of the choice lines that go inside the local areas defined according to the traverse permeability criterion do not provide any clue for a further sub-area division at least this is what visual inspection suggests. In fact insofar as the choice core expands — so including lines with lower choice values — the number of lines that crosses the interior of the conjectured local areas will increase dramatically, yet the significance of these lines as a boundary parameter is doubtful. At any rate, for comparative purposes with the traverse permeability boundaries, the percentage of 5% core as given in Fig. 3.10 seems to provide at least for the current case a clear picture on the performance of choice lines as spatial boundaries.

In sector B the configuration of the street grid is apparently more homogeneous if compared with the patchwork of conspicuously distinct grid configurations observed in sector A. Nevertheless the relationship between ruptures in traverse permeability and configurational distinctions visually identifiable are also noticed here (Fig. 3.11). SB62 is an orthogonal grid which by missing bits and pieces turns into a 'pinwheel-like' pattern. The adjacent system — SB30 — is a small

1 The codes of the conjectured local areas are given in Fig. 3.09.
2 This is the case mentioned as an example in the previous section (Fig. 3.01) where the masterplan of Porto Alegre prescribes five distinct zones inside the same orthogonal grid. The choice line referred to here represents precisely the main route that separates the zones proposed by the masterplan.
deformed grid. The two configurations are rather similar, yet the conjectured spatial boundary presents a strong rupture in traverse permeability.\(^1\) SB54 is most of it an orthogonal grid. The adjacent system is SB127, a more deformed grid to which short axial lines given by housing estates are added up. SB83 is a rather 'labyrinthine' pattern. For these cases the distinctive grid configurations are kept apart by ruptures in traverse permeability.

The distribution of the choice core in sector B confirms most of the boundaries defined by ruptures in traverse permeability (Fig. 3.12). However by contrast with what was observed for sector A the outer boundaries of the system is hardly described by choice lines. Nevertheless in the interior of the system most of the traverse permeability boundaries are confirmed by the choice core. Choice lines, same as in sector A, penetrate the interior of the conjectured local areas. One particular case is worth to refer. These are two choice lines that permeate in angle the middle of SB127. These axial lines set up a limit between the part of SB127 where housing estates are infilled and the rest of the system. The position of the choice core in that part of the grid seems to suggest a further decomposition of SB127 so allowing for the analysis of the 'portion' of grid that carries the housing estates as a system detached from its surroundings.

Next step the analysis shifts towards the pattern of integration. More than testing out the decomposition strategy - as defined by traverse permeability and choice measurements - the analysis that follows aims to verify the 'extent of the autonomy' of each one of the proposed local areas. As it was already explained 'autonomy' is applied here in the syntactic sense. The 'extent of the autonomy' of each local area will be given by the measurements of 'overlap', 'definition' and 'difference' as already proposed. This set of measurements is expected to provide some clarification on whether each one of the proposed sub-areas is in effect a part of the whole systems initially set up - as sector A and sector B -

\(^1\) This boundary will be further confirmed by a strong choice line as well.
or they might be regarded as syntactically detached from these 'start-up' wholes. In other words the question that remains, after the setting up of an initial local area division, is concerned with a precise definition of which surroundings will actually affect the syntactic performance of each local area when local areas are globally described, i.e. are measured as interacting with surrounding areas.

This question is central in the subsequent development of the current investigation when syntactic descriptions are matched with land use distributions. If on the one hand the matching of syntactic descriptions and land use at the local level may rely upon boundaries locally defined - by traverse permeability and choice lines - on the other hand, at the global level, it is threatened of having relied upon distorted syntactic descriptions if a local area comes to be regarded as a part of larger surroundings which do not correspond - either by being greater or by being smaller - to the surroundings that actually affect its syntactic performance at the global scale. In principle it seems fair to accept that the urban grid interacts syntactically as a whole insofar as spatial continuity exists. Nevertheless the conjecture here - which in fact is a specification of the general hypothesis stated at the outset of this thesis - is precisely that different 'degrees of spatial continuity' tend to bring about a pattern of local area formation where each local area has a peculiar relationship with its surrounding areas. The syntactic nature of such a relationship is conjectured here as being an effective factor in defining the way land uses are arranged in the urban grid.

This question is in effect very much open inside the syntactic studies and the solutions so far proposed, such as Hillier's 'catchment area of the catchment area' - yet it depicts clearly all the components of the problem - are far away from proposing objective means of dealing with spatial boundaries neither at the local nor at the global scale. At this stage of the current investigation the combined traverse permeability

---

1 Hillier, B. et al. *Natural movement: or, configuration and attraction in urban pedestrian movement*, Unit for Architectural Studies, Bartlett School, 1989, p. 11.
/choice criterion seems to be an acceptable if not an effective way of approaching the definition of local areas. The more complex problem of defining the boundaries of the larger surroundings which affect the syntactic performance of each local area - the catchment area of the catchment area - is the central point in what follows.

Different from the distribution given by the highest choice value lines - which is rather spread throughout - the integration core of 6A is strongly concentrated at one of its halves; the part of the whole system at east of São João cemetery (Fig. 3.13).1 In this sector the core has a sort of 'feather-like' configuration. A continuous sequence of axial lines, starting at the east end of the system, traverses the sector westwards. This main route - which carries in itself the three most integrated lines of the whole system - gives birth to a series of 'branches' which departing from the central 'spine' penetrate different parts of the system. Nevertheless when the central 'spine' goes into the west part of the whole system - the sector at west of São João cemetery - the picture changes in two ways. First the 'spine' does not extend to the west end of the system as it does at the east side. It rather 'dies' half way performing a sort of 'L-shaped' termination. Second the core loses its 'feather-like' configuration and becomes a short linear core, shallow - for no branches emerge from the from the 'spine' - and largely surrounded by segregated lines.2

Some explanations can be conjectured for such a core configuration. Two factors acting simultaneously might be accounted. The first and probably the most important is the conspicuous decrease in spatial continuity that is brought about by São João cemetery and Floresta sports centre (Fig. 3.13). In effect both these large scale public facilities more than

---

1 In what follows the code SA stands for Sector A.
2 The integration core depicted in Fig. 3.13 includes the 5% most integrated lines (thickest lines) and the 10% (thinner lines) as well. The 5% percentage seems to provide in this case a clearer representation than the 10% integration core. If the percentage is increased to 10% the concentration of core lines inside the east part of the system increases further - 'branches' will turn into 'rings' - while the number of core lines in the west part tends to remain rather stable and, to be more precise, will include just two more axial lines.
provoking spatial discontinuities - which have been accounted here as ruptures in traverse permeability - bring about an explicit obstruction in the street grid in those 'sections' which are in fact hardly crossed eastwestwards by three axial lines - the 'spine' plus the north and south edges.1 Although these 'obstructions' if taken in isolation do not seem to be strong enough to cause the scarce spread of core lines observed for the west part of sector A. Despite the obstructions the 'pattern of branches' emerging from the central spine could be at least partially extended inside the west part of SA.

The reason this is not so - and this seems to act as a complementary factor - is that the concentration of axial lines inside the east part of SA, where short axial lines abound, is much higher than in the west part, the more griddy half of sector A where long axial lines are predominant. The figure for axial density per unit of area for the west part of sector A (the more griddy half) is 25.09 axial lines per sq. Km. In the east part of the system where a more labyrinthine pattern of short axial lines predominates the figure for axial density almost quadruplicates to 102.45. This figure includes the short axial lines given by the housing estates located at the eastern part. If these lines are not computed the density of axial lines per area will decrease yet it still triplicates (73.28) if compared with the figure observed for the west part of the system. However the housing estates are influential in generating what might be called 'axial fragmentation' these figures show that at any rate - with or without the housing estates - the grid configuration given by the east part of SA is conspicuously more fragmented. Since the calculation of integration values, as already explained, is based upon the concept of depth when the west part of SA is measured as a part of the SA whole it becomes a rather segregated system deeply positioned in

---

1 The term 'section' describes here an hypothetical north/south transversal strip more or less at the middle of sector A; a strip that carries in itself both Floresta sports centre and São João cemetery in an almost aligned position.
Fig. 3.14 Sector A: the global core and the local curvatures
The axial maps at the top row describe global integration lines in each conjectured local area. The maps at the bottom row describe the integration core for each local area 'as detached'.

(a) S4C0/G6E5
(b) S4C7/G6E5
(c) S4T7/G6E5
(d) S4A6/G6E5
(e) S4A6/G6E5
(f) S4A2/G6E5
(g) S4A2/G6E5

NORTH
relation to an integration core explicitly centred at the east part of the whole system.¹

The configuration of the integration core described above seems to provide a clear evidence on how the setting up of spatial boundaries affects the measurement of integration. The conjunction of factors described above brings about a further hypothesis to be verified. The conjecture here is that the street grid given by sector A includes at least two 'syntactically autonomous' systems. One at west of São João cemetery, the more 'griddy' pattern, other at east, the 'patchwork-like' configuration. A comparative analysis between the syntactic performance of each of the proposed local areas, firstly measured as detached and later as parts of the whole sector A, seems to have the potential of revealing some clues not only on 'the extent of the autonomy' of each local area but also on the extent to which their syntactic performance can be regarded as supportive of the decomposition of SA as suggested above.

When SA60, the more regular grid at west in the whole system, is analysed separately it presents a distributed and explicitly eastwest oriented integration core (Fig 3.14 B). It includes five long eastwest lines which are crossed more or less at their centre by one north-south line which is only the fourth in the order of integration. The three most integrated lines will intersect at the edge of the system the only line belonging to the global core that reaches SA60 (Fig 3.14 B). Segregated lines are mostly concentrated at the southern part of the system where the orthogonal grid turns into a deformed one.² The comparison between cores locally and globally measured shows that no lines belonging to the local core 'overlap' lines of the global core. The mean integration value

¹ The mathematical explanation for that is straightforward. Since an integration value is a ratio between the mean number of axial steps a line is in relation to all other lines in the system and the total number of axial lines inside this same system, the concentration of axial lines in the east part of SA - for the conspicuous increase in axial fragmentation - will work as an attractor pulling the core towards that direction by increasing the integration value of the lines there located.

² The 30% most segregated lines are represented by dotted lines.
observed for SA60 is 0.42, in effect the most integrated of all local areas when these are examined in separate as autonomous systems (Table 3.02). Nevertheless if SA60 is analysed as a part of sector A its integration value drops to 0.96. It becomes a rather segregated part of the whole system. The 'difference' between the two measurements (RRA and RRAemb) is 0.54, the highest difference all local areas compared (Table 3.02). The 'definition' is 1.93, again the highest definition of all local-areas or, in Peponis' terms, the most distinct of all local areas.

The system immediately above - SA77 - presents what might be called a globally integrated core composed of lines and sequences of lines that link the centre to the periphery of the system (Fig 3.14 D). The most segregated lines are rather evenly distributed at the interstices in between core lines. These characteristics make of it a rather integrated system; its RRA is 0.59 which is only the third highest all local areas compared (Tab 3.02). Again in this case the core of the whole system edges SA77 yet without penetrating inside (Fig 3.14 C). The overlap is zero. The difference is 0.34 so decreasing if compared to the value observed for SA60 (Tab 3.02). As expected the topological proximity - that in this case is also a metric proximity - from the core of the whole system makes SA77 less globally segregated than SA60. At the same

---

1 The code 'RRA' in table 3.01 is another way of referring to mean integration values. It stands for 'real relative asymmetry', i.e. the extent of asymmetry the system of interest carries if compared with a 'diamond-shaped' pattern of the same size. This way of measuring and relativising integration values has been explained in chapter two, as part of the methodology. For a full mathematical description of these procedures see Hillier and Hanson's The Social Logic of Space, Cambridge University Press, 1984, pp. 108-115. In the analysis that follows the code 'RRA' refers to the integration values of each local-area measured in separate while the codes 'RRA/665' or 'RRAemb' refer to the integration value of the system measured as interacting in the whole system.

2 It is said that integration 'drops' because the higher the RRA value the less integrated, in the syntactic sense, is the system. In other words the higher is the asymmetry of the axial map given by an urban area as compared with a theoretical diamond-shaped pattern of the same size the more segregated the system will be in syntactic terms. The decrease in the measurement of RRA coincides with an increase of syntactic integration. This is the reason why in the case under discussion (SA60) it is said that integration 'drops' while the RRA value of the system had increased.

3 As proposed by Peponis, definition is the ratio between the mean RRA value observed for the whole sector A (SA665) and the mean RRA observed for SA60 as measured in separate. The mean RRA for SA665 is 0.81.
### Table 3.02

<table>
<thead>
<tr>
<th>Syst Code</th>
<th>RR/R665</th>
<th>RR</th>
<th>RRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA60</td>
<td>.96</td>
<td>.54</td>
<td></td>
</tr>
<tr>
<td>SA77</td>
<td>.43</td>
<td>.93</td>
<td></td>
</tr>
<tr>
<td>SA16</td>
<td>.86</td>
<td>.66</td>
<td></td>
</tr>
<tr>
<td>SA128</td>
<td>.86</td>
<td>.79</td>
<td></td>
</tr>
<tr>
<td>SA72</td>
<td>.70</td>
<td>.81</td>
<td></td>
</tr>
<tr>
<td>SA71</td>
<td>.68</td>
<td>.88</td>
<td></td>
</tr>
<tr>
<td>SA184</td>
<td>.81</td>
<td>.81</td>
<td></td>
</tr>
<tr>
<td>SA106</td>
<td>.81</td>
<td>.81</td>
<td></td>
</tr>
</tbody>
</table>

#### Fig. 3.15 Sector A: Line charts for differences, definitions and overlaps

1. **Line Chart for column: X1 Difference**
   - Chart showing differences for SA60, SA77, SA16, SA128, SA71, SA106.
   - Observations:
     - SA60
     - SA16
     - SA128
     - SA71
     - SA106

2. **Line Chart for column: X1 Definition**
   - Chart showing definitions for SA60, SA16, SA128, SA71, SA106.
   - Observations:
     - SA60
     - SA16
     - SA128
     - SA71
     - SA106

3. **Line Chart for column: X1 Overlap**
   - Chart showing overlaps for SA128, SA72, SA184.
   - Observations:
     - SA60
     - SA77
     - SA16
     - SA128
     - SA71
     - SA106
time 'definition' decreases to 1.37, which is still a high value if compared with the 'definition' values for the four systems at east - SA72, SA71, SA184 and SA106 (Tab 3.02). The lack of overlap between local cores and global core lines coupled with high definitions and moreover with high differences between mean integration values when locally and globally measured seem to provide at least a provisional evidence on the syntactic autonomy of these two systems (SA60 and SA77) in relation to the bulk of sector A. Similar measurements for the subsequent local areas may provide some clarification in this respect.

The following system eastwards is SA16, the small orthogonal grid at the centre of the whole system. Its integration core, locally measured, is composed of three parallel eastwest lines (Fig 3.14 F). The global core, unlike the previous cases, penetrates right in the middle of the system (Fig 3.14 E). Nevertheless the pattern of 'no overlap' is maintained. No lines of the local core are also global core lines.1 Difference has now decreased to 0.25. The high integration value observed for SA16 - which is second most integrated among all proposed SA local areas - brings about a high definition for this part of the grid. Definition increases sharply to 1.88 almost matching the value observed for SA60 (Tab 3.02).

This set of graphic and numerical information allows for some conjectures with respect of the larger surroundings to be regarded as affecting the syntactic performance of SA16 at the global scale. On the one hand the spatial ruptures brought about by Floresta Sports Centre and São João Cemetery at its west and south sides seem to keep SA16 syntactically apart from the west part of the whole system.2

1 The local cores represented in Fig. 3.14 include the 10% most integrating lines instead of the 5% utilized in the description of the whole system. By expanding to 10% the integration range taken for describing the local cores, it is possible to increase the number of detected overlaps and at the same time preserve the clear description provided by the 5% most integrated lines at the global level.

2 An experiment carried out by grouping SA60, SA77 and SA16 interacting as a whole system has shown that under these circumstances SA16 becomes the set of most segregated lines in the system. This experiment has been described in Aguiar, D.V. Space, Land Use and Design, working paper n° 3, UAS, Bartlett School, Jan 1989.
other hand the figures for definition and difference coupled with the lack of overlap seem to indicate that this system cannot be regarded just as a part of the east half as well. **Tab 3.02** shows that difference decreases but still is much higher than the figures observed for the four systems at east - SA71, SA72, SA184 and SA106. Definition is also remarkably high, actually the second highest of all local areas. A third ingredient is that despite the lack of overlap the global core penetrates right into the middle of the system showing that this part of the grid is more affected by global syntactic effects than SA60 and SA77, the two areas at west already described. The combined result of these syntactic descriptions seem to indicate that if SA16 is to be analysed in terms of the larger area that affect its syntactic performance it must be regarded as a rather autonomous system which interacts 'moderately' with both the east and the west parts of sector A. If this conjecture is accepted, a reasonable alternative for a proper syntactic description of SA16 at the global level seems to be its 'embedding' in the whole SA665 so allowing for the measurement of syntactic effects coming from both its sides.

The area beside - at south of SA16 - is SA128, a more labyrinthine configuration right at the centre of the whole system. Here the pattern of overlap changes dramatically. While for the previous systems no overlap at all was observed for this system the two most integrated lines locally (**Fig 3.14 H**) are also part of the global integration core or, more precisely, they are axial segments of the central 'spine' which traverse sector A eastwestwards. These lines are third and fifth in the order of global integration (**Fig 3.14 G**). From the thirteen lines of the local core eight are also part of the global core that permeates the system, corresponding to a 0.61 overlap (**Tab 3.02**). The difference, compared with the previous cases, decreases sharply to 0.10 (RRA=0.64, RRAemb=0.74). Nevertheless the definition value remains high (1.27) if compared with the definitions observed for the four systems more at east of the whole system.\(^1\)

---

\(^1\) The four systems referred to here are SA71, SA72, SA106 and SA184. Their definition values are given in **Table 3.02**.
Apparently in this case there is a contradiction between what is suggested by the measurements of overlap and definition. Can a system be strongly 'defined' — what in Peponis' view is an evidence of syntactic autonomy — and at the same time present a high degree of overlap between its local integration core and the global core of the larger area it is a part. This is precisely the output given by the current case. SA128 is both the system of highest overlap amongst all SA systems yet simultaneously it presents a relatively high definition value. Nevertheless there are other features which seem to perform in favour of the syntactic 'autonomy' of SA128 despite the strong overlap observed. These factors are both the strong ruptures in traverse permeability in all its boundaries and the well defined contour of choice lines observed all around the system (Fig 3.09 and 3.10). Let alone the conspicuous change in the configuration of the street grid since SA128 is an explicit labyrinthine pattern entirely surrounded by more 'griddy' systems.

If one is to rely upon these evidences — ruptures in traverse permeability, contour of high value choice lines and visually observable changes in grid configuration — in order to support the hypothesis of local area formation it might than be assumed that the strong overlap observed in the specific case of SA128 is an evidence of how distinctive this system is if compared with any of the proposed local areas where the degree of overlap is consistently lower. If this is accepted the strong overlap taken in isolation cannot be regarded, as Peponis suggests, as an indication of no local area formation. SA128 seems to be distinct from the other local areas precisely for its high overlap which as it has been shown is the single highest overlap amongst all SA systems. If this hypothesis is accepted no contradiction lasts between the definition of SA128 and its overlap characteristics. A comparison of these results with the performance of the remaining four systems can shed some light on the interrelationships between these measurements — overlap,
definition and difference - and as a consequence a further clarification of the conjectured autonomy of SA128.

The remaining four systems - SA71, SA72, SA106 and SA184 - are more or less symmetrically arranged around the central 'spine' that crosses the east part of the whole system (Fig 3.09). Despite the shape distinctions which are outstanding if the configurations of the local cores of these systems are compared some significant characteristics - shared by the four systems - emerge from the matching of these local cores with the distribution of global core lines (Fig 3.14). For the four cases there seems to be a rather 'balanced' overlapping between the two core modes. The term 'balanced' needs explanation. The pattern of overlap for SA71, SA72, SA106 and SA184 is rather different from 'limiting' cases such as SA60, SA77 and SA16 where no overlapping exist and SA128 where on the other hand the overlap is remarkable. The axial maps show that for for SA71, SA72, SA106 and SA184 the global core penetrates deep inside each one of these systems and moreover that a consistent overlap occur with at least one of the lines of the local core (Tab 3.02). The local cores are all deeply located inside each system yet in all cases extending and reaching the 'central spine' of globally integrated lines. It is in this precise sense that the relationship between local cores and global core lines inside these eastern systems is said to be a rather 'balanced' one.

The balanced overlap described above provides some clarification if compared with what was observed in SA128. In that case local and global cores are strongly overlapped while the interior of the system is, except for one line, a virtually continuous lump of segregation (Fig 3.14 G and H). By contrast in the four systems more at east - SA71, SA72, SA106 and SA184 - local cores and global core lines are to a certain extent autonomous yet some overlap occurs between them. The differences are

---

1 The integrating line that penetrates the system is hardly the sixth in the rank of local integration (Fig 3.14 H).
for the four cases rather small ones.\(^1\) Definition values also decrease if compared with the other four systems previously described (Table 3.02). Such a combination of low differences, low definitions and 'balanced' overlaps sets up a sort of standard which is shared by the four systems located at the east part of SA. Each part has strong local characteristics yet at the same time each part is globally integrated. These features, as shared by these four eastern systems, seem to set up in a rather clear fashion the extent of their differentiation in relation to the four systems at west previously described. If this conjecture is accepted these four systems might be regarded as constituting a whole system in themselves detached from the rest of sector A.

Fig. 3.15 gives the line charts representing differences, definitions and overlaps for all SA systems. The differences for the five systems at east of São João cemetery - SA128, SA72, SA71, SA106 and SA184 - are rather concentrated inside a small range, that is to say the variations between the 'differences' of RRAs locally and globally measured oscillate between -0.1 and 0.15 (linechart 1). For the remaining systems insofar as the 'topological distance' from the east part of the whole system increases the 'difference' increases dramatically. For 'definition' the picture changes just slightly. The four systems at east of the whole system (SA72, SA71, SA106 and SA184) are the least 'defined' (linechart 2). From SA128 towards the west end of the whole system definition will increase in general yet this increase is not linear as it would be expected if difference and definition were to perform in parallel which is not the case. At any rate the pattern of definitions shows that the four local areas more at west in the whole system (SA60, SA77, SA16 and SA128) are more defined than the four areas at east. The pattern of overlaps performs in opposition to the patterns of differences and definitions (linechart 3). That is to say in the most defined and high difference systems the local core is not overlapped by global core lines. The 'peak' given by the strong overlap observed for

---

\(^1\) SA72 is even more integrated locally than when analysed as a part of the whole system (Table 3.02).
SA128 in an exception in the conjectured model. In effect this 'peak' divides the line chart in two rather evenly distributed groups, one at west where no overlap at all occurs and another at east where the 'balanced' overlap already described sets up the standard.

As a whole the results observed above seem to challenge the validity - or accuracy - of integration values taken for sector A as a whole as the system of reference for the measurement. The combined patterns of difference, definition and overlap suggest three distinct performances amongst the SA systems. SA60 and SA77 might be regarded as two local areas virtually detached from the rest of sector A. If this is the case these two sub-areas - as supporting the hypothesis previously raised - instead of being a part of the whole sector A might be regarded as constituting a whole system in themselves, i.e. SA60 and SA77 as an autonomous whole to which just them both syntactically refer. This assumption is not only based upon their high differences and lack of overlap, but also in the rather timid way the global integration core penetrates the west part of the sector A as a whole (Fig 3.13).

A second situation is given by SA16 and SA128 which are, for their position more or less at the centre of the whole system, local areas whose global description seems to require an 'embedding' inside the whole sector A in order to capture syntactic effects coming from both their east and west sides. The particular case of SA16, if the 'no overlap' criterion is accepted, should be regarded as part of a whole system to be composed by SA60 and SA77. Nevertheless the symmetrical relationship of this system with the global core (Fig 3.14 E) coupled with the obstruction of the street grid at its west side - provoked by Floresta Sports Centre - seem to recommend its embedding in the whole sector A when its global integration analysis is required. Similar proposition seems to suit SA128 although in this case the strong overlap between local and global cores provides a clearer syntactic evidence for an 'embedding' of this system in SA665 (the whole sector A) for the purposes of global analysis. The third situation is given by the four
systems at east (SA72, SA71, SA106 and SA184) where the shared 'balanced' overlap coupled with low differences and low definitions seem to recommend their grouping as a detached system at east on their own.

The description given by the pattern of integration measured for lines up to three axial steps away from each line (radius three integration) has confirmed to a large extent the decomposition strategy proposed above. The first feature that emerges from the description given by radius three integration is that three distinct cores emerge at three distinct parts of the whole sector A (Fig 3.15 A). One at the eastern part of the system (inside SA60), other at the and western part (inside SA184) and another inside SA128. These three cores are tied together by just one core line. This applies for core lines located in the west part of sector A, which are linked to the smaller core inside SA128 by just one core line; a line that performs as part of the south boundary of sector A. This also applies to the core lines located in the east part of sector A which are linked to the smaller core inside SA128 by just one core line as well; in this case a line that traverses the interior of SA128 to become the central spine of sector A east.

That is to say, three distinct concentrations of core lines take place; two close to the edges of the system, one at the centre. The centrifugal character of east and west cores coupled with a third concentration of core lines right at the middle of the system (inside SA128) provides a further evidence in support of the decomposition strategy proposed for sector A, on the basis of the patterns of overlap, definition and difference. It is also noteworthy that from the standpoint of radius three integration SA16 - the small orthogonal grid at the centre of the system - will also perform as a rather detached system, both in relation to the east and west parts of the core and also in relation to the portion of the core that concentrates inside SA128. In other words, from the standpoint of radius three integration SA128 and SA16 seem to perform again as autonomous systems in the middle of east and west.
Besides providing another description for the syntactic autonomy of different parts of sector A, the pattern described by radius three core lines have to a large extent highlighted either the contour or both contour and interior of the conjectured local areas. This is the case of SA60 where a significant part of the contour and interior of the system is described by radius three core lines. In fact the core lines that describe the interior are more concentrated in one part of the system.1 By contrast the local area beside - SA77 - is scarcely reached by radius three core lines in its interior, yet most of its contour is clearly indicated. Here again the pattern described by radius three integration provides an indication towards the further decomposition of this system. Two core lines cross the interior of SA77 in the eastwest direction. This lines might be seen either as dividing SA77 in two smaller systems or as the lines that tie up the system.

For the east part of sector A the concentration of radius three lines is polarized between SA128 and SA184. The central route that traverse sector A eastwards seem to tie the parts together but, on the other hand, the concentration of core lines inside SA128 seem to reinforce the syntactic autonomy of that part of the grid. The same might be said in respect of SA16; a part of the grid that is left out both of the contour described by the radius three core at east and at the same time is not reached by core lines belonging to the west part of sector A, apart from one long line in its periphery. Again, this time from the stand point of radius three, SA128 and SA16 seem to perform as rather autonomous portions of the grid.

By contrast the four systems more at east - SA71, SA72, SA106 and SA184 - seem to be tied together by the 'central spine' that traverse that east part of sector A. Here again either the contour or contour and interior of the four local areas is described by radius three core lines. This applies for SA184, the part of sector A east where most core lines

1 This concentration of radius three core lines in one part of SA60 will be taken, in a subsequent step of this analysis, as an evidence in support of a further decomposition of SA60.
are concentrated and to the other systems - SA71, SA72 and SA106 - whose interior is hardly reached by radius three lines but whose contour is clearly indicated both by lines of the central spine or by lines that emerge from the central spine.

As a whole the pattern described by radius three core lines provide a description that is much in tune both with the boundaries set up according to traverse permeability and choice measurements, which are to a large extent confirmed by radius three measurements, and moreover in tune with the decomposition strategy emerged out of the analysis of patterns of overlap, definitions and differences. **Fig 3.16** represents the decomposition emerged out of the range of analysis carried out above. The diagram indicates the tendency of east and west parts of sector A of performing as autonomous wholes, each one carrying out its own sub-area division. SA16 and SA128 tend to perform as more autonomous systems between east and west wholes. Since further decompositions will be applied both to east and west wholes the diagram presented in **Fig 3.16** might be regarded as a first order decomposition of sector A.

Unlike sector A where the integration core is linearly arranged sector B carries a 'star-shaped' core where four sequences of axial lines emerge from a common centre towards the periphery of the system (**Fig 3.17**). In this case the large scale public facilities located right at the middle of the system obstruct the street grid, yet to a lesser extent than the obstructions noticed at the middle of sector A. At least six spatial continuities are allowed between the areas at west of the public facilities referred to above - SB62 and SB30 - and the areas at east - SB54, SB127 and SB83. Nevertheless despite these continuities the global integration core is here again strongly concentrated in the east part of the whole system. The core in effect just edges the west part of sector B yet without penetrating it, except for one short axial line at the southeast part of SB62. Despite their conspicuous shape distinction the integration cores given by the two areas of study - sector A and sector B
Fig. 3.17 Sector B: Integration Core

- 5%
- 10%
- are both of them strongly concentrated in one part of the system. Here again, same as in sector A, obstructions in spatial continuity coupled with the increase of axial density in one specific part of the system are influential factors in the distribution of the core.\(^1\) Another characteristic that is shared by sectors A and B is their virtually identical mean integration values (0.81 and 0.82 respectively). These figures show that despite the conspicuous variety of grid configurations inside the two systems there is a kind of balance in their composition. That is to say both systems carry an equivalent proportion of more integrated and more segregated patterns inside themselves.\(^2\) This characteristic might also be taken as supportive of the comparability criterion as proposed at the outset since both sector A and sector B seem to depict in a consistent way the 'typical' diversity of grid configurations available in Porto Alegre.

**Fig 3.18** match the integration core of each conjectured local area inside sector B with global core lines. SB62, the 'pinwheel grid' at the western part of the whole system has a globally integrated core composed of long axial lines which cross the system throughout in both directions (**Fig 3.18 B**). This core configuration however similar to SA60 - the orthogonal grid at west in SA - seems to be more evenly spread. While in SB62 the segregated lines are distributed at the interstices between core lines, in SA60 the segregated lines are mostly grouped at one edge of the system and away from the core lines.\(^3\) No overlap exists between the local core and global core lines which in fact just that edge the east part of SB62 (**Fig 3.18 A**). The mean RRA of SB62 measured as detached is 0.53, while if the system is measured as a part of SB351 (the whole sector B) the figure increases to 0.82 (**Tab 3.03**). So in terms of overlap and difference these results are rather similar to ones observed for the systems more at west in SA - SA60,

\(^1\) Short axial lines given by housing estates and by one self-produced development located close to the east boundary of the system contribute strongly for the increase in axial density.

\(^2\) The 'equivalent proportion' referred to here has a topological sense, it does not mean a proportionality in areal terms.

\(^3\) The local core of SA60 is presented in **Fig 3.14 B**.
SA77 and SA16 – where the lack of overlap is also coupled with a high difference. Definition is 1.55, a figure that compared with the standard set up by the SA systems is rather high. So from the definition standpoint SB62 also performs similarly to by the SA western areas.

SB30 – the small deformed grid at south – repeats to a large extent the features observed for SB62. No overlap is detected (Fig 3.18 C and D). Definition and difference are high. Not so high as for SB62 although significant if compared with the values observed for the remaining SB systems (Tab 3.03). The empirical evidence that has supported the decomposition of sector A is virtually reproduced here. The syntactic performance of SB62 and SB30 in relation to the whole sector B is remarkably similar to what was observed for the systems more at west in sector A – SA60 and SA77. If we are to be consistent with the decomposition criteria applied in that case a similar strategy is recommended here.

The area immediately above is SB54, the most orthogonal amongst all SB systems. Its local core is globally integrated spreading through most parts of the system (Fig 3.18 F). At the same time global core lines surround and permeate the area with no less than fifteen lines (Fig 3.18 E). Three lines of the global core are also part of the local core so giving a 0.50 overlap.1 Despite the high overlap SB54 is strongly defined. The figure for definition goes higher to 1.58 which is the highest all SB systems compared (Tab 3.03). In other words despite the high overlap SB54 is strongly defined as a local area so reproducing to a large extent what was observed for SA128. A strong overlap – which suggests that SB54 is more a part of a larger area than an autonomous part of the grid in itself – is coupled with a strong definition which, on the other hand, suggests syntactic autonomy. Yet the figure for difference (0.14) confirms the conjectured autonomy of SB54 – based upon its definition.

1 Compare maps E and F in Fig 3.18.
Table 3.03 Sector B: Measurements for differences, definitions and overlaps.

<table>
<thead>
<tr>
<th>Syst Code</th>
<th>Syst 351</th>
<th>Difference</th>
<th>Definition</th>
<th>Overlap</th>
</tr>
</thead>
<tbody>
<tr>
<td>S862</td>
<td>.53</td>
<td>.82</td>
<td>0</td>
<td>1.55</td>
</tr>
<tr>
<td>S830</td>
<td>-.29</td>
<td>.61</td>
<td>.15</td>
<td>1.34</td>
</tr>
<tr>
<td>S869</td>
<td>-.15</td>
<td>.64</td>
<td>.06</td>
<td>1.28</td>
</tr>
<tr>
<td>S854</td>
<td>.06</td>
<td>.52</td>
<td>.14</td>
<td>1.58</td>
</tr>
<tr>
<td>S8127</td>
<td>.88</td>
<td>.86</td>
<td>.02</td>
<td>.95</td>
</tr>
<tr>
<td>S883</td>
<td>.82</td>
<td>.86</td>
<td>.04</td>
<td>.95</td>
</tr>
</tbody>
</table>

Fig. 3.19 Sector B: Line charts for differences, definitions and overlaps.
it also suggests that the degree of autonomy is in this case lower than for SB62 and SB30.¹

The system immediately beside is SB127, a deformed grid permeated by lumps of short axial lines. Some of these are given by housing estates located at the south part of the system. Others are given by a self-produced settlement in its north. These developments carry the most segregated lines of the system both at the local and at the global level (Fig 3.18 G and H). SB127, measured as detached, has a clearly defined cross-shaped integration core (Fig 3.18 H). When SB127 is measured as a part of the whole SB its south part will be surrounded by six lines given by the global core (Fig 3.18 G). From this edging core three lines emerge penetrating the interior of the system precisely at the south part that is not reached by the local core. These three global core lines perform a ring which surrounds the part of the system that contains lumps of short axial lines given by housing estates. It is noteworthy that this is performed exactly in the same fashion as this same perimeter has been surrounded by lines of the choice core (Fig 3.12). The syntactic characteristics described above seem to reenforce the already conjectured further decomposition of SB127. Two lines of the local core overlap global core lines yet, unlike in SB54, the overlap happens over the boundaries of the system and not inside the system itself (Figs 3.18 G and H). In this case the measurement of overlap might be regarded as providing an ambiguous result in terms of an assessment of the syntactic autonomy of the system. Is a 'peripheral overlap' to be accounted as so significant as an 'internal overlap'? For the current case the answer seems to be positive since the figures for definition (0.95) and difference (.02) are rather low and suggest that SB127 might be seen more as a part of a larger whole than an autonomous system in itself.

A rather similar performance, as compared with the description given for SB127, is followed by the system more at south of sector B - SB83.

¹ Compare differences in Tab 3.03.
Here again the local core is overlapped by global core lines at the edge of the system (Fig 3.18 I and J). Both systems have identical RRAs (0.86) and their differences are just slightly distinct in view of the marginal increase observed for RRA globally measured in SB83 (Tab 3.03). Their definitions are also virtually the same; 0.96 and 0.95 respectively. These figures, following what was observed for SB127, suggest that SB83 might be regarded more as a part of the SB whole than a syntactically autonomous system in itself.

Fig 3.18 (K and L) show SB69. This is an experiment which is performed by isolating the axial lines around the star-shaped global integration core of SB351 (the whole sector B) as a detached system. The perimeter of this system is not arbitrarily defined. It is mostly given by high value choice lines. Some of them such as the long axial line at its west limit are not part of the 5% core yet all of them are at least a part of the 10% choice core. The traverse permeability criterion is not met for this case. The objective of analysing the syntactic properties of this specific fragment separately is that it contains in itself, as radiating from the centre, the four most integrating lines of the whole SB351. Besides this system is made up of portions of the grid taken from the west and from the east of sector B, so including part of SB54, part of SB62 and the central area where Sao Miguel Cemetery and the football stadium are located, an area whose local description is not covered by the SB systems so far described.

Such a configuration itself suggests that for the purpose of global analysis this system shall be regarded as embedded in the whole SB351 so capturing syntactic effects coming from both its east and west sides. In supporting this conjecture the system keeps both locally and globally the star-shaped integration core with a 0.67 overlap. The difference is just marginal and apparently confirms the condition of SB69 as part of the whole, as already given by the strong overlap. Nevertheless the figure for difference is also ambiguous. On the one hand it is higher than two of the local areas at east (SB127 and SB83), on the other hand it is much
lower than the difference observed for SB54. In other words, from the standpoint of difference SB69 is less syntactically autonomous than SB54 yet more autonomous than SB127 and SB83. The figure for definition is high so assigning a certain degree of autonomy for this system and as such recommending its analysis in separate.

As a whole the syntactic characteristics described above for sector B reproduce to a large extent the syntactic description previously given by sector A. This description has eventually led to the proposition of the decomposition of that system. In sector B the patterns of difference and definition make it clear that three of the conjectured local areas are strongly autonomous - SB62, SB30 and SB54. Although while for two of them - SB62 and SB30 - difference and definition values are supported by an explicit lack of global core lines inside those systems, for the third - SB54 - the overlap contradicts what difference suggest. SB54 presents a 0.50 overlap between local and global cores. By contrast, in the case of SB62 and SB30 the syntactic autonomy of that part of the grid seems to be clear. The lack of global core lines and high differences are further supported by strong definitions. These results strongly indicate that these two systems might be analysed in separate as a whole system at west on its own.

The two remaining systems - SB127 and SB83 - present low differences and definitions coupled with 'balanced' overlaps (Tab 3.03). These figures suggest that both SB127 and SB83 should be regarded more as a part of the SB whole than as autonomous systems in themselves. Eventually only in the case of SB54 the output given by the set of measurements proposed here is contradictory. Nevertheless despite the strong overlap observed for SB54 its adjacency in relation to the global integration core - together with SB127 and SB83 - suggests that these three conjectured local areas might also be measured as a whole system detached from the west part of sector B.
Fig. 3.19 describes the pattern of overlap observed for the SB systems as a whole ([linechart 3]). The similarity with what was observed for sector A is clear. As for the previous case the whole system performs as two groups, one at east another at west. Nevertheless in sector B the performance of these two groups is not so contrasting as for the previous case (sector A) especially from the point of view of the observed differences which are generally lower for the current case.¹ That is to say the difference between RRA values measured for each area 'as detached' and 'as embedded' is much lower in sector B than the differences observed in sector A. In other words if the evidence given by difference values is accepted, the extent of the autonomy observed for any of the conjectured SB local areas seems to be lower than for the previous case.

This might be taken as a consequence of the higher number of spatial continuities between the two conjectured whole systems, one at east other at west in SB. This is distinct from what was noticed in sector A where just three spatial continuities are allowed between the systems at east and west. As a consequence, in order to satisfy both these evidences the conjectured SB local areas should be analysed both as a part of SB351 (the whole sector B) and also as a part of two distinct systems one at west - composed by SB62 and SB30 - and another at east - composed of SB54, SB127 and SB83. SB69, since it is half way between the two groups and also for its high definition, shall be analysed both as an autonomous system and also as a part of the whole sector B.

The description given by the pattern of integration measured for lines up to three axial steps away from each line (radius three integration) in sector B seems to be to a large extent supportive of the decomposition strategy proposed above. The first feature that emerges from the description given by the radius three integration core is that core lines are concentrated in two distinct parts of the system - inside SB62 and SB54 (Fig 3.19 A). Following what has been observed for sector A,

¹ Compare tables 3.02 and 3.03.
Fig. 3.19 A Sector B: Radius three integration core
eastern an western cores of sector B are tied up by just one core line which emerges from the star shaped centre of the system and penetrates inside SB54.

Nevertheless, by contrast with what was observed for sector A, the interior of the east part of sector B is reached by four core lines emerged from the west part of the system. This description seems to indicate that despite the conspicuous concentration of the radius three core in the two specific parts of the grid – SB62 and SB54 – east and west parts of sector B are more attached to the each other, in the syntactic sense, than in the case of sector A where east and west parts seem to perform as quite autonomous systems.

On the other hand, despite the strong radius three core lines located right at the middle of the system as pushing for the spatial interaction between east and west parts, these same core lines hardly reach other parts of sector B. It is noteworthy that this lack of core lines in specific parts of the system comes eventually to reinforce the proposed sub-area division. This applies for the western part of the system where the radius three core is all concentrated within SB62 and no core lines penetrate the interior of SB30. The same applies to the eastern part of sector B where most radius three lines are concentrated within SB54 yet two isolated core lines emerge at the middle of SB127 as to indicate the autonomous character of that portion of the grid. The boundary between SB63 and SB127 is also marginally indicated, together with a line that penetrate the interior of the latter.\footnote{This line will be taken further in this analysis, as an indication for a subsequent decomposition of SB127.} The same might be said about SB83 whose interior is hardly reached by radius three core lines, but whose countour is to a large extent described. Finally it is noteworthy that the pattern described by radius three core lines have emphasized both the interior and a significant part of the contour of SB69, the system that embodies the star-shaped centre of the whole sector B, whose analysis
Fig. 3.20 First order decomposition of sector B
as a separated system has already been suggested both by the pattern of overlap and by the strong definition of the part of the grid as well.

In other words, while the radius three analysis of sector A has suggested a conspicuous detachment of east and west parts, in the case of sector B radius three has delivered an ambiguous result which on the one hand points out to the partition of the system in its east and west portions and, on the other hand, seems to make explicit the interdependence of these same east and west parts. This result confirms what has already been observed in previous analysis of sector B, that is to say while the stable pattern of low differences (especially if compared with the high differences observed in sector A) stresses the entirety - or the global syntactic performance - of the whole sector B, the patterns of overlap and definition have pointed towards the partition of the system in its east and west parts. This further decomposition of sector B is depicted in Fig. 3.20 where SB54, SB127 and SB83 compose an eastern system, SB62 and SB30 compose a western system and SB69 takes part of both and as such embodies the geometric centre of the whole area, a portion of the grid whose syntactic interaction takes place both with the eastern and the western parts of the whole system.

As a whole the comparative analysis proceeded above for local and global cores - in terms of overlaps, definitions and differences - coupled with the analysis of the radius three integration has provided a fair account on how each one of the conjectured local areas might be grouped for the purposes of a global syntactic description. The proposed decomposition criteria have performed rather effectively in identifying the larger areas that actually affect the syntactic performance of each local area when its integration is globally measured. The analysis of sectors A and B after the first order decomposition proposed above is what follows in the subsequent step of this investigation.
Fig. 3.20a Four systems of interaction.
Further Decompositions

The following sections develop further the syntactic analysis of sectors A and B now decomposed in four systems of interaction as represented in Fig 3.20 A. System of interaction is regarded here as a system larger than the conjectured local areas within which these same local areas interact. In other words a system of interaction gives the description of the larger area which has been conjectured as affecting the syntactic performance of each local area. In what follows systems of interaction may also be termed as system of embedding.

The whole sector A, following what the analysis so far developed has recommended, has been divided in two systems of interaction. One is SA west, the more griddy half of sector A, the other is SA east, the more labyrinthine half of the same sector. In a similar way sector B has been divided in two other systems of interaction; SB west and SB east. In what follows each of the proposed local areas will be analysed as a part of these systems of interaction. For instance SA60 and SA77 – two local areas that have been initially analysed as a part of the whole sector A – will be now syntactically assessed as a part of SA west (SA143), that is the west portion of the grid produced out of the decomposition of the whole sector A or, from another standpoint, is the system emerged from their interaction (SA60 and SA77) with the each other. The same applies to SA71, SA72, SA106 and SA184, the four local areas at the east part of sector A, that will be assessed as a part of SA east (SA418) that is the system emerged out of the interaction of the four systems referred to above as well. The same also applies for the local areas in which sector B has been divided. Inside the four proposed systems of interaction all conjectured local areas interact.1

Besides, a series of further decompositions of the local areas initially defined will be tested out, in order to verify the extent of the syntactic

---

1 Except for SA16, SA128 and SB69 whose systems of interaction will be the wholes sectors A and B respectively.
autonomy of specific portions of the grid that have performed distinctively in the analysis so far proceeded. This applies to the more griddy part of sector A where both SA60 and SA77 will be measured as decomposed in view of the performance of this part of the grid under radius three analysis and also for institutional reasons, to be further discussed. This also applies to SB127, whose partition has been suggested both by the performance of the highest choice value lines and by the results obtained from the radius three analysis. This also applies to SB54, whose axial description will be reduced to its more orthogonal part. These tests are explained in detail in the following sections.

The analytical procedure that follows starts by reassessing the pattern of syntactic integration for the four proposed systems of interaction, now syntactically measured as detached from the initially given sectors A and B. Overlaps, definitions and differences will be remeasured for each local area, but now as embedded in the proposed systems of interaction produced out of the first order decomposition. This procedure aims to verify whether the distortions observed when sectors A and B are measured as a whole have been removed after their decomposition in the current systems of interaction. The most conspicuous of these 'distortions' are the high definitions, high differences and lack of overlap observed for the systems at west in sector A; distortions that eventually have been taken as a strong factor in support of the decomposition of that whole, if an accurate syntactic measurement is to be achieved.

In the subsequent step, the analysis describes the four systems of interaction in terms of three other syntactic measurements: choice, connectivity and axial length. These measurements, coupled with the analysis of the pattern of integration, constitute the set of syntactic descriptions to be dealt with, as a spatio-morphological benchmark, in the subsequent chapters of this thesis. As it has already been explained connectivity and axial length are, syntactically speaking, local parameters and as such would apparently have little relevance in the
Fig. 3.21 SA west: Integration core (5% and 10%)
Below integration core for the whole sector A.
discussions so far which have been concerned with decisions to be taken at the global scale of the street grid as depicted by measurements of choice and integration. Although, as the analysis intends to show, these local characteristics (connectivity and axial length) are strongly related and influential in the performance of choice and integration, the two global parameters. The analytical procedure describes the performance of each one of these measures inside the four proposed systems of interaction and, in a subsequent step, identifies how these measures relate to the each other by comparing statistically their performance within the same system(s).

In short, the remaining sections of this chapter complete the analysis of the areas of study selected for this investigation. They carry out with the syntactic analysis of the four proposed systems of interaction given by the first order decomposition of sectors A and B. The analysis starts by reexamining patterns of definition, difference and overlap for each local area, yet now as embedded in the four proposed systems of interaction. This procedure aims to exhaust the description of all possible spatial boundaries (as far as this analysis has detected) within the areas of study under investigation. This is paralleled by the analysis of the four systems of interaction from the standpoint of three other measurements - choice, connectivity and axial length - whose performance in relation to the each other will be assessed. This set of procedures will complete the syntactic analysis of the areas of study selected for this investigation.

**SA west: the griddy half of sector A**

*Fig 3.21* shows the integration core of SA west (SA143). The 5% most integrating lines expand from the south to the centre of the system performing a continuous ring that includes the seven most integrating lines. The order of integration indicates that the core is oriented towards the south of the system, rather detached from the integration
Table 3.04 SA west: differences, definitions and overlaps.

<table>
<thead>
<tr>
<th>Syst Code</th>
<th>RRA</th>
<th>RRA/143</th>
<th>Difference</th>
<th>Definition</th>
<th>Overlap</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA60</td>
<td>.42</td>
<td>.48</td>
<td>.06</td>
<td>1.26</td>
<td>.50</td>
</tr>
<tr>
<td>SA34</td>
<td>.45</td>
<td>.49</td>
<td>.04</td>
<td>1.17</td>
<td>.34</td>
</tr>
<tr>
<td>SA30</td>
<td>.33</td>
<td>.45</td>
<td>.12</td>
<td>1.60</td>
<td>.67</td>
</tr>
</tbody>
</table>

Fig. 3.22 SA west: The global core and the local cores
The axial maps at the top row describe global integration lines in each conjectured local area. The maps at the bottom row describe the integration core for each local area as detached.
core of sector A measured as a whole (below in the same figure). In effect it will be only by the sixth line in the current order of integration that a line belonging to the former integration core (for the whole sector A) will coincide with a line belonging the current core (SA west). The eighth most integrating line in SA west will be the first to include the 'central spine' which, measured as a part of SA west will become a segregated line two axial steps further.¹

This core configuration seems to confirm the extent to which SA west is syntactically detached from the initially given sector A. The mean RRA value observed for SA west decreases sharply (to 0.53) if compared with the mean RRA observed for the whole sector A (0.81) showing that when SA west is measured on its own it is a relatively integrated system instead of a large lump of segregation as it is depicted when measured as a part of the whole sector A. The most segregated lines are shallow in the system, distributed at the interstices in between core lines and as such mostly at one or two axial steps away from core lines so constituting what might be called a globally integrated grid all tied up by a globally integrated core.

The relationship between the integration cores of the proposed local areas and global core lines changes radically under the current configuration (SA143). For SA60 - the more orthogonal part of SA west - three amongst the six lines of the integration core are also globally integrated lines so providing a 50% overlap (Fig. 3.22 A and B). If SA60 is further decomposed the picture changes. The decomposition of SA60 aims to check whether there are significant effects coming from the position of a wide avenue - that crosses north-south this part of the grid more or less at its middle - on the pattern of land use distribution.² As it has been said the masterplan regards the areas adjacent to both sides of the mentioned avenue as different zones. The 'wide avenue' referred to above carries a closed and continuous bus corridor at its

¹ The dotted lines represent the 30% most segregated lines.
² The position of this route is indicated in the axial map presented in Fig. 3.22 A.
**Fig. 3.23** SA west: the global core and the local cores

The axial maps at the top row describe global integration lines in each conjectured local area. The maps at the bottom row describe the integration core for each local area 'as detached'.
centre. Spatial continuity in that route is in effect broken if one thinks in terms of how far one can see and how far one can go - the syntactic concept of axiality. In this particular case the spatial rupture is not described by ruptures in traverse permeability. Besides this same avenue is part of the 5% choice core of sector A measured as a whole (Fig 3.10).

Both SA34 and SA30, the two parts produced out of the decomposition of SA60, still have their local cores overlapped by lines of the global core (Fig. 3.22). The overlap will be higher (0.67) for SA30 and decreases (0.34) for SA34 that is the part of SA60 deeper positioned in relation to the global core lines (Tab 3.04). The distinct overlaps seem to support the hypothesis of sub-area formation. The same might be said in respect of the mean RRA values. The mean RRA for SA30 is 0.33 while for SA34 it increases to 0.45.1

This is the opposite of what happens in SA77, the 'deformed grid' adjacent to SA60 (Fig 3.23 A and B). For this system the overlap decreases to 0.28 and will be kept rather stable for the two systems after decomposition - SA59 and SA21.2 The overlap is 0.34 for both cases (Tab 3.05). The mean RRAs for SA77 and its two conjectured local areas is rather stable around 0.59 (Tab 3.05). To be consistent with the hypothesis of local area formation raised above, SA77 might be regarded as a non divisible system from the syntactic standpoint.3

---

1 In effect both systems are quite integrated as compared with the mean RRAs observed within the current sample. Even though the distinct mean integration values can also be taken as supportive of the hypothesis of sub-area formation.

2 The decomposition of SA77 is carried out for similar reasons as the decomposition of SA60. The route that divides the two conjectured local areas is also a wide avenue carrying a bus corridor in its centre. This route is indicated in Fig. 3.23 A. Although the traverse permeability criterion is not met in this case this route is also part of the 5% choice core (Fig 3.10).

3 The matching of the syntactic description of different systems with land use distributions to be carried out in chapters five and six may provide further clarification upon the relevance of the decompositions proposed during the current chapter.
The figures for 'definition' seem to be supportive of this hypothesis. SA60 and its two local areas are all strongly defined systems, especially SA30 where definition increases to 1.60 reenforcing the syntactic autonomy of that part of the street grid (Tab 3.04). By contrast the definition of SA77 is rather low especially if compared with the standard set up by the definitions already observed for the whole sector A. Definition remains low for the two systems given by the decomposition of SA77 (Tab 3.05). These results suggest that SA77 and its two conjectured local areas might be regarded more as a part of SA west than as syntactically autonomous systems on their own. This is right the opposite of what is observed for SA60. The high 'differences' observed when both SA60 and SA77 were measured as a part of the whole sector A have decreased remarkably when these same systems are measured as a part of SA west. Here all differences are kept stable within a small range between -.07 and 0.12 (Tab 3.04 and 3.05).

As a whole these figures seem to confirm the adequacy of the proposed decomposition of the whole sector A. While overlaps and definitions make it clear that SA60 remains to a large extent as a syntactically autonomous system - as it was as a part of the whole sector A - the low differences reassure its condition as a part of SA west. On the other hand SA77 literally reproduces the 'balanced' overlap already observed for the systems at east of sector A.¹ In this case as it has already been noticed the figures for definition and difference confirm the 'balanced' overlap and as such the lower degree of syntactic autonomy of that part of the grid.

Next in this analysis SA west will be described by three other syntactic measurements - choice, connectivity and axial length. The 5% highest choice value lines in SA west does not perform the continuous sequence of axial lines observed for the choice core of the whole sector A. Instead

¹ These systems are SA71, SA72, SA106 and SA184. These results are in table 3.02 (p.155).
choice lines are now more dispersed in what might be called 'fragments of choice' scattered throughout the system (Fig 3.24). Nevertheless these fragments provide some clues on the formation of local areas inside SA143. On the one hand they confirm most of the contour of SA60, yet not its further decomposition in SA30 and SA34. On the other hand they explicitly divide SA77 in two systems by defining most of the contour of SA59. In effect while the patterns of overlap and definition have suggested the partition of SA60 and the syntactic unity of SA77, the distribution of the highest choice value lines seems to recommend the opposite. Confirming what has already been suggested this is a case where different alternatives on local area formation must be matched with the pattern of land use distribution inside each system in order to verify how the local area hypotheses raised here come to perform, either by supporting or by contradicting these propositions.

Despite these somewhat contradictory evidences in general choice is strongly correlated with integration in SA west. The two highest choice value lines are also the two most integrating lines (Fig 3.24). The third line in the choice rank does not belong to the integration core but amongst the eight highest choice value lines five are also part of the 5% integration core. The correlation between choice and integration all lines compared is -.780 (p=.0001)(Fig 3.25). Both for choice and integration the measurements are logged. The histogram for RRA shows a slight positive skew while for logged RRA the distribution comes rather close to the normal.\footnote{The number of classes utilized for testing the normality of both variables is approximately the square root of the number of observations, as recommended in Norcliffe, G. \textit{Inferential Statistics for Geographers}, Hutchinson of London, 1977, p. 64.} For choice the transformation is more radical. Choice has a strong positive skewness in its linear form and logtransformation brings the distribution closer to normal so providing a clearer picture on the extent of differentiation between choice values.\footnote{The logtransformation applied to both cases aims to suffice the assumption of bivariate normal distribution for the correlation analysis, as recommended by Norcliffe, G., op.cit., p. 177. It is assumed here, following Norcliffe, that the removal of skewness is a pre-condition for the efficiency of a parametric test, yet as this author also acknowledges that for larger samples this assumption may be relaxed. For a full discussion on this issue see Norcliffe, op. cit. pp. 177-182.}
FIG. 3.25 S4 WEST: Correlation analysis for choice and integration

$R^2 = 0.760 \quad p = 0.004$
The distribution of the 5% most connected lines of SA west shows an outstanding concentration of strongly connected lines at the orthogonal part of the grid at west (Fig 3.26). In effect the 5% most connected lines are all but one inside the orthogonal part of the grid referred to above. This brings about an apparent lack of relationship between the 5% most connected lines and the integration core (below in the same figure) that is conspicuously distributed throughout the system. Nevertheless a more accurate observation of both ranks does not confirm that. The most connected line is not in fact part of the 5% integration core yet it is part of the 10% core. The second most connected is also the most integrated. Three of the seven most connected lines are also part of the 5% integration and six of these same seven most connected are also part of the 10% integration. In fact for all lines computed integration and connectivity are strongly correlated. The coefficient is -0.800 \( (p=.0001) \) (Fig 3.27 A).

As it has already been explained the extent of the correlation between the measurements of integration and connectivity inside an urban system has been conjectured by Hillier and Hanson as the syntactic way of measuring the intelligibility of the system. These authors suggest that the intelligibility might be described by the extent to which local information given by connectivity and global information given by the pattern of integration are correlated inside the same system. The conjecture, as already discussed in chapter two, is that the higher is the correlation between integration and connectivity the more intelligible is the system. In this precise syntactic sense SA west is a relatively 'intelligible' system.\(^1\) For connectivity against choice the correlation decreases to 0.714 \( (p=.0001) \) (Fig 3.27 B). The correlation with choice still is high but the scattergram shows that in this case the distribution of points is more dispersed around the regression line so undermining to some extent the significance of the coefficient.

\(^1\) The property of syntactic intelligibility is the subject of a specific section during chapter four.
Fig. 3.27 SA west: correlation analysis for connectivity against integration and choice
The distribution of the longest axial lines inside SA west coincides strongly, except for one line, with the 5% most connected described above (Fig 3.28). As expected the high connectivity observed for the long lines given by the orthogonal grid at west plays a decisive role for that. The correlation for length against connectivity is 0.856 (p=.0001) (Fig. 3.29 C). The pattern of integration in SA west is also strongly associated with axial length yet the coefficient in this case has dropped to -.704 (p=.0001) (Fig 3.29 A). For choice the correlation with axial length decreases to .581 (p=.0001) (Fig 3.29 B). It is noteworthy that this distinction between the coefficients for axial length as compared for integration and choice is even stressed if just the lines belonging to the 5% core of both choice and integration are computed. In effect despite the fact that both highest choice value lines and most integrating lines tend to be long axial lines, the order of choice at the top of the rank is much less associated with length than the order of integration, at least inside SA west.

As a whole the analysis of the syntactic performance of SA west has clarified a range of different issues. The comparison of local cores - the integration core of each local area inside SA west - and global core lines has confirmed to a large extent the conjectures made when these same SA west local areas were measured as a part of the whole sector A. The performance of overlaps, definitions and differences have to a large extent confirmed the adequacy of the proposed decomposition of the whole sector A. While the performance of overlaps and definitions have made it clear that SA60 remains to a large extent as a syntactically autonomous system - as it was as a part of the whole sector A - the low differences have reassured its condition as a part of SA west. On the other hand SA77 literally reproduces the 'balanced' overlap earlier

1 If just the core lines are computed the correlation between axial length and integration will remain high at -.673 (p=.0001) while for choice the coefficient drops sharply to .296 (p=.0278).
Below integration, choice and connectivity cores.
Fig. 3.29 SA west: correlation analysis for length against integration, choice and connectivity

Histogram of LEN

Histogram of log(x) of LEN

Bar chart for volume: log(x) of LEN

\( y = -2.054x + 1.236, R^2 = 0.497 \)

\( y = -2.71x + 2.56, R^2 = 0.528 \)

\( y = 1.11x - 1.17, R^2 = 0.794 \)

**LEN**: RRA \( r = -0.704 (p < 0.001) \)

**LEN**: CHC \( r = 0.584 (p < 0.001) \)

**LEN**: CON \( r = 0.856 (p < 0.001) \)
observed for the systems at east of sector A. In this case as it has already been noticed the figures for definition and difference confirm the ‘balanced’ overlap and as such the lower degree of syntactic autonomy of that part of the grid.

Apart from integration, the analytical procedure has assessed the performance of other syntactic measurements - choice, connectivity and axial length - in SA west. These results will be, further in this chapter, compared with similar measurements taken for the three remaining systems of interaction. These measurements will be also compared, during chapters five and six of this thesis, with the pattern of land use distribution given by all systems (local areas and systems of interaction) under scrutiny. These tests will provide not only further clarification on the performance of these measures but also their effectiveness in describing a socio-economic dimension of the urban phenomenon, as given by the distribution of land uses. For the moment the set of properties described above seems to provide a fair picture of the syntactic performance of SA west. Further analysis is added in subsequent chapters according to the needs of each particular case. The three remaining systems of interaction are described next, following similar analytical procedure.

SA east: the patchwork half of sector A

Fourteen amongst the twenty one most integrated lines in SA east are grouped at the southeast part of the system in the area where the housing estates are located (Fig 3.30 A). This eastwards orientation of the integration core observed for SA east is precisely the opposite of what was noticed to SA west where the integration core and especially the order of integration is strongly westwards oriented. Fig 3.30 (C and D) shows how the integration cores observed for east and west

---

1 These systems are SA71, SA72, SA106 and SA184. These results are in table 3.02 (p.155).
Fig. 3.30 SA east: integration cores
Beside comparison of orders of integration
'repel' the each other as expressed in their respective orders of integration. This seems to provide a further evidence in support of the decomposition of the initially given sector A.

Yet all observed evidence has supported consistently the decomposition of the whole sector A - as a way of describing more accurately the syntactic characteristics of that part of the sample - it seems worthwhile to verify the extent to which the high concentration of short axial lines given by the housing estates inside SA east affects the syntactic description given for that part of the grid. The 'feather-like' configuration given by the integration core of the whole sector A in its east part has clearly suggested a globally integrated configuration where core lines are rather evenly distributed throughout the four proposed local areas (Fig 3.21 below). It is precisely this even distribution that is missing when the east part of sector A (SA418) is measured on its own (Fig 3.30 A). The description of this same part of the grid having the short axial lines given by the housing estates deleted will allow for an assessment on how the proposed set of syntactic measurements perform under such conditions and, for subsequent steps of this investigation, an assessment on which of these configurations - with or without the syntactic effects given by the housing estates - provide the most effective syntactic description for the pattern of land use distribution in that part of the grid.

**Fig 3.30 B** is an axial description of SA east where the axial lines given by housing estates are not computed (SA299). Under such configuration the pattern of integration has changed significantly as compared with SA418. The first and second most integrated lines still belong to the central spine - same as in SA418 - but the third and fourth most integrated lines go in opposite direction in relation to the southeast part of the system where the housing estates are located. Only the fifth most integrated line will enter that part of the system. The integration core becomes globally distributed - the most integrating lines permeate most

---

1 The pattern of 'balanced' overlap then observed confirms that (Table 3.06).
parts of the system - and more balanced between the southeast and northwest parts of the grid (SA72 and SA184) which carry eight and six global core lines respectively. The northeast and southwest parts of the system (SA106 and SA71) remain less permeated by the integration core, same as when the housing estates are computed. The position of the two major lumps of segregation, one at northeast other at southwest, is not changed yet their size decreases significantly especially at northeast. It is also noteworthy that despite the deleting of the short axial lines given by the housing estates the integration core for SA299 still keeps the eastward orientation observed for SA418. The order of integration for the five most integrating lines confirms that (Fig. 3.30 B). Despite the conspicuous change in the distribution of the integration core - from SA418 to SA299 - the consistency observed for the order of integration indicates a stable eastwards orientation for both these core modes so supporting the conjectured syntactic detachment of SA east in relation to the whole sector A initially proposed.

This analysis is not supposed to make an option in terms of which of the two descriptions given for SA east depicts more accurately the pattern of integration inside that part of the street grid. In fact both these configurations will be further tested out against the pattern of land use distribution inside that area. It might be the case that the distribution of certain use categories are better described by SA299, while for others the inclusion of the housing estates (SA418) may improve the description. Nevertheless for an assessment of the pattern of overlap between local cores and global core lines inside SA east it seems that the description given by SA299 provides a more accurate picture of those axial lines that actually integrate the system as a whole. In fact if the lines belonging to the housing estates are computed the overlap will be strongly concentrated inside SA184 - the local area where most housing estates are located - and virtually insignificant for the three other local areas. This seems to be a quite unrealistic picture, especially if one takes into account the 'balanced' overlap observed for these same local areas when measured as a part of the whole sector A (Tab 3.02). In
view of that for the purpose of a comparison between local cores and
global core lines the core description given by SA299 will be taken as
the global reference.

Table 3.06 gives the figures for differences, definitions and overlaps
as observed for the four conjectured local areas inside SB east namely
SA72, SA71, SA106 and SA184. The pattern of difference is now
remarkably stable, more than when these same systems were analysed
as a part of the whole sector A (Tab 3.02). All differences oscillate
between 0.09 and 0.10. That is to say all local areas are just marginally
more integrated when analysed on their own than as a part of the system
of interaction (SA299). Such a stable difference has already been noticed
in the syntactic performance of SA west, the more griddy half of sector
A already analysed. Same as for that case the current pattern of
differences seems to confirm that none of the conjectured local areas in
which SA299 is decomposed present a difference value high enough to
suggest its syntactic autonomy in relation to the system of interaction.
By so performing the pattern of differences observed for SA east seems
to be much supportive of the decomposition strategy adopted for this
portion of the street grid.

The figures for definition seem to confirm to a large extent the 'even'
pattern of differences (Tab 3.06). In fact the output for definition also
preserve much of the pattern observed when these same four systems
were measured as a part of the whole sector A. The range of definition
in that case varies between 0.94 for SA71, the less 'defined' system, and
1.16 for SA184, the most defined, in a configuration (the whole sector A)
where definitions went as high as 1.93 (Tab 3.02). For the same
systems, now described as a part of SA299, definitions vary between
1.01 for SA71 that remains as the less defined and 1.31 for SA184 that
remains as the most defined.¹

¹ If the mean RRA for SA418 is utilized as the reference for the calculation of the definition
values instead of the mean RRA for SA299 - the figures for definition will drop just
marginally showing that the short axial lines given by the housing estates hardly affect the
pattern of definition inside SAeast. These figures are in Table 3.06 (column 'Def418').
### Table 3.06 SA east: differences, definitions and overlaps

<table>
<thead>
<tr>
<th>Syst Code</th>
<th>RRA</th>
<th>RRRemb</th>
<th>Difference</th>
<th>Def 299</th>
<th>Def 418</th>
<th>Overlap</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA72</td>
<td>.70</td>
<td>.80</td>
<td>.10</td>
<td>1.20</td>
<td>1.17</td>
<td>.28</td>
</tr>
<tr>
<td>SA71</td>
<td>.86</td>
<td>.95</td>
<td>.09</td>
<td>1.01</td>
<td>.95</td>
<td>.14</td>
</tr>
<tr>
<td>SA184</td>
<td>.66</td>
<td>.76</td>
<td>.10</td>
<td>1.31</td>
<td>1.24</td>
<td>.22</td>
</tr>
<tr>
<td>SA106</td>
<td>.80</td>
<td>.89</td>
<td>.09</td>
<td>1.08</td>
<td>1.02</td>
<td>.10</td>
</tr>
</tbody>
</table>

### Fig. 3.31 SA east: The global core and the local cores

The axial maps of the top row describe global integration lines in each conjectured local area. The maps at the bottom row describe the integration core for each local area 'as detached'.

---

**Diagram Descriptions**

- **(a) SA72**
- **(b) SA71**
- **(c) SA184**
- **(d) SA106**
- **(e) SA181/182**
- **(f) SA184**
The pattern of overlap is also significantly stable oscillating within a small range between 0.10 and 0.28. The configuration of the local cores present three distinct situations. SA72 and SA184 present globally distributed cores with segregated lines arranged at the interstices between core lines (Fig. 3.31 B and H). Both these local cores are overlapped by two global core lines. For SA106 the configuration changes and the local core is pushed southwards while the most segregated lines form two lumps at the north part of the system (Fig 3.31 F). The overlap decreases to 0.10. A third situation is given by SA71 (Fig 3.31 D). Here again the local core is apparently a globally distributed one. Nevertheless the most integrating line is right at the centre of the system in a sort of tying up position, same as if it were connecting two different systems. The subsequent order of integration will then alternate lines coming from both sides of this most integrating line. The configuration of the global core lines that reach SA71 show at southwest of the system a large lump of segregation while at the opposite side are all the globally integrated lines (Fig 3.31 C). The most integrating line locally ties up the two opposed sets.

In general the comparison between local cores and global core lines inside SA east has confirmed to a large extent the observations made when the same local areas were measured as a part of the whole sector A. As for that case differences and definitions remain at low figures but the pattern of overlaps is now more evenly distributed throughout the four conjectured local areas. As a whole these results seem to reassert the condition of SA west as the system of interaction for the four proposed local areas. Moreover these results seem to confirm that none of the four conjectured local areas present characteristics - either of difference, definition or overlap - that suggest its syntactic autonomy in relation to the proposed system of interaction.

1 Compare results given in tables 3.02 and 3.06.
2 When these same local cores were compared with global core lines given by the whole sector A the overlap inside SA184, as biased by the short axial lines given by the housing estates, was predominant.
Fig. 3.32 SA east: choice cores
Beside integration cores
**Fig. 3.32** shows the 5% highest choice values for both SA418 and SA299. For SA418 – the system that includes the housing estates – the two highest choice value lines are also the two most integrating lines. Both these lines belong to the 'central spine'. The third highest choice value line goes inside SA106 but in so far as the choice core expands ten out of the remaining seventeen core lines are inside the part of the system where the housing estates are located. The highest choice value lines virtually surround this southeast part of the system and penetrate through most of its interior. Same as for integration the distribution of choice lines is strongly affected by the high axial density given by that portion of the grid. Instead of what was observed for SA west where choice lines are evenly spread throughout the system, in SA east the 'shortest paths' are strongly concentrated in one part of the system.

The explanation for that is straightforward. The large number of short axial lines inside the southeast part of SA418 brings about a strong increase in the 'shortest path' value of axial lines there located, most particularly the long lines connected to rows of short pathways inside the housing estates. This result – following what has already been suggested during the analysis of the integration core of this same system – seems to challenge the accuracy of global measurements so strongly affected by a local factor (the high density of short axial lines given by the housing estates). It is true that the choice lines represented in **Fig 3.32 A** are in effect the shortest paths between all lines in this system. Nevertheless it is also true that the axial density given by one particular portion of the grid will eventually affect the description of strong choice lines located in other parts of the system; lines that despite their high choice value in relation to their respective local areas will be lower in the global choice rank just for the 'artificial' increase of axial density in one part of the grid. In this respect the visual inspection of the axial map is more clarifying than the choice rank itself. The lines depicted in the axial map as high value choice lines inside the
Fig. 3.34 SA east: correlation analysis for choice and integration
Housing estates included (SA418)

\[ r = -0.423 \] (p < 0.001)

\[ r = -0.807 \] (p < 0.001)

Fig. 3.34 SA east: correlation analysis for choice and integration
Housing estates deleted (SA299)

\[ r = -0.505 \] (p < 0.001)

\[ r = -0.807 \] (p < 0.001)
southeast part of the system seem to perform more as local choice lines than as global choice lines.¹

When SA east is measured having the housing estates axial lines deleted (SA299) the three highest choice value lines remain the same but for the subsequent order of choice the core expands more evenly including not only lines that go inside the four proposed local areas but also lines that describe at least in part of their contour (Fig 3.32 B). It is conjectured here that this particular configuration (SA299) gives a distribution of choice lines which corresponds to the 'actual' global choice lines of the system so following what has already been noticed for the integration core.²

Despite their common performance in respect of the 'deleting' of the housing estates, choice and integration values are now much lower correlated than they were in SA west. If the system is measured carrying the short axial lines given by the housing estates (SA418) the correlation is -0.423 (p=.0001). If these lines are deleted (SA299) the correlation increases yet marginally to -0.509 (p=.0001).³ These low correlations seem to contradict the picture given by the comparative inspection of both axial maps where not only the core lines but also the orders of choice and integration are rather similar (Fig. 3.32 A and B). In fact their similarity at the core level surpasses what visual observation suggests. If just the core lines are computed the correlation

---

¹ In effect ten amongst the eleven highest choice value lines that penetrate SA184 - the local area where the housing estates are located - are part of the 5% highest 'control value' lines of all system. Control value is a local measurement which describes the extent to which a line controls access to and from its immediate neighbours. It is calculated by summing the reciprocals of the connectivities of all lines connected to the selected line. As Hillier explains: 'If the line is a neighbour's only connection it acquires a value of one from that neighbour, if it is one of two connections then it acquires 1/2, if one out of three, then 1/3, and so on'. In Hillier et al. Natural Movement, op cit. p.9. If high control value lines are taken as a possible description for strong 'local choices' such a coincidence between high control value lines and high choice value lines might be taken as an indication of the strict local character of the highest choice value lines given by SA418.

² Again for this case, both core versions will be matched with the patterns of land use distribution, in order to prospect for further clarification on this issue.

³ Fig. 3.33 and 3.34 give the tests of normality for each variable and the scattergrams for their correlations.
Fig. 5.33 SA east: Six most connected firms
Beside integration and choice cores
increases from -.423 to -.801 (p=.0001). The coefficient remains unchanged from SA418 to SA299 showing that the relationship between choice and integration at the core level is not affected by the presence of the housing estates. It is also noteworthy that such an increase in the correlation RRA:CHC when measured at the level of the core, is particularly higher for the current case (SA east). Inside SA west the coefficient at the core level also increases yet not to the same extent.  

**Fig. 3.35** show the 5% most connected lines. For SA418 the six most connected lines are here again concentrated in the part of the grid where the housing estates are infilled. The figure shows that the high connectivity of these lines is more a product of intersections with the short axial lines coming from ‘inside’ the housing estates – which tend to perform as local rings composing a series of microgrids ‘inside’ pre-existing blocks – than a product of their connectivity at a more global scale. Such a concentration of strongly connected lines in the southeast part of the system confirms what has been observed both for the choice and integration core as well. This output was already expected since, as it has been explained in chapter two, both the measurements of integration and choice are produced - yet in different ways - by topological ‘distances’ as given by the number of axial steps between lines or, in other words, connectivities.

The correlation between connectivity and integration for SA east is -.336 (p=.0006)(**Fig 3.36**). In this case the lower ‘intelligibility’ observed for SA east, as compared with SA west, confirms what visual observation suggests. Despite the imprecision of such a description it might be said that the labyrinthine configuration given by most of SA east is in fact less intelligible than the griddy configuration given by SA

---

1 The set of lines belonging to the 10% integration core is taken as a reference.
2 In SA west, the coefficient for CHC:RRA increases from -.780 (p=.0001) all lines compared to -.898 (p=.0001), at the core level.
3 The lines belonging to the ‘central spine’ are only the seventh and the eighth in the rank of connectivity.
4 The measurements of connectivity are logtransformed as the tests for normality, given in **Fig 3.36 and 3.37**, recommend.
SA east: correlation analysis for connectivity against integration and choice
Housing estates included (SA418)

CON: RRA $R = -0.336$ ($p = 0.0004$)

CON: CHC $R = -0.666$ ($p = 0.0001$)

Fig. 3.37
SA east: correlation analysis for connectivity against integration and choice
Housing estates deleted (SA299)

CON: RRA $R = -0.480$ ($p = 0.0001$)

CON: CHC $R = -0.677$ ($p = 0.0001$)
If the correlation is measured at the level of the core it decreases further to \(-.293\) \((p=.21)\) following what has happened in SA west.\(^1\) Intelligibility, the figures for both cases seem to indicate, must be computed for the system as a whole for a significant measurement. Nevertheless the inspection of the scattergram for intelligibility (RRA:CON) in SA418 at the core level shows that the three most connected lines of the system perform as strong outliers in the correlation (Fig 3.38 A). These three axial lines are right at the middle of the area where the housing estates are infilled at the southeast of the system (Fig. 3.35 A). These lines, despite their high connectivity are lower in the rank of integration.\(^3\) If these lines are not computed the correlation at the core level increases to \(.725\) \((p=.0001)\) showing that, by contrast with what was observed to SA west, the syntactic intelligibility of SA418 is much higher at the core level than for the system as a whole (Fig 3.38 B).

For SA299 - the same system without the housing estates - the pattern given by the most connected lines becomes spread throughout the system same as it has happened to the integration and choice cores (Fig 3.35 B). The 'central spine' carries the two most connected lines. These same lines are also the two most integrated and the two highest choice values. The syntactic intelligibility of the system increases yet just marginally to \(-.480\) \((p=.0001)\) (Fig. 3.37).\(^4\) At the level of the core the correlation goes higher to \(.712\) \((p=.0029)\) matching the coefficient observed for SA418, at the core level, when the three most connected lines are deleted. These figures provide two indications. The first is that either with the housing estates infilled (SA418) or deleted (SA299) the east

---

\(^1\) The figure for intelligibility for SA west is \(-.801\) \((p=.0001)\). A precise measurement of all grid configurations given by the current sample in terms of their syntactic intelligibility is part of chapter four of this thesis.

\(^2\) This is the opposite of what happens to the correlation between integration and choice that, at the level of the core, has increased for both SA west and SA east. Same as for that case the core of reference is the integration core.

\(^3\) 'Lower' if compared with the more general tendency observed for the distribution of points at the bulk of the sample. This is shown in scattergram A (Fig 3.38).

\(^4\) The correlation RRA:CON for SA418, the same area included the housing estates, is \(-.336\) \((p=.0004)\).
Fig. 3.38 SA east: intelligibility at the core level (SA418)

(A) Intell. SA418 Core level
\[
y = -0.051x - 0.223, \text{ R-squared: 0.086}
\]
\[
R = -0.293 (0.21)
\]

(B) Intell. SA418 Core level (Three most conn. del)
\[
y = -0.165x - 0.121, \text{ R-squared: 0.527}
\]
\[
R = 0.725 (p=0.001)
\]
Fig. 3.39 SA east: 5% longest lines
Below integration, choice and connectivity cores
part of sector A is conspicuously less intelligible than SA west. The second is that while in SA west intelligibility is a property that spreads throughout the system, for SA east intelligibility is strongly affected by the more labyrinthine configuration of the street grid and as a consequence it becomes more a property of the core - where the most connected lines tend to be shallow in the system - so decreasing in so far as the labyrinthine parts of the grid are computed in the correlation.¹

The correlation between connectivity and choice is just marginally affected by the 'deleting' of the short axial lines given by the housing estates. For SA418 the correlation is .666 (p=.0001) while for SA299 it increases slightly to .677 (p=.0001). In effect the correlations between choice and connectivity will be throughout the current sample as high as these figures. Unlike RRA, whose relationship with connectivity varies strongly - so describing a precise characteristic of urban systems conjectured here as intelligibility - choice for its shortest path character seems to be 'naturally' attached to connectivity and as a consequence the correlations between these two measures do not seem to provide room for further conjectures, at least for the moment.

The five longest lines inside SA east are routes that link the area where the housing estates are to the 'central spine' (Fig 3.39).² In effect these long axial lines set up the 'topological proximity' between the short axial lines given by the housing estates and the 'central spine'. Most of these short lines are at two or three axial steps at the most from the spine. The topological proximity brought about by this set of long lines that traverse the southeast part of the system tend to reduce to a large extent the amount of segregation that would be expected in a portion of the grid so crowded of short axial lines. That is to say the high degree of axial fragmentation seems to be balanced by the long axial segments that traverse the system. This seems to explain the fact that the mean integration values observed for both configurations - SA418

¹ Compare the distribution of integration cores and highest connectivities in Fig. 3.35.
² The 5% longest lines are the same for both SA418 and SA299.
Fig. 3.40 SA east: correlation analysis for length against integration, choice and connectivity. Housing estates included (SA418)

LEN:RAA $R_r = -0.51 (p = .0004)$

LEN:CHC $R_r = 0.593 (p = .0004)$

LEN:CON $R_r = 0.755 (p = .0004)$

Fig. 3.41 SA east: correlation analysis for length against integration, choice and connectivity. Housing estates deleted (SA299)

LEN:RAA $R_r = -0.49 (p = .0004)$

LEN:CHC $R_r = 0.589 (p = .0004)$

LEN:CON $R_r = 0.659 (p = .0004)$
and SA299 - remain rather stable either with or without the housing estates computed. The mean RRA for SA418 is 0.82 while for SA299 it increases just marginally to 0.87.

In fact a marginal increase in the overall segregation of the system is noticed if the housing estates are not computed. This seems to reflect the syntactic performance of the local area where the housing estates are located (SA184). For that system the mean RRA is 0.66 all lines computed. Although if the correlation is measured having the housing estates deleted the mean RRA increases to 0.69. The system becomes internally more segregated. This shows that even at the local level the system is more integrated when it includes than when it excludes the housing estates. These figures seem to reflect the role of the short axial lines given by the housing estates in interweaving and integrating that part of the street grid.

**Fig 3.40 and 3.41** match the rank of axial length with integration, choice and connectivity.¹ The association between length and integration is much weaker now than it was in SA west. The correlations are -.311 (p=.0005) and -.491 (p=.0001) for SA418 and SA299 respectively.² For length against choice the correlations remain quite stable in .593 (p=.0001) and .589 (p=.0001) for SA418 and SA299 respectively, more or less matching the coefficients observed for SA west, that is 0.581 (p=.0001). That is to say choice keeps a stable performance in relation to length both in SA east and west.³ For length against connectivity the pattern changes. Both for SA418 and SA299 the correlation is lower if compared with the coefficient observed for SA west.⁴ If the housing estates are computed (SA418) length is .755 (p=.0001) correlated with connectivity. For SA299 the correlation drops to .609 (p=.0001) pulled down by the sharp decrease in the connectivity of the long axial lines.

---

¹ The measurements of length are logtransformed as the tests for normality given in **Fig. 3.40 and 3.41**, recommend.
² The correlation between length and RRA for SA west is -.704 (p=.0001).
³ This reproduces the stable association between choice and connectivity for both cases as well.
⁴ The correlation LEN:CON for SA west is .856 (p=.0001).
inside the southeast part of the system when the housing estates are deleted.

As a whole the analysis of the syntactic performance of SA east has both clarified and, in a subsequent step, raised a range of different issues. By comparing local cores - the integration core of each conjectured local area inside that system - and global core lines the analytical procedure has confirmed to a large extent the observations made when these same SA east local areas were measured as a part of the whole sector A.¹ As for that case differences and definitions remain at low figures but the pattern of overlaps is now evenly distributed throughout the four conjectured local areas. These results have reasserted the condition of SA west as the system of interaction for the four proposed local areas. Moreover the observed results have to a large extent confirmed that none of the four conjectured local areas present characteristics - either of difference, definition or overlap - that suggest its syntactic autonomy in relation to the proposed SA east as their system of interaction.

Furthermore the analysis has also shown that the relationships (as measured by correlation coefficients) between the performance of the proposed set of syntactic measurements - integration, choice, connectivity and length - varies significantly if the results given by SA east are compared with what was earlier observed for SA west. An overall assessment of the variations - from one system to another - in the way syntactic measurements are associated to the each other will be carried out at the end of this chapter in the light of a comparison between measurements taken for the four proposed systems of interaction. For the moment the set of properties described above seems to provide enough information on the syntactic performance of the east part of sector A. During the matching of these syntactic descriptions with the distribution of land uses, to be proceeded in chapters five and

¹ Compare results given in tables 3.02 and 3.06.
six, further descriptions are provided according to the specific needs of each case.

**SB west: the griddy part of sector B**

The most integrating line inside SB west is precisely the line that according to the traverse permeability criterion performs as a boundary between the two local areas in which this part of sector B has been divided namely SB62 and SB30 (Fig 3.42). In effect this characteristic - of having the most integrating line or lines performing as boundary between two conjectured local areas - repeats what has been observed in the two other systems of interaction already examined. Just as here (SB west) both in SA west and in SA east the first and second lines in the order of integration are lines that, from the standpoint of ruptures in traverse permeability, divide the whole in different local areas and, simultaneously, perform as the spatial element that ties up these different parts setting up a sort of dialogue between attraction (or grouping together) and separation involving the local and the global scales.

A comparison between patterns of integration observed for the whole sector B and the current SB west provides some evidence in support of the decomposition strategy proposed for this part of the street grid. Fig 3.42 shows that the pattern of integration for the whole sector B presents a lump of segregated lines that spreads throughout the west part of the system (below in the figure). Most of this lump of segregation becomes a set of rather integrated lines when SB west is measured on its own. Nevertheless the lump of segregation remains steady at the south part of the system (SB30). These lines were already strongly segregated lines as a part of the whole sector B and so they remain as a part of SB west. The syntactic performance of this set of lines - by retrieving a stable high degree of segregation both as a part of the whole sector B and also as a part of SB west - seems to provide an evidence in
support of the syntactic autonomy of that part of the grid in relation to the remainder of SB west.¹

The two conjectured local areas inside SB west namely SB62 and SB30 present globally distributed integration cores when they are measured as detached (Fig 3.43 B and D). In both cases the three most integrating lines are long routes that connect the centre to the periphery of the system while the most segregated lines are rather shallow and homogeneously distributed at the interstices between core lines. The relatively low mean RRA observed for these systems - .53 for SB62 and .61 for SB30 - confirms the pattern of integration described above.² Difference figures are now remarkably low as compared with the values observed for these same systems measured as a part of the whole sector B (Tab 3.07).³ The differences are now even at .05 for both SB62 and SB30. Both these systems are marginally less integrated as detached than as interacting with each other in SB west.

The figures for definition also decrease sharply if compared with the values observed for these same local areas measured as a part of the whole sector B. In that case the figures were 1.55 and 1.34 for SB62 and SB30 respectively. Measured as a part of SB west the definitions of SB62 and SB30 drop to 1.16 and 1.01 respectively. That is to say the mean integration values of each part are now much less distinctive - as compared with the mean integration value of the whole - than they were as a part of the whole sector B. The pattern of overlap between local and global cores is now stable. The figures are 0.34 for both systems. It is noteworthy that for SB30 the overlap happens at the periphery of the system (Fig 3.43 C and D). Here again the conjectured distinct character of 'peripheral overlaps' might be regarded as providing a

¹ That part of SB west has been coded as SB30.
² The mean integration value observed for SB62 and SB30 is 'relatively low' in comparison with the mean RRA values observed for the 'wholes' sector A and B which for both cases is slightly higher than 0.80.
³ In that case the figures are .29 and .15 for SB62 and SB30 respectively.
Fig. 3.44 SB west: choice core
Below integration core
Fig. 3.45 SB west: correlation analysis for choice and integration

CHC: RRA R = -1.664 (p < 0.0001)

Bar Chart for volume of CHC

Bar Chart for volume of RRA

Histogram of CHC

Histogram of RRA

Histogram of SB west

Legend:

CHC: CHC

RRA: RRA

SB west: SB west
measurement for the extent of autonomy of SB30 in relation to the rest of SB west.

The combined performance of differences and definitions in SB west seem to indicate that none of the two conjectured local areas has presented results that fully support its syntactic autonomy in relation to the proposed large area of interaction (SB west). Despite the 'peripheral overlap' observed for SB30 and also the consistent pattern of segregation observed for this same system at any 'embedding', the figures for definition and difference suggest that this part of the grid is in effect more a part of SB west than a syntactically autonomous system in itself.

Fig. 3.44 shows the distribution of choice lines in SB west. The highest choice value line is also the most integrated. The second idem. In effect up to the fifth line choice and integration ranks are exactly the same yet in a different order. By the sixth line a more significant distinction emerges. The sixth highest choice value line goes into SB30 where the integration core does not penetrate.

The distribution of the choice core in SB west - same as for the previous cases - is more spread than the distribution of the integration core so including routes that are not part of the integration core. At any rate the correlation between choice and integration for SB west is as high as -.664 (p=.0001). This figure approximates the high coefficient observed for SA west (-.780). Both cases are distinct from SA east, the more labyrinthine half of sector A, where the correlation between integration and choice is much lower (-.423).

---

1 The integration core is below in the same figure.
2 Although this line is just out of the 5% choice core the distinction it makes in relation to the integration core is clarifying.
3 The values for both choice and integration are logtransformed as the tests for normality, showed in Fig. 3.45, recommend.
4 In all cases the correlation between choice and integration as measured at the level of the core is higher, yet the increase has been particularly significant in SA east. The relationship between syntactic measurements, as given by variations in the coefficients from one system to another, will be the object of a comparative analysis at the end of this chapter.
Fig. 3.46 SB west: 5% most connected lines
Below integration and choice cores
CON: RRA $R = 0.713$ ($p = 0.000$)

CON: RRA (core) $R = 0.154$ ($p = 0.579$)

CON: CHIC $R = 0.810$ ($p = 0.000$)

Fig. 3.47 SB vest: correlation analysis for connectivity against integration and choice.
The 5% most connected lines are also concentrated inside SB62 same as it happens for the integration core (Fig 3.46). Even if the rank of highest connectivities is expanded to 10% it will include just one line belonging to SB30, the conjectured more autonomous system at south. The most connected line is also the most integrated, but while the order of integration evolves westwards the order of connectivity evolves eastwards. By contrast the order of choice as the figure indicates seems to be more in tune with the order of connectivities. The correlation between choice and connectivity is as high as .810 (p=.0001) so confirming the consistent strong correlations between these two measurements already observed for the previous cases (Fig 3.47 C). By contrast, all lines compared, integration is -.673 (p=.0001) correlated with connectivity inside SB west. Measured at the core level the correlation drops sharply to -.154 (p=.671) (Fig. 3.47 A and B).

These results literally reproduce the performance of syntactic intelligibility observed in SA west, the griddy half of sector A already analysed. Same as for that case the current SB west is rather intelligible when measured as a whole although if intelligibility is measured at the core level it drops sharply. That is to say both these systems are hardly intelligible at the core level.¹ These low ‘core intelligibilities’ are to a large extent produced by a low differentiation amongst RRA values concentrated at the top of the rank. Both SA west and SB west are grids carrying a high degree of regularity if only the core lines are computed. Not only the range of RRAs at the core level is rather small, but also the range of connectivities. The low degree of differentiation observed for both variables seems to affect strongly the correlation. In so far as the ranks of RRA and connectivity are expanded, so including less integrated and less connected lines, ‘differentiation’ increases so eventually bringing about the syntactic intelligibility of the system. This same phenomenon has already been identified by Hanson, as already reviewed,

¹ In SA west, the more griddy part of sector A, integration and connectivity are -.800 (p=.0001) correlated all lines compared. At the core level the coefficient drops to -.350. For the current SB west as for the previous cases the core of reference for measurements at the core level is the 10% integration core.
Fig. 3.48 SB west: 5% longest lines
Below integration, choice and connectivity cores
Fig. 3.49 SD West: Correlation analysis for length against integration.
in her study on syntactic properties of theoretical regular grids. To put it in Hanson's terms, the 'ordered' grids given by the cores of both SA west and SB west will become 'structured' and 'intelligible' in so far as 'differentiation' amongst RRA values (given by the adding up of less integrated lines) increases.\footnote{The relationship between the concepts of order, structure and intelligibility is fully discussed in Hanson, J. \textit{Order and Structure in Urban Space: A morphological history of the City of London}, op.cit. p. 100-102.}

\textbf{Fig. 3.48} gives the 5\% longest lines for SB west. The longest line is not part of the integration or choice cores and is not even amongst the most connected. The second longest will be only the sixth in the order of integration. Visual comparison between the different core modes suggest that integration is much less associated with length in SB west than it has been in the previous cases. This impression is misleading. The correlation between these two measures point out that length is ~.734 (p=.0001) associated with integration (\textbf{Fig 3.49 A}). It is noteworthy that if all cases so far examined are compared the association between axial length and integration has followed to all extent the intelligibility of the different systems, as given by RRA:CON. In the current SB west, length is less associated with choice than with integration. This is another feature shared by the more griddy systems - SA west and SB west. The opposite is observed for SA east, the more labyrinthine half of sector A, where length is more associated with choice than with integration. The correlation between length and connectivity remains consistently high at ~.864 (p=.0001) so confirming its performance as observed in all cases so far analysed.\footnote{A comparative analysis of all coefficients observed between the proposed syntactic measurements, as given by the sample of grid configurations under discussion, is proceeded in the final part of this chapter.}

\textbf{SB east: the patchwork part of sector B}

\textbf{Fig 3.50} shows the integration core of SB east, the eastern system after the decomposition of the whole sector B. The most integrating
lines have now moved from the star shaped part of the system - where they are when integration is measured for the whole sector B - towards the interior (compare axial maps above and below in the figure).\(^1\) The most integrating line is now the boundary between two of the proposed SB local areas namely SB127 and SB83. This line when measured as a part of the whole sector B is only the twentieth first in the order of integration. The second most integrated line goes inside SB127. This line is only the twentieth most integrated as a part of the whole sector B. And so it goes for the subsequent order of integration since the integration core of SB east develops almost entirely inside that portion of the grid (SB127). It is noteworthy that when SB127 is described as a part of the whole sector B it is the most segregated of all SB local areas taken as a reference the comparison between mean RRA values (Tab 3.03). Nevertheless when SB127 is measured as a part of the current SB east its mean integration value becomes virtually levelled with the values observed for the other local areas. As a whole the core description given by SB east is radically distinct from the one observed for this part of the street grid when it is measured as a part of the whole sector B.

Five amongst the eight most integrated lines perform a ring more or less at the centre of the system. This ring surrounds the area where lumps of short axial lines given by housing estates are concentrated (short dotted lines at the centre of the axial map).\(^2\) The syntactic effects coming from these lumps of short axial lines are minor for the current case. The removal of these lines hardly affects the position of the integration core which remains virtually stable at the centre of the system.\(^3\) In effect the two situations - housing estates inside sector A and inside sector B - are rather distinct from the syntactic standpoint not so much for the smaller number of short axial lines given by the

\(^1\) In effect just half of the star shaped part remains for the current configuration (SB east).

\(^2\) In fact this ring develops entirely inside the west part of SB127.

\(^3\) This experiment has been carried out by measuring the system without computing the short axial lines given by the housing estates. As a result even the order of integration remains unchanged.
Fig. 3.51 SA east and SB east: comparison of integration cores before and after decomposition

(A) SA665 East

(B) SA289 East

(C) SA351 East

(D) SB295 East
housing estates in SB but especially for their position in relation to the whole.\(^1\)

The distribution given by the integration core observed for SB east shows that the effects of decomposition upon sector B are quite distinct from these same effects for sector A. The distinction can easily be traced if we compare the integration cores of both their east parts before and after decomposition. The distribution of the most integrating lines inside the east part of sector A is in fact rather similar before and after decomposition. That is to say, either measured as a part of the whole sector A or measured on its own the distribution of the most integrating lines in that part of the grid (SA east) remains to a large extent unchanged (Fig 3.51 A/B).\(^2\) By contrast the decomposition of sector B changes completely the configuration of the core and especially the order of integration. The star shaped core noticed before decomposition is replaced by a ringy core right at the centre of the system (Fig 3.51 C/D).

This conspicuous change of core configuration in SB east – especially if compared with the core stability observed for SA east – provides a further evidence not only upon the distinct ways in which the wholes sector A and sector B have assimilated their respective decompositions but also upon the distinct ways in which they are affected by the 'artificial ruptures' in the spatial continuity of the street grid at their respective centres.\(^3\) In sector A the interruption is more explicit. Its

---

\(^1\) A theoretical experiment has tested out the effects of increasing axial density inside the ring described above. As a result, under different increases the core has consistently retained its ringy configuration yet the order of integration has been slightly altered. The increase in the number of short axial lines at the centre of the system has just reinforced the ringy configuration of the integration core that surrounds that part of the grid instead of provoking major changes in its distribution. This experiment is part of Aguiar, D. Space, Land Use and Design, Working Paper nº4, UAS, Bartlett School, 1989, pp. 26-27.

\(^2\) The similarity remains stable even if the short axial lines given by the housing estates are computed (SA418) yet in this case, as it has already been shown, the distribution of core branches that penetrate into local areas is biased towards the south east of the system.

\(^3\) The 'artificial ruptures' referred to here are, in the case of sector A, the Sports Centre and cemetery already referred. In the case of sector B the spatial break up is provoked by a football stadium and São Miguel cemetery, already referred as well.
east and west parts are connected by just three spatial continuities. The syntactic effects coming from the west part of the system hardly affect the syntactic performance of the east part and, as the stability of the core indicates, the integration core of the east part hardly changes if the west part is removed. By contrast for sector B the rupture is less radical and spatial continuity between east and west is preserved for at least six axial lines. As a consequence, the syntactic effects coming from the west part will affect to a larger extent the syntactic performance of the east part. As a consequence if the west part of the system is removed the configuration of the integration core of the east part is radically altered.

In short the two systems in which the whole sector A has been decomposed, SA west and SA east, have confirmed throughout subsequent analysis their syntactic autonomy in relation to the each other. By contrast the two systems in which sector B has been divided, SB west and SB east, have performed quite distinctively after decomposition. On the one hand SB west has shown throughout subsequent analysis its syntactic autonomy in relation to the whole sector B. On the other hand the core changes observed for SB east clearly indicate that the syntactic performance of this system is strongly affected by decomposition and, in view of that, SB east should be measured as a part of the whole sector B for an accurate syntactic description.

This does not mean that the syntactic performance of all SB local areas at the global scale will necessarily refer to the whole sector B as their system of interaction. This is not the case. A further matching of the syntactic descriptions given during this chapter with the performance of land use distributions inside each system is likely to provide clarifying clues in this respect. In fact for the distribution of some use categories the global area of syntactic reference might be just SB east while for other categories the whole sector B. Let alone uses that might refer just to the local scale. These questions will be thoroughly discussed in chapters five and six when the set of syntactic descriptions provided
Fig. 3.52 SB east: The global core and the global core lines.
The axial maps at the top row describe global integration lines in each conjectured local area. The maps at the bottom row describe the integration core for each local area 'as detached'.
here will be assessed in terms of their response to the distribution of the proposed land use categories.

Despite of the changes in core configuration described above, the differences - between mean RRAs of each proposed local area and the mean RRAs observed for these same local areas measured as a part of SB east - will keep the pattern observed when these same local areas were described as a part of the whole sector B (Tab 3.08). The 0.14 difference observed for SB54 goes slightly higher to 0.19, while for SB127 and SB83 the differences remain slow oscillating between -.04 and 0. These figures reflect on the one hand the lack of syntactic autonomy already observed for SB83 and SB127. On the other hand these figures reflect once again the conjectured autonomous character of SB54 which is in fact reinforced when this system is measured as a part of SB east. The conjecture is made even stronger if we decompose SB54 and retain just its more orthogonal part (Fig 3.52 C and D). The difference when SB44, the orthogonal part of SB54, is taken as the reference for measurement goes even higher to 0.25.

It is also significant that the configuration of the integration core changes completely from SB54 to SB44 (Fig 3.52 B and D). The most integrating line in SB54 will be only the fifth in SB44. The second most integrated in SB54 is not even part of the integration core in SB44. Besides, the syntactic features of one particular global core line that penetrates the middle of the system (the twelfth in the order of global integration) provides another clue on the distinctive syntactic performance of these two configurations - SB54 and SB44 - which otherwise seem to be rather similar. The interesting about this particular line is that however it is a part of the global core of SB east, it is totally detached from the 'integration ring' located at the centre of system (Fig 3.50) same as if it belongs to another 'whole' or at least to a syntactically autonomous local area which according to the former

1 This decomposition is not fortuitous. SB54 is cut in a 'section' where not only 'traverse permeability' decreases but the configuration of the global integration core delivers a strongly segregated line (Fig. 3.51 A).
conjecture would be SB54, or SB44 if only the orthogonal part of the system is retrieved. The significance of that in respect of the distinction between SB54 and SB44 is that this global core line is not part of the local integration core of SB54 yet it is the most integrating in SB44. Here again two distinct syntactic descriptions are given for the same area. These descriptions, despite the small variations in the system of reference (from SB54 to SB44), are conspicuously distinct from the syntactic point of view and both of them convey to all extent its own internal coherence.¹

The definitions of the conjectured local areas inside SB east, following the pattern of differences, hardly change if compared with the definitions already measured taking the whole sector B as the global reference (Tab 3.08). The variations in definition are also in tune with the variations in difference when the measurements taken for SB east are compared. This is made clear in the increase in definition observed for SB54 (1.55) when the system is reduced to SB44 (1.72). The increase in definition follows to all extent the increase in difference for the same area as measured in two distinct ways. The definition values observed for the other local areas remain around one. That is to say the mean RRAs for SB127 and SB83 are approximately the same as the mean RRA for SB east so confirming the lower degree of syntactic autonomy already observed for these systems.

The overlaps between the integration cores of each proposed local area and global core lines, now referred to SB east, will reflect the conspicuous changes occurred in the distribution of the global core under such configuration. Tab 3.08 shows that the overlap for SA127, that was 0.16 when this system was measured as a part of the whole sector B, has increased to 0.25 for SB127 measured as a part of SB east (Fig 3.52 E and F). If SB127 is further decomposed, following the perimeter

¹ The variations in the ‘system of reference’ referred to here mean that the same urban area is being measured in two distinct ways. In other words, two configurations (SB54 and SB44) are taken as reference for the syntactic measurement as a way of testing two distinct boundaries for the same area.
defined by the ring of global cores lines, the degree of overlap remains high for SB45 - the system inside the ring (Fig 3.52 I and J) - and decreases for the remainder of the system namely SB96 (Fig. 3.52 G and H). The concentration of overlapped lines inside SB45 seems to provide a further evidence in support of the decomposition of SB127 as another description - probably more accurate - for the pattern of sub-area formation in that part of SB east. The measurements of difference and definition observed for the two systems emerged out of the decomposition of SB127 seem to confirm that (Tab 3.08). For SB96 both difference and definition increase significantly if compared with the value observed for SB127. By contrast for SB45 the figure for definition is kept rather close to the value observed for SB127 - 1.00 and 0.94 respectively - while the figure for difference is literally the same. In other words from the standpoint of the parameters given above SB45 and SB96 tend to perform as two distinct systems.

For SB83 the combined performance of difference, definition and overlap presents a distinct situation as compared with the results observed for the two other local areas in which SB east has been initially divided - SB54 and SB127. The figure for difference now is zero. The difference when the whole sector B was taken as the global reference was -.04 (Tab 3.08). This shows that SB83 is just slightly more integrated as a part of the whole sector B than it is as a part of SB east. This slight change in difference does not seem to be at all significant as an indication of the system of interaction SB83 belongs, since both its definition and its overlap will remain rather stable either as a part of SB east or as a part of the whole sector B. These results suggest that this system is hardly affected by different 'embeddings' and performs consistently as a syntactically dependent 'part of the whole'. At any rate it remains the fact that in the case of SB83 the overlapped global core lines are located at the periphery of the system (Fig 3.52 K and L). These lines are only seventh and eighth in the order of local integration.

1 As it has already been shown this same perimeter is also described by the choice core as measured for the whole sector B.
If 'peripheral overlaps' are disregarded, the 0.25 overlap observed for SB83 will be reduced to zero, so suggesting a higher degree of autonomy for SB83 despite the low figures for difference and definition. Both alternatives will be tested out when the syntactic description of SB83 is matched with land use distributions.

The performance of the SB east local areas in terms of the observed patterns of definition, differences and overlaps have reflected the significant changes occurred with the position of global core lines after the decomposition of the whole sector B (Tab 3.08). The dislocation of the core towards the centre of the system has provoked a chance in the overlap of all local areas. The results show that SB54 - the more orthogonal part of the grid at north - is more autonomous, in the syntactic sense, when it is measured as a part of SB east than as a part of the SB whole, when 50% of its local core are also global core lines. This decrease in overlap is more in tune with the strong definition observed for this system either as a part of the SB whole or as a part of SB east. Its difference also remains quite unchanged. That is to say apart form the decrease of overlap - which is expected in view of the change in the position of global core lines - SB54 has consistently performed as a syntactic autonomous system either as a part of the SB whole or as a part of SB east.

Similar performance was observed for the other local areas - SB127 and SB83 - in the sense that their definitions and differences have remained stable either in relation to the whole sector B or in relation to SB east so indicating a consistent attachment to the whole or, in other words, a consistent condition of dependence instead of a condition of autonomy. The overlaps observed for SB127 and SB83 have been kept inside the range earlier defined as a balanced overlap where local and global scale intermingle without the predominance of one or another. This pattern of
balanced overlap also includes SB54 (or SB44) when this system is measured as a part of SB east.¹

As a whole these results have shown that the decomposition of the whole sector B has generated two systems of interaction where, for both cases, a pattern of balanced overlaps is predominant. This applies both to SB west - analysed in the previous section - and to SB east where a pattern of low definitions, low differences and balanced overlaps was observed. These results seem to be supportive of the decomposition of the whole sector B, yet not in the same explicit way as the decomposition of sector A was proposed. While the syntactic autonomy of sector A east and west was made explicit throughout the analytic procedure, the emergence of somewhat contradictory results in the analysis of sector B has come in support of its syntactic non-divisibility. In view of that both alternatives - sector B as a whole and sector B decomposed in its east and west portions - will be taken into account when the syntactic information on this area is compared with land use distributions in chapters five and six of this thesis.

A final assessment on the problem of syntactic autonomy and dependence of portions of the street grid is part of an overall discussion on the decomposition strategy applied to the urban systems under investigation to be presented at the end of this chapter.

Correlations between syntactic measurements:
A search of regularities

This section has a two folded development. On the one hand it describes SB east from the standpoint of highest choice value lines, most connected lines and highest axial lengths, as it has been done for the other systems of interaction. The relationships between these

¹ When this part of the grid is measured as a part of SB east its overlap drops and under such conditions it oscillates between 0.16 and 0.20.
Fig. 3.53  SB east: choice core
Below integration core

Fig. 3.54  The whole sector B: integration and choice cores

Sector B: Integration Core

Sector B: SE highest choice value lines
measurements inside SB east will then be assessed, as it has been
proceeded for the other cases. In a subsequent step all correlations
observed between syntactic measurements - for the four systems of
interaction - will be compared. This exercise aims to verify whether any
regularities emerge in the performance of the observed correlation
coefficients in so far as the comparison between syntactic parameters
is taken for different parts of the grid, which carry contrasting grid
configurations.

Although the number of cases covered by this investigation is not enough
to produce a conclusive evidence on recurrent performances this
comparative assessment of correlations will provide indications both on
the extent to which syntactic measures are affected or tied up to the
each other and, moreover on the extent to which some of these
coefficients vary when systems are measured at the core level. These
variations in the relationships between syntactic parameters - both
from one system to another and also inside the same system when the
correlation is measured for core lines in separate - will be matched in
subsequent chapters with the performance of land use distributions in
each system.

The distribution of the highest value choice lines in SB east is mostly
superimposed to the integration core (Fig 3.53). This is a significant
change if the current integration and choice cores are matched with the
cores given by the whole Sector B before decomposition (Fig 3.54). In
that case while the choice core surrounds and enters the different local
areas, the integration core is concentrated at the northeast part of the
system especially inside SB54 the more orthogonal part of the grid. By
contrast under the current configuration (SB east) both cores describe
most of the contour of the proposed local areas yet the choice core will
include the interior of SB53, that is not reached by the most integrating
lines. From the fifteen highest value choice lines nine are also part of
the integration core but the orders of choice and integration are rather
distinct (compare maps above and below in Fig. 3.53). The correlation
Fig. 3.55 SB east: correlation analysis for choice and integration

**SB295 Logtransformations**

- Histogram of \( X_1 \): RRA
- Histogram of \( X_1 \): log(C) of RRA

**SB295 Bar Charts**

- Bar Chart for column: \( X_1 \): RRA
- Bar Chart for column: \( X_1 \): CHC

**SB295 Scatter Plots**

- Scatter plot: \( \log(C) \) of RRA vs. \( \log(C) \) of CHC

**Statistical Analysis**

- \( r = -0.50 \), \( p < 0.001 \)

**Correlation**

- \( CHC : RRA \quad R = -0.603 \quad (p < 0.0001) \)
Table 3.09 Sector A: correlations between syntactic measurements.

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SWest</th>
<th>SWest core</th>
<th>SEast</th>
<th>SEast core</th>
<th>SEast (hd)</th>
<th>SEast core (hd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHC:ARA</td>
<td>-.780</td>
<td>-.898</td>
<td>-.423</td>
<td>-.801</td>
<td>-.509</td>
<td>-.801</td>
</tr>
<tr>
<td>CON:ARA</td>
<td>-.800</td>
<td>-.350</td>
<td>-.336</td>
<td>-.293</td>
<td>-.480</td>
<td>-.712</td>
</tr>
<tr>
<td>CON:CHC</td>
<td>.714</td>
<td>.666</td>
<td>.614</td>
<td>.677</td>
<td>.589</td>
<td>.609</td>
</tr>
<tr>
<td>LEN:ARA</td>
<td>-.704</td>
<td>-.304</td>
<td>-.311</td>
<td>-.310</td>
<td>-.491</td>
<td>-.327</td>
</tr>
<tr>
<td>LEN:CHC</td>
<td>.581</td>
<td>.593</td>
<td>.755</td>
<td>.609</td>
<td>.589</td>
<td>.609</td>
</tr>
<tr>
<td>LEN:CON</td>
<td>.856</td>
<td>.755</td>
<td>.689</td>
<td>.609</td>
<td>.589</td>
<td>.609</td>
</tr>
</tbody>
</table>

Note: In the columns SEast (hd) and SEast core (hd) the lumps of axial lines given by the housing estates are not computed.

Table 3.10 Sector B: correlations between syntactic measurements.

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SBWest</th>
<th>SBWest core</th>
<th>SBeast</th>
<th>SBeast core</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHC:ARA</td>
<td>-.664</td>
<td>-.790</td>
<td>-.603</td>
<td>-.536</td>
</tr>
<tr>
<td>CON:ARA</td>
<td>-.673</td>
<td>-.154</td>
<td>-.565</td>
<td>-.272</td>
</tr>
<tr>
<td>CON:CHC</td>
<td>.810</td>
<td>.662</td>
<td>.682</td>
<td>.682</td>
</tr>
<tr>
<td>LEN:ARA</td>
<td>-.734</td>
<td>-.470</td>
<td>-.647</td>
<td>-.107</td>
</tr>
<tr>
<td>LEN:CHC</td>
<td>.669</td>
<td>.533</td>
<td>.689</td>
<td>.689</td>
</tr>
<tr>
<td>LEN:CON</td>
<td>.864</td>
<td>.689</td>
<td>.689</td>
<td>.689</td>
</tr>
</tbody>
</table>
between choice and integration is -.603 (p=.0001) (Fig. 3.55) and will remain rather stable at the core level (Tab 3.10).

A comparison of all cases examined during this section in terms of the coefficients observed for the correlation RRA:CHC (integration compared with choice) indicates distinctive performances for sectors A and B. The decomposition of the whole sector A has brought about two systems in which choice and integration relate in a rather contrasting ways (Tab 3.09). In SA west, the more griddy half of sector A, integration is -780 (p=.0001) correlated with choice. For SA east, the more labyrinthine half of sector A, the coefficient drops to -.423 (p=.0001). The coefficient is higher for the more griddy half of sector A where the analysis already carried out has shown that choice and integration tend to perform hand in hand while for more labyrinthine half of sector A the two measurements tend to perform more independently. In fact the comparative analysis of choice and integration for both these systems has shown that while in the first case (SA west) choice lines and integrating lines are to a large extent coincident (Fig. 3.24), for the second case (SA east) choice lines tend to cover parts of the grid that are not covered by integrating lines (Fig. 3.32). By contrast in the whole sector B the decomposition of the system has brought about parts where the correlation RRA:CHC is rather similar. The coefficients are -.664 for SB west and -.603 (p=.0001) for SB east (Fig 3.10). These results contradict the conjecture raised above since despite the ‘patchwork’ character already observed for SB east choice and integration remain fairly correlated inside that system.

The distribution of the most connected lines inside SB east shows as expected a concentration of high connectivities inside the more orthogonal part of the system (Fig. 3.56). Ten of the fifteen most connected lines are inside SB44, the local area at north in the system.

1 Table 3.09 shows that the correlation RRA:CHC for SAeast (SA418) is rather similar to the same correlation observed for the whole Sector A before decomposition (SA665). The figures are -.423 for SA418 and -.448 for SA665. The correlation for SA143 measured as a separate system (-.780) seems to provide another evidence on the extent of differentiation of this system in relation to the more labyrinthine half of Sector A (SAeast).
Fig. 3.56 SB east: 58 most connected lines
Below integration and choice cores
The most integrating line is just the eleventh in the order of connectivity. The picture given by a comparison between the two distributions suggests that integration and connectivity are hardly correlated in SB east, at least at the core level. The correlation between the two measurements is in fact low and confirms what visual inspection suggests. The coefficient is \(-0.272\) (\(p=0.4456\)) (Tab 3.10). Nevertheless if the number of observations is expanded so including all lines the correlation increases to \(-0.565\) (\(p=0.0001\)) (Fig 3.57 A).

Here again - same as it has happened to the observed variations in the relationship between integration and choice - the 'intelligibilities' observed for SB west and east are just marginally distinct especially if we compare with the way in which connectivity and integration are correlated in sector A (Tab 3.09 and 3.10). In that case while for SA west the figure for intelligibility is as high as \(-0.800\), for SA east it drops sharply to \(-0.336\). By contrast for the SB systems 'intelligibility' varies just from \(-0.673\) in SB west to \(-0.569\) in SB east, a change that compared with the strong decrease observed for the systems emerged out of the decomposition of sector A is rather marginal. These similar intelligibilities might also be taken as a further evidence in support of the conjectured syntactic unity or non-divisibility of the whole sector B.

The correlation between connectivity and choice (CON:CHC) for SB east is higher than RRA:CON, same as it has been for all systems observed except for SA west where RRA:CON is just slightly higher (Tab 3.09). Yet the correlation CHC:CON remains high for all cases observed, it has systematically followed RRA:CON in respect of variations at the core level. Nevertheless the high correlations observed for CHC:CON when all observations are computed do not allow much room for comparisons and further hypothesis on the syntactic performance of the urban systems under scrutiny. The observations coming from the current sample suggest that the association between connectivity and choice might be seen more as a general characteristic - maybe common to most urban systems - than a feature of specific grid configurations. By contrast the
Fig. 3.57 SB east: correlation analysis for connectivity against integration and choice.

Histogram of Fig: CON

Bar Chart for analysis: log CON

\[ y = -1.001x + .272, R^2 = .22 \]

\[ y = .199x + 1.235, R^2 = .439 \]

CON: RRA \( R = -.565 \) (\( p = .0001 \))

CON: CHC \( R = .662 \) (\( p = .0001 \))
correlation RRA:CON by varying conspicuously from one system to another seem to provide a significant description for a precise characteristic of urban systems, a characteristic that seems to be inherent just to some urban areas yet lacking in others. This precise characteristic has been described by Hillier as the syntactic ‘intelligibility’ of an urban system.

Fig. 3.58 shows the 5% longest lines in SB east. These lines are concentrated in the north part of the system yet to a lesser extent than the most connected lines. Nevertheless, same as for that case the position of the longest lines is totally detached from the integration core. Lengths and integration are in fact hardly correlated at the core level. The correlation is -.107 (p=.5746) (Tab 3.10). Although if the computed observations are extended to all lines the correlation increases to -.647 (p=.0001) (Fig. 3.59 A). It is particularly interesting that the correlation between axial lengths and integration increases and decreases following intelligibility - as given by the correlation RRA:CON - all systems compared (Tab 3.09 and 3.10). The combined variation of these correlations - RRA:CON and RRA:LEN - indicates that the syntactic intelligibility of the four systems of interaction under scrutiny (SA east and west; SB east and west) is very much associated with the length of the axial lines that compose the system. It is relevant to stress once again that the measurement of length is not referred to the length of streets, but to the length of the various axial segments that compose different streets. As such the measurement of axial length describes a precise architectural property that is distinctive for each part of the public open space in an urban area, a property that according to the results observed above is strongly associated with the syntactic intelligibility of the system. These results by retrieving a consistent association between axial length and intelligibility seem to depict, from the syntactic standpoint, a precise perceptual feature of urban areas.1 In other words what intuition suggest in respect of the ‘perceptual

1 ‘Perceptual’ is applied here in the sense utilized by Lynch namely for describing how the urban space is perceived by people.
Fig. 3.59 SBeast: Correlation analysis for length against integration, choice and connectivity.
dimension of the urban space is to a large extent matched by the syntactic description of intelligibility.

The correlation between length and choice for SB east is .533 (p=.0001) (Fig. 3.59 B). The coefficient is lower than the one observed for length against integration so reproducing the performance observed for all previous cases (Tab 3.09 and 3.10). In effect the coefficients observed between length and choice, following the observed relationship between choice and connectivity, remain rather stable throughout the sample so preventing further conjectures beyond the implicit association between these measurements. The correlation between length and connectivity in SB east is lower than when measured for SB west (Tab 3.09). In that case (SB west) the coefficient was .864 (p=.0001) while for the current case (SB east) it has dropped to .689 (p=.0001) (Fig 3.59 C). It is noteworthy that a similar output was observed for sector A. In that case while for SA west the coefficient is as high as .856 (p=.0001), for SA east it drops to .609 (p=.0001). These figures suggest that the association between length and connectivity is high for the two more griddy systems where long axial lines predominate (SA west and SB west). For the more labyrinthine patterns where the short axial lines predominate (SA east and SB east) the association between the two measurements tends to decrease (Tab 3.09 and 3.10).1

The performance of the different systems at the core level has also allowed for the observation of a number of regularities.2 Fig. 3.60 shows that in SB east while both the longest and the most connected lines are strongly concentrated inside one specific part of the system, the most integrating and the highest choice value lines are much spread throughout, especially the choice core that include lines and entire parts of the system, that are not reached by the integration core whose

---

1 The description of grid configuration in terms of average length and mean connectivity is to be dealt with in chapter four.
2 The 'core level' referred to here is not necessarily the integration core. Instead it refers to the sets of axial lines at the top of the different ranks namely the ranks of integration, choice, connectivity and axial length.
description seems to be less global than the description given the distribution of the highest value choice lines. This characteristic - concentration of the longest and the most connected lines in one local area and distinct spreads for choice and integration cores - was also observed in SA west where the 5% longest lines and the 5% most connected are strongly concentrated inside the more orthogonal part of the system and, at the same time, the choice core includes lines that are not allowed to the integration core (Fig. 3.60).

For the east part of sector A (SA east) the performance identified above stands but only if the short axial lines given by the housing estates are not computed. If the lumps of short axial lines are computed all cores - integration, choice, connectivity and length - are pushed into the southeast part of the system. Nevertheless if the lines given by the housing estates are deleted the highest choice value lines will spread into areas that are not reached by the integration core whose description remains more concentrated around the central spine (Fig. 3.60). Also confirming what was observed for SA west, the longest lines are strongly concentrated in the southeast part of the system. By contrast the pattern described by the most connected lines is very much spread throughout the system, clearly approximating the distribution of the most integrating lines and as such they contradict the conjectured model. In SB west the four descriptions seem to intermingle, although the sixth line in the order of choice penetrates right into the middle of SB30, the local area at south that is kept apart from the integration core. This characteristic seems to reproduce, yet to a lesser extent, the regularity - concentration of integration coupled with the spread of choice - observed for the other systems of interaction.

The pattern of correlations presented in this section has revealed a number of regularities in the performance of the different systems. These regularities are summarized in the following way. The correlation

---

1 The correlation between connectivity and integration for SA299, at the core level, is \(-.712, p=.0001\).

2 SB30 is kept apart from the integration core even if the core is 10% expanded.
between connectivity and integration (RRA:CON) and the correlation between choice and integration (RRA:CHC) go up and down together in all cases when all observations are computed. At the core level RRA:CON (intelligibility) tend to decrease strongly, while RRA:CHC tend to increase. This is true for all systems except for SB east where intelligibility increases at the core level. Choice and connectivity are strongly correlated for all systems. Length is consistently more associated with choice than with integration. Both RRA:CON and RRA:CHC tend to decrease for the more labyrinthine configurations yet to a lesser extent in sector B. The significance of these results will be reassessed in chapter four, when the parts emerged out of the proposed decompositions will be compared from the standpoint of a range of descriptions of grid configuration.

Notes on chapter 3:
Three Orders of Decomposition

Two parallel, if not coincident, targets were aimed at the outset of this chapter. One was to provide a spatial description for the current sample of urban grids and for that a syntactic analysis was applied as the descriptive instrument. The second - which is a prerequisite for the accomplishment of the first - was the setting up of objective criteria in order to decompose the street grid for analytical purposes.

Visual inspection had made clear from the outset that inside the current sample a variety of distinct grid configurations coexist side by side within the global spatial continuity provided by the urban grid so 'composing' such a global spatiality as well. How to define the size of these parts, how to assess their relationship with the whole and moreover how to define how large such a whole or larger surroundings (which affect the syntactic performance of the part) are became necessarily the specification of the general target initially stated. In other words description and decomposition have then become coincident
insofar as it was acknowledged that despite the overall spatial continuity some 'portions' of the street grid are in fact more related or connected - in syntactic terms - to the surrounding areas than others. The problems of how to describe objectively the size of these 'portions', their degree of dependence or autonomy in relation to their surrounding areas and more over the size of the larger surroundings that affect their syntactic performance, have become the central issues to be dealt with.

The range of criteria applied in order to clarify these issues have performed complementary. The measurement of traverse permeability proposed at the outset, in spite of its explicit local character, has proved itself a useful tool for detecting specific parts of the grid - the so called sections where discontinuities are predominant. Furthermore the matching of ruptures in traverse permeability with the highest choice value lines has not only enlarged the scope of possible boundaries but also provided a syntactic confirmation for the set of boundaries initially conjectured. Although some exceptions were noticed where the two criteria do not match for most cases ruptures in traverse permeability were consistently confirmed by the choice criterion.

In a subsequent step the parts emerged out of the decomposition strategy referred to above have been tested out in terms of the extent of their dependence or autonomy in relation to the whole systems initially proposed. The performance of the pattern of integration inside each conjectured local area - as given by overlaps, definitions and differences - was taken as a parameter for measuring the extent of the autonomy of each part.\(^1\) These measurements as a whole have performed as effective tools yet some collisions between indications of autonomy and indications of dependence have also emerged. In these cases both descriptions will be taken into account as reference in further analysis.

\(^1\) For the first order decomposition of sectors A and B, the results emerged out of the performance of overlaps, definitions and differences have also been matched with the radius three cores of both areas, which have confirmed the proposed decomposition.
Fig. 3.61 Decomposition diagrams
Besides the performance of the pattern of integration - as given by overlaps, definitions and differences - has provided a quite effective parameter for comparing the syntactic performance of alternative configurations or alternative boundaries for the same area. Moreover the combined performance of these measurements has also provided an efficient way of testing out the same local area against different embeddings so allowing for an assessment of how each of them perform in relation to the proposed systems of interaction which eventually are conjectured as being the larger surroundings that affect their syntactic performance.\footnote{As it has already been said, a further assessment on the performance on the boundaries proposed during this chapter is given during chapters five and six when syntactic descriptions are matched with land use distributions.}

The output given by this chapter is summarized in the decomposition diagram given in Fig 3.61 which includes all alternative boundaries conjectured for the current sample of grid configurations. Three orders of decomposition have emerged. In the first order the wholes sectors A and B are decomposed in four systems of interaction (SA east and west, SB east and west) plus the local areas centrally positioned whose global syntactic description is conjectured as given by their interaction with both east and west sides. The second order is given by the decomposition of the four systems of interaction in eleven local areas. The global description of these local areas is conjectured as given by their embedding in the four proposed systems of interaction.\footnote{As it has already been explained, for subsequent analysis all SB local areas will also be assessed in terms of their syntactic relationship with the whole sector B, while the SA local areas will be assessed just as a part of either SA east or west as the output given by the patterns of integration has recommended.} The third order is given by the further decomposition of some of the conjectured local areas in view of significant syntactic features observed in these systems. The decomposition strategy depicted in the diagrams given in Fig 3.61 contains all systems whose configuration is to be described during chapter four and whose relationships with patterns of land use distribution will be assessed in chapters five and six.
Fig. 4.01 Typologies of urban grids

**SPATIAL ORGANIZATIONS**

1. **CENTRALIZED**
   - A central, overall space with a number of secondary spaces organized.

2. **LINEAR**
   - A linear sequence of secondary spaces.

3. **RADIAL**
   - A central space from which linear organizations of spaces extend in a radial manner.

4. **CLUSTERED**
   - Spaces grouped by proximity or the sharing of a common urban tissue or relationship.

5. **GRID**
   - Spaces organized within the field of a structure or other three-dimensional grid.

**Krier's**

**Ching's**

**Spreiregen's**

**Lynch's**
The literature reviewed during chapter two has presented a number of attempts by different authors to describe the configuration of the urban grid. As a whole the works reviewed share the common feature of being quite ineffective in the description of actual grid configurations, as the ones under investigation in this thesis, and especially as instruments of comparison between actual cases (Fig. 4.01). These 'typologies' are in broad terms either too simple to be useful - radial/orthogonal, regular/irregular and so on - or so detailed as to be idiosyncratic. This is particularly evident in the more detailed classifications, such as Lynch's or Krier's, for whom the matching with actual urban grids - where the spatio-morphological continuum carries configurations whose distinction merges almost imperceptibly into one another - shows in a straightforward way the narrow limits of such classification efforts.

Instead of following the path given by the works referred to above - and so providing another list of 'types of grids' - the description of configuration to be carried out in what follows will examine the quantitative dimensions of the spatial continuum in order to verify the internal logic of relations between spatial variables. Having the proposed sample of street grids already decomposed, this chapter attempts to describe the range of configurations observed in the parts which emerged out of the proceeded decomposition. The analytical instruments to be applied are aimed at investigating the wide range of subtle changes in configuration between the limiting cases of explicit 'griddy' or orthogonal systems and conspicuous 'labyrinthine' patterns, all interacting within the current sample of urban grids.

The analysis so far carried out have described each system (the conjectured local areas and also their systems of interaction) in terms of the syntactic identity of each individual axial line as expressed by
their corresponding ranks.\textsuperscript{1} By contrast this chapter describes each system (and compares different systems) in terms of the mean value observed for each syntactic measurement. In other words grid configuration will be described in terms of the \textit{syntactic identity of each system} as a whole as given by the mean value of the measurements observed for all axial lines inside the system of interest. In other words while the analysis so far carried out has concentrated mostly on \textit{line effects}, the analysis that follows will concentrate in \textit{system effects}, as given by a range of \textit{descriptions of grid configuration}.

The configuration of each system will be initially described in terms of the mean values observed for 'deep structure' measurements namely integration and choice. Furthermore it will be assessed how these two descriptions relate. This is followed by a description of the pattern of 'syntactic intelligibilities' as given by the correlations between integration and connectivity observed for all systems in the current sample. The description of intelligibility includes an assessment of how this measurement is affected by variations in 'scale' and 'size', and moreover how syntactic intelligibility relates to the pattern of integration.\textsuperscript{2}

In a subsequent step grid configuration will be described in terms of a set of \textit{immediately graspable} or \textit{visually observable} features which have already been noticed for the different systems in previous analysis, yet not observed in a systematic way.\textsuperscript{3} These features which are more conspicuous in some cases and more subtle in others, include the different degrees of 'axial fragmentation' observed for the different systems, the average length of the axial lines, the pattern of ringyness of the system, the pattern of connectivities and finally the proportion between 'solids' and 'voids', which might be seen as a 'figure-ground

\textsuperscript{1} Except for the analysis of differences and definitions which has been based on the comparison of mean RRA values.

\textsuperscript{2} The distinction made here between scale and size in the context of the current analysis will be further explained.

\textsuperscript{3} The measurements that describe these immediately graspable features in the context of this investigation have already been referred to during chapter two.
ratio'. The parameters that are taken into account for measuring this set of qualities are explained in what follows.

It is suggested here that the understanding of the performance of these 'visually observable' features might bring about a set of useful urban design tools at straight reach of the eyes and hand of the urban designer, possibly even in a more straightforward way than 'deep structure' measurements - patterns of integration, distribution of shortest paths, intelligibility - whose identification through direct visual inspection is less accessible and can easily misguide the observer and whose more accurate measurement will necessarily require computer generated analysis and modelling. In effect the visually observable features proposed here seems to perform as a sort of façade which to a large extent embodies and anticipates the deeper syntactic identity of each urban area.\(^1\) The proposed set of visually observable characteristics will be assessed both in terms of the extent of their association to each other and also in terms of their association with mean values given by 'deep structure' measurements.

**Integration and choice: Mean values**

Patterns of integration will be discussed in what follows in terms of the mean integration value observed for each one of the conjectured local areas or, in other words, the mean given by the integration values of all axial lines belonging to the system of interest. As it has already been shown the mean integration value of a system has both a local description, that is given by the measurement of the system as detached from its surroundings, and a global description, given by the mean integration value observed when the system is measured as a part of the proposed systems of interaction. In other words distinct mean integration values will emerge insofar as the same system is measured

\(^1\) These characteristics are supposed to be 'visually observable' not only in the inspection of the cartographic material but also observable 'in situ'.

Fig. 4.02 Ranks of mean integration and mean choice values

Table 4.01
Mean integration and mean choice values

<table>
<thead>
<tr>
<th>Syst Code</th>
<th>RRA</th>
<th>RRA/</th>
<th>RRA//</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR143</td>
<td>.53</td>
<td>.53</td>
<td></td>
</tr>
<tr>
<td>SR60</td>
<td>.42</td>
<td>.48</td>
<td></td>
</tr>
<tr>
<td>SR50</td>
<td>.33</td>
<td>.45</td>
<td></td>
</tr>
<tr>
<td>SR34</td>
<td>.45</td>
<td>.49</td>
<td></td>
</tr>
<tr>
<td>SR77</td>
<td>.59</td>
<td>.55</td>
<td></td>
</tr>
<tr>
<td>SR39</td>
<td>.60</td>
<td>.53</td>
<td></td>
</tr>
<tr>
<td>SR21</td>
<td>.58</td>
<td>.54</td>
<td></td>
</tr>
<tr>
<td>SR16</td>
<td>.43</td>
<td>.60</td>
<td></td>
</tr>
<tr>
<td>SR128</td>
<td>.64</td>
<td>.74</td>
<td></td>
</tr>
<tr>
<td>SR418</td>
<td>.82</td>
<td>.82</td>
<td></td>
</tr>
<tr>
<td>SR299</td>
<td>.87</td>
<td>.87</td>
<td></td>
</tr>
<tr>
<td>SR71</td>
<td>.86</td>
<td>.85</td>
<td></td>
</tr>
<tr>
<td>SR72</td>
<td>.70</td>
<td>.80</td>
<td></td>
</tr>
<tr>
<td>SR104</td>
<td>.89</td>
<td>.89</td>
<td></td>
</tr>
<tr>
<td>SR184</td>
<td>.66</td>
<td>.76</td>
<td></td>
</tr>
<tr>
<td>SR169</td>
<td>.69</td>
<td>.61</td>
<td></td>
</tr>
<tr>
<td>SR186</td>
<td>.62</td>
<td>.62</td>
<td></td>
</tr>
<tr>
<td>SR418</td>
<td>.82</td>
<td>.82</td>
<td></td>
</tr>
<tr>
<td>SR299</td>
<td>.87</td>
<td>.87</td>
<td></td>
</tr>
<tr>
<td>SR71</td>
<td>.86</td>
<td>.85</td>
<td></td>
</tr>
<tr>
<td>SR72</td>
<td>.70</td>
<td>.80</td>
<td></td>
</tr>
<tr>
<td>SR104</td>
<td>.89</td>
<td>.89</td>
<td></td>
</tr>
<tr>
<td>SR184</td>
<td>.66</td>
<td>.76</td>
<td></td>
</tr>
<tr>
<td>SR169</td>
<td>.69</td>
<td>.61</td>
<td></td>
</tr>
<tr>
<td>SR186</td>
<td>.62</td>
<td>.62</td>
<td></td>
</tr>
<tr>
<td>SR418</td>
<td>.82</td>
<td>.82</td>
<td></td>
</tr>
<tr>
<td>SR299</td>
<td>.87</td>
<td>.87</td>
<td></td>
</tr>
<tr>
<td>SR71</td>
<td>.86</td>
<td>.85</td>
<td></td>
</tr>
<tr>
<td>SR72</td>
<td>.70</td>
<td>.80</td>
<td></td>
</tr>
<tr>
<td>SR104</td>
<td>.89</td>
<td>.89</td>
<td></td>
</tr>
<tr>
<td>SR184</td>
<td>.66</td>
<td>.76</td>
<td></td>
</tr>
<tr>
<td>SR169</td>
<td>.69</td>
<td>.61</td>
<td></td>
</tr>
<tr>
<td>SR186</td>
<td>.62</td>
<td>.62</td>
<td></td>
</tr>
<tr>
<td>SR418</td>
<td>.82</td>
<td>.82</td>
<td></td>
</tr>
<tr>
<td>SR299</td>
<td>.87</td>
<td>.87</td>
<td></td>
</tr>
<tr>
<td>SR71</td>
<td>.86</td>
<td>.85</td>
<td></td>
</tr>
<tr>
<td>SR72</td>
<td>.70</td>
<td>.80</td>
<td></td>
</tr>
<tr>
<td>SR104</td>
<td>.89</td>
<td>.89</td>
<td></td>
</tr>
<tr>
<td>SR184</td>
<td>.66</td>
<td>.76</td>
<td></td>
</tr>
<tr>
<td>SR169</td>
<td>.69</td>
<td>.61</td>
<td></td>
</tr>
<tr>
<td>SR186</td>
<td>.62</td>
<td>.62</td>
<td></td>
</tr>
<tr>
<td>SR418</td>
<td>.82</td>
<td>.82</td>
<td></td>
</tr>
<tr>
<td>SR299</td>
<td>.87</td>
<td>.87</td>
<td></td>
</tr>
<tr>
<td>SR71</td>
<td>.86</td>
<td>.85</td>
<td></td>
</tr>
<tr>
<td>SR72</td>
<td>.70</td>
<td>.80</td>
<td></td>
</tr>
<tr>
<td>SR104</td>
<td>.89</td>
<td>.89</td>
<td></td>
</tr>
<tr>
<td>SR184</td>
<td>.66</td>
<td>.76</td>
<td></td>
</tr>
<tr>
<td>SR169</td>
<td>.69</td>
<td>.61</td>
<td></td>
</tr>
<tr>
<td>SR186</td>
<td>.62</td>
<td>.62</td>
<td></td>
</tr>
<tr>
<td>SR418</td>
<td>.82</td>
<td>.82</td>
<td></td>
</tr>
</tbody>
</table>
either as detached (RRA) or as interacting with larger surroundings (RRA/and RRA/) (Tab 4.01).

This is so for all SA and SB local areas except SA16, SA128 and SA69 whose systems of interaction will be the whole of sectors A and B, as the syntactic analysis has recommended. It is also worth recalling that the analysis carried out during chapter three has not provided a conclusive evidence in support of the decomposition of the whole sector B, at least not in the clear way that it has recommended the decomposition of sector A. As a consequence for all SB local areas the mean integration values apart from being measured for all systems as detached will also consider all local areas both as a part of 'immediate surroundings' (SB east and SB west) and eventually as a part of the whole sector B.1

In the rank of mean integration values measured for all systems as detached (RRA) the most integrated of all local areas is SA30, the 'portion' of the orthogonal grid right at the centre of SA west (Fig. 4.02 A).2 This same system is also the most integrated when all systems are measured as embedded (Fig. 4.02 B). As a whole the ranks shown in bar charts A and B clearly indicate that the so called 'griddy' or more orthogonal systems are all at the bottom of the ranks as the most integrated, while the visually observed 'labyrinthine' systems tend to be amongst the most segregated carrying the highest mean RRA values.3 This applies both for mean RRA values locally measured and for RRA values measured for the systems as embedded in the proposed systems of interaction.

1 These measurements are given in Table 4.01 where values observed for systems as detached are coded 'RRA', values as embedded in either SB west or SB east are coded 'RRA/' and values as embedded in the whole sector B are coded 'RRA//'.

2 The decomposition diagrams presented at the end of chapter three can also be opened from the back cover of this volume as a reference map so allowing the reader a simultaneous observation of the axial maps (and codes) emerged from different decompositions while following the analytical procedure.

3 As it has already been explained from the syntactic standpoint the lower is the mean RRA value the more integrated is the system.
Fig. 4.03 Housing estates and the global core lines

SA84 as a part of SAeast

SB45 as a part of SBeast
The integration ranks also show that either measured as detached or interacting with surrounding systems the visually observed more 'griddy' systems tend to be amongst the most integrated. In other words, systems that are well integrated locally tend for most cases to be also amongst the most integrated globally.\(^1\) And so it is both amongst SA and SB systems. SA16 - the orthogonal grid at the centre of sector A - is an exception. This system is just the second in the rank of mean RRAs measured as detached, yet as embedded it drops to the middle of the rank. It is noteworthy that it is precisely as embedded in the whole sector A that SA16 has its mean RRA value lowered. Such a 'difference' has already been regarded as an evidence in support of the syntactic autonomy of this system.

Another exception is given by SA184, the system that carries large lumps of short axial lines at the east of sector A. This system is positioned at the middle of the integration rank, either as a detached or as an embedded system, showing clearly the integrating role played by the long axial lines that connect the 'central spine' of global core lines to the lumps of housing estates (Fig 4.03 A).\(^2\) A similar phenomenon happens in SB45, the local area that contains the housing estates right at the middle of SB east (third order decomposition). This system is the fourth most segregated system measured as detached. Nevertheless when measured as a part of SA east it comes to the middle of the rank of integration showing clearly the integrating role played by the ring of global core lines that explicitly surrounds this part of the street grid (Fig. 4.03 B).

These observations suggest that the problem of spatial segregation often observed in housing estates is more a problem of the way in which these developments are related to their immediate surroundings than a consequence of their internal arrangement. Both in SB45 and in SB184

---

\(^1\) Compare the ranks expressed in the bar charts with the reference map.

\(^2\) This characteristic has already been observed in chapter three during the syntactic analysis of this particular system.
Fig. 4.04 Correlation analysis for integration and choice.

**A**

\[ r = 0.86 \ (p = 0.0004) \]

**B**

\[ r = 0.658 \ (p = 0.0326) \]

**C**

\[ r = 0.466 \ (p = 0.2946) \]

**D**

\[ r = 0.903 \ (p = 0.0137) \]

**E**

\[ r = 0.01 \ (p = 0.9635) \]

**F**

\[ r = -0.204 \ (p = 0.3826) \]
the lumps of short axial lines given by the housing estates are adjacent to global core lines. While the first is surrounded by the core the second is penetrated by it. As a consequence both systems, despite the lumps of short axial lines, are not amongst the most segregated when measured as embedded.

The strong association between local integration (RRA) and global integration (RRAemb), as observed for the most part of the bar charts, is confirmed in the correlation coefficient between the two measurements. When all the systems are compared (SA and SB) the mean RRA values observed for the different systems as detached are 0.860 (p=.0001) correlated with mean RRA values observed for these same systems as embedded (Fig 4.04 A).1 This seems to confirm the conjecture which emerged from the visual inspection of the bar charts. When a system is well integrated locally it tends also to be well integrated globally and vice-versa, i.e. the most segregated systems as locally measured tend to be the most segregated globally as well. SA16, the system that has performed as an exception to this rule, appears as an outlier in the scattergram.2

Nevertheless the proposition above - the linkage between local and global performances of integration - seems to hold just inside a specific set of boundaries, i.e. just when each local area is measured as a part of the proposed systems of interaction. If the system of interaction is further enlarged the correlation will decrease. This is what happens when the system of embedding for the SB systems is enlarged from SB east and west (RRA/) to the whole sector B (RRA//). The correlation drops to 0.658 (p=.0328).3 The low probability of the correlation

---

1 The tests of normality carried out for these two measurements have shown that the sample of mean RRAs has a rather normal distribution, while the mean RRAs embedded have a rectangular distribution with a slight negative skewness. The logtransformation of RRAemb has brought about a strong positive skewness. In view of that both measurements are used here in their linear form.

2 SA16 is the black dot in scat. 1 (Fig. 4.04).

3 The mean RRAs for the SB systems measured as embedded in the whole sector B are coded as RRA// in table 4.01.
reflects the rather dispersed distribution of points in the scattergram (Fig 4.04 B). If, for a further test, the RRAs brought about by the two embeddings proposed for sector B are compared to the each other - RRA/ and RRA/\ - the correlation drops further to 0.466 (p=.2446). The inspection of the scattergram shows that two particular systems perform as strong outliers, contrasting with an apparent linearity observed for the distribution of the remaining points (Fig 4.04 C). These two points represent SB30 and SB62 (black dots in the scattergram). Their performance in the scatter diagram provides another description for the strong 'differences' observed when these two local areas are measured as a part of the whole sector B.

If SB30 and SB62 are not computed - so following the proposed decomposition of sector B - the correlation between the mean RRAs given by the two different embeddings increases to .903 (p=.0137) (Fig 4.04 D). This output shows that while the association between mean RRAs 'as detached' and mean RRAs 'as embedded' tends to decrease insofar as the system of interaction is enlarged (scattergrams A and B), the correlation between the mean RRAs measured for different embeddings - as it has been proposed for the SB systems - will remain rather stable at the level of the coefficient initially observed between local and global RRA values (compare coefficients given by scattergrams A and D).

The sample of mean RRA values presented in table 4.01 also allows for some conjectures with respect of the relationship between patterns of integration and the size of the systems as given by the number of axial lines. The 'larger' SA143 (SA west) is less integrated than SA60, that is precisely its more griddier part (see reference map). Nevertheless SA143 is more integrated than SA77, that is its other part after decomposition. A similar phenomenon happens if the mean RRA values of the other systems of interaction are compared with the mean RRA values of the local areas into which they are decomposed (tab 4.01). These measurements seem to indicate that integration and size are virtually
independent. Nevertheless if the rank of local areas is examined as a whole - that is to say without taking notice of the correspondence between systems of interaction and local areas - it becomes apparent that the systems with the fewest and the longest axial lines are at the bottom of the rank as the most integrated, so suggesting that, for the present sample insofar as size - as given by the number of axial lines - increases there is a tendency of increase in the mean RRA values (decrease of integration).

The question of the relationship between RRA and size has already been dealt with in the literature of urban design. Hanson (1989) has studied a theoretical sample of orthogonal grids and concluded that for this particular case the mean RRA tends to decrease consistently insofar as the grid is enlarged.¹ On the other hand, for a sample of theoretical radial grids Hanson's experiments have shown that for this particular case the mean RRA will increase consistently with size.² In dealing with a large sample of real cases Hillier et al (1987) have concluded that 'the mean integration of urban layouts of all kinds is .93, and this is not influenced by size; layouts can be more or less integrating regardless of scale; this confirms a property often noticed in individual town studies, that as towns grow they maintain their overall degree of integration more or less constant.³

The current sample of grid configurations includes cases that approximate the perfect orthogonal grid (SA30, SA16, SB44), cases that approximate a radial grid (SB295, SB69) and a range of cases that seem to mix the two polar cases as it comes to happen for most real towns. If all systems in the current sample are compared the correlation between

¹ For a theoretical orthogonal grid with ten axial lines the mean RRA value is .3636. If the grid is enlarged for 18 lines the mean RRA drops to .2479 and as enlarged to 80 lines the mean RRA will be .1288. Hanson, J. Order and Structure in the Urban Space: A morphological history of the city of London, op. cit. p. 92.
² ibid., p.96. In this case for a system with twenty one lines the mean RRA will be .43. For a system with fourteen lines, .38 and for a system with eight lines, .36.
Fig. 4.05 Correlation analysis for integration and size

A

\[ y = 0.36x + 0.10, \text{R}^2 = 0.455 \]

\[ R = 0.634 \ (p = 0.0004) \]

B

\[ y = 0.34x + 0.012, \text{R}^2 = 0.307 \]

\[ R = 0.597 \ (p = 0.0033) \]

C

\[ y = 0.21x + 0.297, \text{R}^2 = 0.254 \]

\[ R = 0.504 \ (p = 0.0124) \]

D

\[ y = 0.207x + 0.22, \text{R}^2 = 0.445 \]

\[ R = 0.666 \ (p = 0.0356) \]
the mean RRAs and the size of the systems as given by the number of
textlines is 0.634 (p=.0004). For this test all local areas are measured as
detached from their surroundings and the systems of interaction are also
included (Fig 4.05 A). If the ‘larger’ systems of interaction are not
computed the correlation decreases to 0.597 (p=.0033) (Fig 4.05 B).
Both correlations suggest that the increase in size tends to be followed
by a decrease in integration. Even though the sample is small both
correlations present probability values inside acceptable limits (<.005)
and a fairly homogeneous distribution of points in the scattergram. The
evidence presented here – which indicates a systematic decrease in
integration insofar as the size of the system increases – is made
stronger if we consider that when the larger systems of interaction are
included the correlation becomes stronger. If instead of mean RRA values
‘as detached’ we compare size with the mean RRAs as embedded the
coefficients decrease just marginally yet remaining significantly high as
scatter diagrams C and D indicate (Fig 4.05).1

Next step in this analysis mean integration values are compared with
mean choice values observed for the different systems. The rank of mean
choice values presented in bar chart C (Fig 4.02) seems to reflect the
position of each local area with relation to the system of interaction it
is a part. That is to say, SA59 and SA30 are the systems which carry the
axial lines more centrally located inside SA west, both from the
topological and also from the geometric standpoint. The same happens to
SB45, the third highest mean choice value, a system that is centrally
located inside SB east and also to SA128 in relation to the whole sector
A (see reference map). The comparison between integration and choice
ranks seems to provide a fair description for the extent of
differentiation of the two measurements this time from the standpoint
of their mean values.2 Bar chart B (Fig 4.02) shows that the most
integrated systems – both at the global and at the local scale – are all

1 Yet for these cases the probability of the correlations drops outside the acceptable limits.
2 A comparative analysis on the performance of integration and choice, at the level of values
assigned to individual axial lines, has already been presented in chapter three of this thesis.
inside SA west and also that systems that are located more peripheral inside larger areas, such as SA34 and SA21, can also be highly positioned in the rank of integration. In other words the 'shallowness' condition required for a line or system to be well integrated is not necessarily related to centrality in the geometric sense, but it is more a topological property. By contrast the shortest path condition, that must necessarily be met for a high choice value, seems to be related to centrality in the sense of belonging to a central position inside the larger area where the system is embedded.

The correlations between mean choice values and mean integration values, as the visual inspection of the bar charts suggests, are non-existent. All systems in the current sample compared choice is totally uncorrelated with RRA and \(-0.201 \ (p=.3826)\) correlated with RRAemb (Fig 4.04 E and F). It is noteworthy to clarify that while integration has been measured both locally (for systems as detached) and also globally (for systems as embedded in larger areas), the measurements of choice have always considered each system as a part of the larger area it belongs, so satisfying the strict global nature of the measurements. By contrast the measurement of integration even when it is locally measured, i.e. for systems as detached from their surroundings, will express a pattern of integration locally observable which despite being distinct from the RRA values embedded will be strongly associated to those, as the correlation analysis has suggested.

**Intelligibility, Scale and Size**

The syntactic concept of intelligibility describes how patterns of integration are associated with connectivity. Its measurement is given

---

1 Compare ranks of mean integration values and the reference map.
2 The mean choice values presented in table one are mean values taken from choice measurements already logtransformed.
3 'Larger area' is used here as another way of referring to the proposed 'system of interaction' the local area is supposed to belong.
by the extent to which RRA values are associated with the number of intersections observed for each axial line.\(^1\) While the number of intersections is a local (and constant) characteristic of each axial line, the mean depth as it has been shown can vary, sometimes strongly, for the same line measured as a part of different 'embeddings' and, as a consequence, for the same area measured as a part of different larger areas or systems of interaction. In view of that, patterns of integration have been measured both from the standpoint of the mean RRA of each local area - measured as an isolated grid detached from its surroundings - and also from the standpoint of the mean RRA for each local area as embedded into larger surroundings.

These variations in the mean depth of each axial line - as measured for different systems of embedding - allows for the conjecture that the same urban system might also be 'intelligible' in different ways, all depending on the system of reference according to which it is observed or measured. This conjecture, whilst it carries a strict syntactic basis, seems to reflect what happens in real towns where the 'perception' of the parts - districts or even part of districts - can vary strongly all depending on the standpoint of the observer. In other words the different parts of a town will be intelligible in different ways for observers located at different points. This multi-sided character of urban intelligibility has already been noticed by Lynch in a survey on the perceptual dimension of the urban space. Lynch's questionnaires have shown that the prominence of a street in the minds of inhabitants is increased by 'the visual exposure of the path itself or the visual exposure from the path to other parts of the city':\(^2\) The statement carries a clear reference to the role of the global scale of a town in affecting the performance of particular axes where the superimposition of how far one

\(^1\) The measurement of syntactic intelligibility in urban systems has been originally proposed in Hillier et al (1986): 'the correlation between local and global properties (RRA and connectivity) might be a mathematical way of expressing the intelligibility of a system, in the sense of how well the properties of the system as a whole can be understood from its parts'.

Hillier et al. \textit{Spatial configuration and use density at the urban level: towards a predictive model}, op.cit. p. 6.

\(^2\) Lynch, K. \textit{The image of the city}, op.cit. p. 51.
can see and how far one can walk - which is the essence of the axial line - is a determinant factor. Lynch eventually suggests following the perceptual approach of his thesis that 'there is a pleasant feeling of relationship to be gained simply from standing on a street which continues to the heart of the city, however far'.

This section provides an attempt to describe, from the syntactic standpoint, these different intelligibilities as 'perceptually' noticed by Lynch. The idea here is to match the distinct syntactic intelligibilities emerged out of measurements of the same system as detached and as embedded. In other words, for the purposes of the tests that follow all SA local areas will have assigned both intelligibility values locally measured - based upon integration values observed for each system 'as detached' (CON:RRA) - and intelligibility values globally measured - based upon integration values observed for each system as a part of a larger system of interaction (CON:RRAemb) - so corresponding to embeddings either in SA west or in SA east. The SB local areas, apart from their local intelligibility and global intelligibility as a part of either SB west or SB east, will be also measured as a part of the whole sector B.

This relationship between syntactic intelligibility and 'scale' - in terms of local and global scales - has already been studied by Peponis (1990) in dealing with a sample of Greek towns. Peponis' experiments suggest that the 'intelligibility of the parts' or local areas tends to be higher than the 'intelligibility of the whole', i.e. the intelligibility of the larger areas of which local areas are a part. Peponis does not clarify whether he has

1 ibid. p. 52.
2 The analytical part that follows shall be read simultaneously with the visual observation of the decomposition diagram attached to the back cover of this volume.
3 The codes Intell, Intell/ and Intell// refer to local intelligibility, global intelligibility with relation to larger surroundings and global intelligibility with relation to still larger surroundings, that is specific for the SB local areas in view of their embedding in the whole Sector B.
4 In Peponis' study, the intelligibility of Kerkyra, for example, is .45 while the intelligibility of its five 'sub-areas' oscillate between .51 and .74. The intelligibility of Kypseli (a district of Athens) is .79 while the intelligibility of its parts oscillate between .94 and .96. The same happens for the other larger areas - Nauplion, Mytilini and Tessaloniki -
used local RRAs (as observed for each local area as a detached system) or global RRAs (as observed for each local area as embedded) in order to specify his intelligibility values. Nevertheless the numerical output given in his paper shows that just one intelligibility value is considered so suggesting that Peponis has not made a distinction between local and global intelligibilities and has restricted his observations more to variations in size as given by the number of axial lines than to actual variations in scale as given by changes in the system of reference for the measurement.

In effect these seem to be two distinct issues or descriptions, which may or may not related. One is the problem of scale, that is to say a system can be highly intelligible in itself, i.e. as detached from its surroundings, yet this same system can be rather unintelligible from the standpoint of its surrounding areas, i.e. measured as embedded in a larger area. By contrast the problem of size seems to involve specifically whether urban systems become more or less intelligible insofar as they increase in size. Nevertheless a joint discussion of these characteristics - scale and size - becomes possible if it is considered that the interface between the two descriptions comes to happen when increases in size are matched with intelligibility values produced out of different embeddings or 'scales' of measurement.

These issues are to be dealt with in what follows on the basis of the measurements observed for the current sample of grid configurations, so aiming to shed some light on how these two characteristics - scale and size - are associated to the syntactic intelligibility of the urban grid. The barchart given in Fig 4.06 A depicts the variations in intelligibility values - local intelligibility in this case - observed for all SA systems. The intelligibility values observed for the local areas produced by the

---

1 this same value is also relativised to the mean intelligibility value observed for the UAS sample of 75 towns.

2 The 'larger areas' systems of interaction are represented in black bars.
Fig. 4.06 Bar charts for intelligibility: sector A

A Bar Chart for column: X1 Intell

Observations

B Bar Chart for column: X2 Intell/

Observations

Table 4.02
Intelligibility values for SA systems

<table>
<thead>
<tr>
<th>Syst Code</th>
<th>Intell</th>
<th>Intell/</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR145</td>
<td>.75</td>
<td>.75</td>
</tr>
<tr>
<td>SR60</td>
<td>.65</td>
<td>.65</td>
</tr>
<tr>
<td>SR30</td>
<td>.96</td>
<td>.96</td>
</tr>
<tr>
<td>SR34</td>
<td>.70</td>
<td>.70</td>
</tr>
<tr>
<td>SR77</td>
<td>.75</td>
<td>.75</td>
</tr>
<tr>
<td>SR39</td>
<td>.70</td>
<td>.70</td>
</tr>
<tr>
<td>SR21</td>
<td>.75</td>
<td>.75</td>
</tr>
<tr>
<td>SR16</td>
<td>.90</td>
<td>.90</td>
</tr>
<tr>
<td>SR128</td>
<td>.56</td>
<td>.56</td>
</tr>
<tr>
<td>SR418</td>
<td>.65</td>
<td>.65</td>
</tr>
<tr>
<td>SR299</td>
<td>.53</td>
<td>.53</td>
</tr>
<tr>
<td>SR71</td>
<td>.68</td>
<td>.68</td>
</tr>
<tr>
<td>SR72</td>
<td>.83</td>
<td>.83</td>
</tr>
<tr>
<td>SR184</td>
<td>.68</td>
<td>.68</td>
</tr>
<tr>
<td>SR69</td>
<td>.72</td>
<td>.72</td>
</tr>
</tbody>
</table>
decomposition of SA west (SA143) show that the 'whole' is more intelligible (0.75) than the two local areas which have emerged from its decomposition (SA60 and SA77) whose intelligibility values are 0.65 and 0.73 respectively. Nevertheless the same SA143 is less intelligible than the local areas generated by a third order decomposition. SA30, SA34 and SA59 are all more intelligible than the larger SA143.1 For the east part of sector A (SA418/299) the output is more in tune with Peponis' results. Both configurations given for SA east (SA418 and SA299 that is the same area having the housing estates deleted) are significantly less intelligible than the local areas produced out of their decomposition (Fig 4.06 A).

Nevertheless if instead of local intelligibilities we compare global intelligibility values for the different systems - intelligibility values observed for each local area as embedded in their respective systems of interaction - interesting variations will occur, especially inside SA west (SA143). Fig 4.06 B shows that SA60 and SA77 are now more intelligible than their parts given by a third order decomposition. The intelligibility of the whole SA west (SA143) becomes something in between the intelligibility of its two parts given by second order decomposition (SA60 and SA77). As a whole the description given by global intelligibility values as displayed in bar chart B seems to be more in tune (than local intelligibility) with the visually observable characteristics of the different parts produced by the decomposition of SA west.2 That is to say SA60, a continuous regular grid is more intelligible before than after its decomposition. SA77 is just marginally more intelligible than SA59 its larger part and much more intelligible than SA21 its smaller part, which is hardly intelligible as a detached system. The particular case of SA21 - for its low global intelligibility value - suggests that variations in intelligibility might be taken as another way of testing out the pertinence of the different decompositions and, in some cases, the legitimacy of the boundary

---

1 See decomposition diagrams.
2 Compare barchart B and the decomposition diagram.
proposed. As a whole from the standpoint of size the results presented above contradict what was observed in Peponis sample of Greek towns where in general the 'wholes' are markedly less intelligible than the parts. For the current SA west - if global intelligibility values are plotted - insofar as the parts are put together intelligibility tends to increase.

The comparison given in bar chart B (Fig 4.06) between the global intelligibility value assigned for SA143 and the values assigned for each one of its parts after decomposition could also be described in terms of order and structure, as it is stated by Hanson (1989). Hanson suggests that the intelligibility of an urban system is associated with the extent of differentiation observed in the syntactic identity of the axial lines that compose the system, as expressed in its range of RRA values. In Hanson's terms, the whole SA143 is more structured - and intelligible - than SA60, a more regular grid where order prevails. SA60 in its turn is more structured (and intelligible) than SA30, the almost perfect orthogonal grid at its east side. It is significant that SA30 is strongly intelligible from the standpoint of local intelligibility values. If the association made by Hanson between structure (as given by 'differentiation') and intelligibility is to count, the figures observed in barchart A for local intelligibility are unacceptable. For SA77 - the other part produced by the decomposition of SA143 - the range of RRA values ('the extent of differentiation') is much wider and as a consequence this system will be more intelligible than the whole SA west (Fig 4.06 B). These results seem to support Hanson's conjecture on the association, if not coincidence, between the concepts of structure and syntactic intelligibility.

1 This is what happens for both SA west and east if local intelligibility values are plotted (Fig 4.06 barchart A). It might then be the case that Peponis' measurements of intelligibility have regarded all systems 'as detached'.
2 Hanson, J. Order and Structure in the Urban Space: A morphological history of the city of London, op. cit.
3 While in SA60 RRA values vary between .266 and .695, in SA77 the range includes values as low as .352 and as high as 1.06.
4 Here again the conjecture does not stand if local intelligibility values are plotted. SA77, from the standpoint of local intelligibility is less intelligible than its parts.
In SA east the figures for global intelligibility (as given in Fig 4.06 B) contradict the 'clear' picture provided by local intelligibility values (as given in Fig 4.06 A), according to which all local areas are more intelligible than the whole, so matching Peponis' results. By contrast if global intelligibility values are plotted, SA71 and SA106 - the two systems where the integration analysis has pointed out large lumps of segregated lines - will be less intelligible than the whole SA299 (Fig 4.06 B).\(^1\) A comparison of barcharts A and B (Fig 4.06) also shows that SA184 has its intelligibility increased when it is globally measured so indicating that despite the sharp increase of axial density, provoked by the housing estates, SA184 is comparatively a rather intelligible system if assessed in global terms. This characteristic of SA184 has already been detected during the analysis of the pattern of integration in SA east. The long axial lines that traverse this system so connecting the lumps of short axial lines to the global integration core - seem to play an effective role in guaranteeing the intelligibility of that part of the urban grid. Again in this case the figures given by global intelligibility seem to be more in tune not only with visually observed characteristics but especially with the syntactic characteristics already identified in individual systems.

The performance of SA106 provides yet another example. This system is strongly fragmented yet if its intelligibility is measured 'as detached' (local intelligibility) it will show itself as a relatively intelligible system. That is to say local intelligibility is not affected by the fragmentation of the system. Locally measured SA106 is second in the rank of intelligibility considering the four local areas at east of sector A (Fig 4.06 A).\(^2\) Nevertheless if global intelligibility is considered SA106 will be the least intelligible of the four local areas at east of

\(^1\) Yet only SA106 will be less intelligible than SA418 - the same larger area with the housing estates included.

\(^2\) In fact the bar chart indicates that SA69 is the second in the rank. This system actually does not exist. It is just an hypothetical version of SA184 having the housing estates deleted. Thus SA106 is in reality the second most intelligible amongst the four SA east local areas.
sector A and even less intelligible than the whole (either SA418 or SA299). This shows that in SA east, following what has already been noticed for SA west, the 'larger area' is more intelligible than at least one of its parts when intelligibility is measured on the basis of global RRA values.

For the two systems in the middle of sector A - SA16 and SA128 - the intelligibility values globally measured seem to be also more accurate than the local version. Both these systems as it has been explained have their global embedding measured as a part of the initially given whole sector A. SA16 is the most intelligible of all SA local areas if measured as detached (.98). Globally measured its intelligibility decreases to .74, so more or less matching the intelligibility values observed for the local areas belonging to SA west (Table 4.02). By contrast SA128 is a highly fragmented system, its global intelligibility will be the lowest of all local areas (.28) despite its central position in relation to the whole sector A. As the analysis of the pattern of integration in SA128 has shown, however, this system is traversed by the most integrated lines of the whole sector A, its interior is crowded with large lumps of segregated lines so lacking that globally distributed core that seems to be a characteristic of more intelligible systems (whose segregated lines tend to be located at the interstices between core lines). \(^1\) These cases seem to provide clear examples of how intelligibility is strongly attached to a balance between local and global properties of the street grid.

For the SB systems the measurements of local intelligibility repeat literally what has been observed for the east part of SA (SA418/299). Both SB west and SB east- the two systems of interaction given by the first order decomposition of sector B - are less intelligible if locally measured than their parts, except for SB83 (Fig 4.07 A). Nevertheless if instead of local values we consider global intelligibility values SB89

\(^1\) This is the opposite of SA184, a system that despite its high degree of axial fragmentation has a globally distributed core. These core characteristics are fully presented and discussed in chapter three.
### Table 4.03
Intelligibility values for SB system

<table>
<thead>
<tr>
<th>Syst Code</th>
<th>Intell 1</th>
<th>Intell 2</th>
<th>Intell 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB89</td>
<td>.77</td>
<td>.77</td>
<td>.6</td>
</tr>
<tr>
<td>SB62</td>
<td>.90</td>
<td>.73</td>
<td>.7</td>
</tr>
<tr>
<td>SB30</td>
<td>.91</td>
<td>.59</td>
<td>.7</td>
</tr>
<tr>
<td>SB69</td>
<td>.83</td>
<td>.73</td>
<td>.7</td>
</tr>
<tr>
<td>SB295</td>
<td>.69</td>
<td>.60</td>
<td>.7</td>
</tr>
<tr>
<td>SB54</td>
<td>.83</td>
<td>.83</td>
<td>.7</td>
</tr>
<tr>
<td>SB44</td>
<td>.86</td>
<td>.83</td>
<td>.7</td>
</tr>
<tr>
<td>SB127</td>
<td>.62</td>
<td>.51</td>
<td>.7</td>
</tr>
<tr>
<td>SB96</td>
<td>.66</td>
<td>.51</td>
<td>.7</td>
</tr>
<tr>
<td>SB45</td>
<td>.75</td>
<td>.70</td>
<td>.7</td>
</tr>
<tr>
<td>SB85</td>
<td>.58</td>
<td>.57</td>
<td>.7</td>
</tr>
</tbody>
</table>
(SB west) becomes more intelligible than its two parts while SB295 (SB east) will be something in between, i.e. it becomes more intelligible than some of its parts and less intelligible than others (Fig 4.07 B). If all local areas are further embedded in the whole sector B another description for intelligibility will emerge providing some clarifying evidence on the relationship between intelligibility and changes of scale (Fig 4.07 C). As a part of the whole sector B SB89 will remain as a rather intelligible system, just less intelligible than when measured as a detached system (its intelligibility value decreases from .77 to .65). On the other hand its two parts - SB62 and SB30 - become virtually 'unintelligible' measured as a part of the whole sector B. The intelligibility values are .10 and .25 respectively (table 4.03).

This seems to exemplify clearly three different intelligibilities attached to three different standpoints of the observer as it has been suggested at the outset. Locally SB30 and SB62 are more intelligible than SB89 - the sum of the two (Fig 4.07 A). If SB30 and SB62 are measured as a part of SB89 the 'whole' will become more intelligible than the parts, yet the parts still remain rather intelligible on their own (Fig 4.07 B). Nevertheless SB30 and SB62 are totally unintelligible as distinct local areas from the point of view of the whole sector B (Fig. 4.07 C). From this global point of view only SB89 - that is the sum of SB30 and SB62 - is intelligible, and highly intelligible as compared with the standard given by the other areas (table 4.03). In other words, locally SB62 and SB30 are intelligible as two distinct local areas, yet globally the distinction between the two is not intelligible at all and only their interaction in SB89 will make that 'portion' of the street grid intelligible from the standpoint of the global scale, i.e. from the standpoint of the whole sector B.

SB east (SB295) performs something in between when it is globally measured (Fig 4.07C). As it has already been said it is more intelligible than some of its parts - SB96 and SB127 - and less intelligible than the others. SB54 and SB44 are highly intelligible systems either locally or
globally measured, yet their embedding in the whole sector B will provide the highest intelligibility values. It is noteworthy that in terms of global intelligibility SB54 will be always more intelligible than its SB44 version. This provides another situation where variations in intelligibility may shed some light on the problem of spatial boundaries. The conjecture here is that from the standpoint of the global scale the more accurate spatial boundary for that part of the grid is as it is defined in SB54 and not as in SB44.

By contrast the local area beside - SB127 - will have its intelligibility decreased insofar as the area of embedding is enlarged. It is noteworthy that even when locally measured SB127 is a low intelligibility system. Nevertheless the third order decomposition that has divided SB127 shows that SB45, the west part emerged from such a decomposition, becomes a highly intelligible local area; in effect one of the highest intelligibility values observed after the decomposition of SB295 (SB east) either locally or globally measured. On the other hand for SB96, the eastern system given by the decomposition of SB127, the intelligibility value will be much lower at any of the proposed embeddings. In other words from the partition of SA127 two systems with rather contrasting intelligibilities have emerged. If it is accepted as it is suggested above that variations in intelligibility might be taken as a guide for the testing out of the proposed boundaries, the third order decomposition that has divided SB127 in the two smaller systems SB96 and SB45, seems to be a more accurate way of measuring the syntactic character of that part of the street grid than its measurement as a whole. The last of the SB local areas - SB83 - is a quite low intelligible system both locally and as also a part of SB east, yet it becomes marginally more intelligible as a part of the whole sector B.

These results suggest that if measurements of intelligibility are examined as attached to scale variations (as it has been carried out above by comparing measurements within different embeddings) the 'size' factor will come to play a rather marginal role in the observed
variations of intelligibility. The size factor is effective only if the sample is locally measured, i.e. when the local areas are measured as detached (Fig 4.06 and 4.07 A). In this case the proposed systems of interaction or 'larger areas' tend to be less intelligible than the parts, so confirming Peponis' results.1 Nevertheless insofar as the local areas are embedded, and the area of embedding is further enlarged, intelligibility becomes to a large extent a positional feature attached to the syntactic identity of each local area in relation to the whole of which it is a part. Thus the proposition that the intelligibility of wholes tend to be lower than the intelligibility of parts might be accepted if - and only if - the measurement of intelligibility is taken in a single scale for systems as detached, in which case the descriptions of scale and size become superimposed so preventing the identification of their subtle yet fundamental distinction. By contrast, if the problem of scale (or variation of 'embedding') is taken into account the results observed above clearly suggest that intelligibility and size are scarcely related.

A joint verification of the relationships between intelligibility and these characteristics - scale and size - is made possible if we consider an 'interface' between the two descriptions. Such an interface comes about if we analyse increases in size (given by the number of axial lines) as matched with intelligibilities given by different scales or embeddings. This seems to be distinct from the way in which Hillier et al (1987) have approached the problem of syntactic intelligibility. Dealing specifically with the problem of size, as detached from the problem of scale, Hillier et al. have suggested (based upon a sample of 75 towns) that 'the mean correlation of connectivity and integration ('intelligibility') of urban layouts is r=.63 and this tends to decrease as the system grows'.2 The last part of this statement can be regarded as an 'alternate' hypothesis in what follows, that is the matching of

---

1 Except for SA143 (SA west) whose intelligibility will be higher than the intelligibility of its two parts (SA60 and SA77) even when they are locally measured.
Fig. 4.5a Correlation analysis for interconnectedness and size:

A. 
\[
y = -3.22x + 1.236, R^2 = 0.623
\]
\[R = -0.789 \quad (p=0.0001)\]

B. 
\[
y = -0.184x + 0.990, R^2 = 0.277
\]
\[R = -0.201 \quad (p=0.161)\]

C. 
\[
y = -0.402x + 1.787, R^2 = 0.602
\]
\[R = -0.95 \quad (p=0.0433)\]

D. 
\[
y = -0.164x + 0.900, R^2 = 0.277
\]
\[R = -0.201 \quad (p=0.161)\]

E. 
\[
y = 0.356x + 0.545, R^2 = 0.889
\]
\[R = 0.624 \quad (p=0.0098)\]

F. 
\[
y = 0.429x - 0.417, R^2 = 0.794
\]
\[R = 0.884 \quad (p=0.0001)\]
absolute variations in size with variations in intelligibility brought about by different embeddings.¹

A plot of local intelligibility against size will confirm to a great extent the hypothesis stated above. All systems computed - both local areas and the systems of interaction - size and intelligibility are -.789 (p=.0001) correlated so making it clear that insofar as size increases intelligibility tends to decrease (Fig 4.08 A)² Nevertheless when global intelligibility is matched with size the correlation drops to -.201 (p=.161) (Fig 4.08 B). It is significant that the position of the points that represent the systems of interaction (black dots in the scattergram) suggests a high correlation amongst these systems while for the bulk of the distribution - where all local areas as embedded are represented - intelligibility and size seem to be uncorrelated. In effect if just the systems of interaction are computed the correlation go as high as -.95 (p=.0133). The probability of the correlation is low, in view of the small number of observations but the points are rather homogeneously distributed along the regression line (Fig 4.08 C)³

These results suggest - and visual inspection of scattergram B seem to confirm - that if global intelligibility values are accounted a decrease in intelligibility with size starts to happen from a 'certain size' onwards. Systems smaller than this certain size seems to perform in a different way. This 'certain size', as far as it is observable within the current sample, seems to be around 80 or 90 axial lines.⁴ The systems smaller than the conjectured size seem to perform in a different way. Visual inspection of Fig 4.08 D shows that the distribution of most points

¹ The conjecture that intelligibility has no relationship at all with size can be regarded as a null hypothesis in the current context.
² The variable size is negatively skewed in its linear form since the systems that carry the highest number of axial lines are fewer in the sample. Nevertheless the logtransformation of NLines will bring the distribution rather close to the normal. The variable intelligibility is normally distributed in its linear form.
³ The two versions of Sa east (SA418 and SA299) are computed in the test so resulting five observations out of the four systems of interaction.
⁴ This will correspond to values between 1.8 and 2 for logged values of the number of axial lines (Fig 4.08 B).
representing systems smaller than ninety spaces (black dots) contradict strongly the tendency so far observed, of decrease in intelligibility following the increase in size. These points include indiscriminately systems coming from sectors A and B and moreover both local areas and larger areas of embedding. Most of these points represent those so called more griddy or more orthogonal systems. It is noteworthy that these systems are separated from the each other in three distinct groups which belong to different periods of the historical development of the city. They include the west part of sector A (SA143 and its different decompositions), the west part of sector B (SB89 and its two local areas) and the more orthogonal part of SB east (SB54/44).

Fig 4.08 E shows what happens if this set of systems is isolated as a separate sample. For these cases insofar as size increases intelligibility also increases (R=.624 p=.0098). The distribution of points in the scattergram shows that if the number of lines goes beyond that 'certain size' the correlation gets lower. SA143, because it is larger than the certain size observed, was deliberately included in the sample in order to test a further increase. These measurements suggest that if the intelligibility of the different systems is globally measured there seems to be an 'optimum' size where the intelligibility of an urban system reaches its peak. Above and below that size intelligibility decreases. If SA143 is not computed the correlation between global intelligibility and size for the proposed set of 'griddy' systems will be 0.684 (p=.0001) (Fig 4.08 F).

---

1 As the vectors of urban growth presented in chapter two have indicated (Fig. 2.04 / pg. 89).
2 SA143 is an outlier in fig 4.08 E (the black dot right in the scatter diagram).
3 The other black dot, at left in fig 4.08 E, is SA16. This system despite its small number of axial lines is highly intelligible measured as a part of the whole sector A so performing against the proposed model. Nevertheless it must be observed that SA16 is a system quite isolated from its surroundings – as the analysis of ruptures in traverse permeability has shown – so hardly allowing for the testing out of its interaction with immediate surroundings as it has been proceeded for the other local areas which were originated by second and third order decompositions, as it seems to be required for testing out the relationships between increases in size and changes of scale as proposed here.
Fig. 4.09 Correlation analysis for intelligibility and size

A. \( R = -0.238 \ (p=0.4563) \)

\[ y = -0.094x + 0.728, R \text{-squared: .067} \]

B. \( R = -0.35 \ (p=0.3565) \)

\[ y = -0.232x + 1.025, R \text{-squared: .133} \]

C. \( R = 0.099 \ (p=0.7744) \)

\[ y = 0.50x + 0.412, R \text{-squared: .011} \]

D. \( R = -0.663 \ (p=0.0547) \)

\[ y = -0.268x + 1.136, R \text{-squared: .429} \]
Here again the relationship between intelligibility and size seems to shed some light on the problem of how to identify the 'actual' spatial boundaries of an urban system. The case given by SA west shows that its four third order decompositions (SA30, SA34, SA59 and SA21) are less intelligible than the second orders SA60 and SA77. Nevertheless if the area is further enlarged - so putting together these two systems in the larger SA143 - intelligibility will decrease again. If an optimum of intelligibility is accepted as a parameter for assessing the reliability of the proposed spatial boundaries, SA60 and SA77 shall be taken as the 'optimum decomposition' for the west part of sector A. Whether or not this definition of local areas according to an 'optimum of intelligibility' has anything to do with the concept of 'catchment area' remains to be seen when intelligibility measures are matched with land use distributions in the subsequent steps of this investigation. At any rate the evidence provided by the small sample of 'griddy' systems presented above contradicts strongly the hypothesis that the intelligibility of urban systems decreases with size.

When the upper part of the rank of number of axial lines is measured separately - as it has been done above to the lower part of the rank (the more griddy systems) - again a tendency is noticed for a decrease in intelligibility with the increase of size (global intelligibility).\(^1\) Nevertheless the correlation now is much less significant than when size was measured against local intelligibility. If the systems of interaction are included the correlation is \(-.238\) (p=.4563) (Fig 4.09 A). Just the local areas computed the correlation increases slightly to \(-.35\) (p=.3565) (Fig 4.09 B).

Finally the relationship between size, scale and intelligibility has been tested out taking into account global intelligibility values given by the embedding of all SB local areas in the initially given whole sector B (Table 4.03). Fig 4.09 C shows that for these cases the correlation is very low yet two particular systems are completely detached from the

\(^1\) These systems are represented in Fig 4.08 D by white dots.
bulk of the observations. These systems are SB62 and SB30 (black dots in the scattergram). As it has been already noticed these two local areas are rather unintelligible as a part of the whole sector B. The description provided by the scattergram seems to just reinforce their syntactic autonomy in relation to the whole sector B if compared with the performance observed for the remaining SB systems. If these two local areas are not computed the coefficient will increase to -0.663 (p=0.0517) so showing that for this particular case - a small sample that includes systems of different sizes - global intelligibility tends to decrease with size (Fig 4.09 D).

Nevertheless such an evidence is not conclusive since, it has already been noticed, the whole SB295 (SB east) - at right in the scattergram - is more intelligible than its parts SB127 and SB96 - the two points at the bottom. It is also noteworthy that SB89, the system of interaction that puts together SB62 and SB30 is now represented by a point close to the regression line. Scattergrams C and D (Fig 4.09), put together, provide another evidence for what has already been conjectured based upon the observation of the bar charts. SB62 and SB30 are not intelligible as local areas from the standpoint of the whole sector B. Nevertheless if the parts are added up, the resulting whole (SB89) will become highly intelligible as a part of the whole sector B. Here again the whole is more intelligible than the parts.

As a whole the experiments presented in this section have shown that if each system is measured detached from its surroundings - local intelligibility - the increase in size tends to be followed by a decrease in intelligibility, so following Hillier et al. proposition. At the same time it has also been questioned here whether measurements based upon RRA values locally measured provide an accurate description for intelligibility. The evidence presented has suggested that local intelligibility values, since they do not describe the interaction of each system with the surrounding areas, may bring about a misrepresentation.

---

1 SB89 is also represented by the black dot in Fig 4.09 D.
Fig. 4.10 Ranks of intelligibility (local and global)
Below correlation analysis for local and global intelligibilities

(A) Bar Chart for column: \( X_1 \) Intell

(B) Bar Chart for column: \( X_1 \) Intell/

(C) \[ y = 0.499x + 0.343 \quad \text{R-squared: 0.34} \]

\( R = 0.489 \quad (p = 0.0208) \)
of the actual syntactic intelligibility of each system. If intelligibility values are globally measured - based on RRAemb values - the correlation between intelligibility and size decreases strongly. Moreover for a significant part of the sample - the so called more 'griddy' systems - an opposite tendency has been observed. By contradicting the earlier observation, in this particular case intelligibility has grown consistently insofar as the systems have been enlarged. In this case the evidence provided by the numerical output seems to be much in tune with the observed characteristics which emerged from visual inspection. Although the sample presented here is not large enough to provide a conclusive evidence on this matter, it has pointed out a series of regularities which have strongly contradicted the assumption that the syntactic intelligibility of urban systems tends to decrease insofar as the system grows.

**Intelligibility and Integration**

The distinct performances observed for local and global intelligibilities, raise a couple further questions upon these two distinct ways (local and global) of approaching this measurement (the measurement of syntactic intelligibility). The first of these questions concerns the way in which local and global intelligibilities relate between themselves. Is the fact that a system is highly intelligible at the local level associated with its intelligibility at the global level? The second question concerns how both ways of approaching intelligibility relate to the pattern of integration. Does the fact that a system is strongly integrated guarantee its intelligibility, either locally or globally?

The ranks of local and global intelligibilities show straightforward their conspicuous distinction (**Fig 4.10 A and B**). Systems such as SA60, SA77, SA184, and SB45 that are high in the rank of global intelligibility (barchart B) will be close to the bottom of the rank when intelligibility is locally measured (barchart A). The correlation between the two
measurements is .489 (p=0.0208) (Fig 4.10 C). The correlation is not as low as it is expected from the observation of the barcharts, although the coefficient is somewhat biased by the performance of SA12B, a system that present the peculiar condition of being at the bottom of both ranks, i.e. this local area is hardly intelligible either locally or globally. If SA12B - the black dot at the bottom of the scattergram - is not computed the coefficient will drop to .379 (p=.0903). This result suggests that the fact that a system is highly intelligible at the local level does not guarantee by any means its global intelligibility. On the contrary the low correlation between the two measurements seems to support the results observed during last section, i.e. for most systems inside the current sample it is precisely their relationship with larger surroundings that will bring about their syntactic intelligibility.

Nevertheless the performance of local intelligibility seems also to provide significant clues on the performance particular systems. This is the case for instance of SB44, a system that in view of its strong 'definition' and 'overlap' has been conjectured as a rather autonomous area in relation to its surroundings. This system is significantly high in the rank of local intelligibility yet it drops dramatically in the rank of global intelligibility.¹ In this particular case, the marked variation in the intelligibility value from local to global seems to provide a further support on the conjectured autonomy of that part of the grid with respect of its surroundings and, if that is accepted, local and global intelligibility measurements are in this case very much in agreement.

The second question raised at the outset concerns the relationship between intelligibility and integration. A comparison of the barcharts given for these two measurements (Fig 4.11) indicates that although intelligibility is calculated on the basis of RRA values this does not mean that the most integrated systems will necessarily be the most intelligible especially if global values for intelligibility and integration are compared. That is to say the fact that a system has a low mean RRA

¹ Compare barcharts A and B.
Fig. 4.11 Ranks of intelligibility and integration
value (a highly integrated system) does not necessarily mean that the integration value of each of its axial lines is strongly associated with their connectivity.

As it has been already explained the conjecture behind the concept of syntactic intelligibility is that the higher is the correlation between the integration value of each axial line within a system and their respective connectivities, the more intelligible is the system. In other words, the local dimension (connectivity) can be taken as a reliable guide for the global dimension (RRA). This does not mean that the mean integration value must be high for the system to be highly intelligible. A system can be low in the rank of integration, poorly connected and still be a fairly intelligible system. This is precisely the case of SB45. This system is low in both ranks of integration and is also the sixth lowest in the rank of mean connectivities (to be further analysed). Even so it is quite high in the rank of global intelligibility (Fig 4.11).

The relationship between intelligibility and integration can be measured either for systems as detached or as embedded into larger surroundings. Some cases to be discussed in what follows may shed light on the effects of these changes of scale. For values locally measured - i.e. for each system measured as detached from its surroundings - intelligibility will be strongly correlated with integration. The coefficient is -0.649 (p = 0.0011) (Fig 4.12 A). Some systems that outlie from the overall tendency noticed in the scattergram will provide useful clues on how the relationship between integration and intelligibility is set up. SA60 is a strongly integrated system (the second in the rank of local integration) yet it is relatively low in the rank of intelligibility. SB30 will provide an example in the opposite direction. This system is strongly intelligible (the fourth in the rank of local intelligibility) yet it is to some extent segregated if the tendency observed for the bulk of the sample, as given in the scattergram, is taken as a standard. SA128 and SA184 provides a third case. These systems are amongst the least intelligible of all
Fig. A: Correlation analysis for interlegibility and integration.

$R = -.649 \ (p = .0044)$

Fig. B: Correlation analysis for interlegibility and integration.

$R = -.416 \ (p = .0606)$

Fig. C: Correlation analysis for interlegibility and integration.

$R = -.709 \ (p = .0001)$

Fig. D: Correlation analysis for interlegibility and integration.

$R = -.413 \ (p = .0324)$
sample (as locally measured), yet they are right at the middle in the rank of integration.

When global measurements are computed - i.e. measurements for each system as interacting with its surrounding areas - the picture changes. The correlation between intelligibility and integration drops to -.416 (p=.0608) and apart from the performance of SA128 no other system can be ‘blamed’ for the lower correlation. In effect the distribution of points is as a whole more dispersed along the regression line so indicating that global intelligibility follows to a much lesser extent the pattern of global integration observed (Fig 4.12 B). SA184 that was quite unintelligible as detached from its surroundings is now highly intelligible as embedded. If this same system is measured without computing the housing estates (SA69) its intelligibility value goes even higher, despite its low mean integration value as globally measured.1

The same does not apply to SA128, another outlier in the plot of local integration against local intelligibility, as given in scattergram B (Fig 4.12). SA128 is scarcely intelligible as locally measured and it will remain so when as embedded. In both cases its integration value is rather high for a too low intelligibility, if compared with the performances observed for the bulk of the distribution. It is noteworthy that this is not a consequence of the large area of embedding proposed for SA128 (that is the whole sector A). The same larger area of embedding has been utilised for the global measurement of SA16 and the intelligibility value for this system will be .74 (as embedded) that is the third highest global intelligibility inside the current sample. This shows clearly that the low global intelligibility value observed for SA128 is more a product of its quite restricted spatial continuity with relation to the surroundings - as the analysis of ruptures in traverse permeability has shown - than a feature produced out of an inappropriate embedding strategy.

1 The mean RRA value for SA69 as globally measured is .81, that is the sixth most segregated of all local areas. (Fig 4.02 B)
The performance of intelligibility in SA60 and its two parts which emerged out of a third order decomposition (SA30 and SA34) also changes radically from the local to the global scale.\(^1\) As it has been already shown this system while being strongly integrated, is scarcely intelligible when locally measured (scattergram A). But if SA60 is measured as interacting with its larger surroundings it will become a highly intelligible system, in this case following its high integration value. At the same time its parts - SA30 and SA34 - will then be lower in the rank of global intelligibility. That is to say, from the standpoint of the global scale of the street grid the two local areas produced out of the decomposition of SA60 will be much less intelligible than the whole SA60.

These exceptional situations, rather than providing some clarification on the distinct character of integration and intelligibility, reinforce a tendency which has already been noticed. If measurements are computed on the basis of global values, integration cannot really be accounted as a reliable guide for detecting the intelligibility of the different systems. It is noteworthy that the measurements presented above do not include the proposed systems of interaction.\(^2\) If the systems of interaction are also computed the coefficient for local intelligibility against local RRA will increase to \(-.709\) (p=.0001) so indicating that the increase in size tends to favour, at least marginally, the observation of a higher association between the intelligibility and integration, when local values are computed (Fig 4.12 C). This correlation virtually coincides with the coefficient given by the sample of seventy five towns studied by Hillier et al, that is \(-.710\).\(^3\) The scale of reference is not discussed in the paper referred to above, but the coincident coefficients - between local measurements given by the current sample and the coefficient

\(^{1}\) Compare scattergrams A and B in Fig 4.12.

\(^{2}\) and SA16, SA128 and SA69; the local areas already emerged out of the first order decomposition (see reference map).

\(^{3}\) Hillier et al., Creating Life: Or, Does Architecture Determine Anything, op.cit., p.238.
observed there - seem to indicate that their results were produced out of measurements carried out for urban areas as detached from surroundings and as such variations in intelligibility brought about by different embeddings were not part of their concern.

By contrast the inclusion of the systems of interaction will hardly affect the correlation between intelligibility and integration for the systems measured as embedded. The correlation will remain rather stable in -0.413 (p=0.0321) (Fig 4.12 D). The distinct performance observed for local and global measurements when the systems of interaction are computed clearly indicates that the effects of size in the association between intelligibility and integration are only felt if measurements are locally measured. For global measurements the increase in size hardly affects the stable poor association between integration and intelligibility, that is to say the correlation will be anyway much lower than when the systems are measured as detached. Whilst this account of the complex performance of local and global intelligibilities is enough for the purposes of the current section, a further discussion on this specific topic is provided when both these measurements - integration and intelligibility - are matched with the distribution of land uses in chapters five and six.

The polarity between axial fragmentation and tension

Distinct degrees of axial fragmentation seem to be the most conspicuous feature noticed in the current sample of grid configurations when different local areas are visually compared. A high degree of axial fragmentation, for instance, is striking in the so called labyrinthine configurations - such as SA106 or SA128 - which tend to be mostly composed of short axial segments and where the continuous change in the direction of routes make the configuration of the street grid, whilst spatially continuous, nonetheless strongly fragmented. In these cases the 'how far one can go' hardly coincides with the 'how far one can see'. 
Fig. 4.13 French and English settlements after Hiller and Hanson

(a) Les Yves 1961 (b) Les Marchands 1968 (c) Les Redons 1968 (d) Les Huguets 1961

(a) Perrotet 1810 (b) Les Redons 1810 (c) Les Yves 1810 (d) Les Huguets 1810

Middlesmoor

Muker
This is the opposite of what happens in the so called 'griddy' systems, where the spatial continuity of the street grid tends to be made up of longer axial lines and where 'how far one can go' and 'how far one can see' are mostly superimposed. The description of grid configuration from the standpoint of axial fragmentation seems to be an effective way of specifying what visual observation has recommended as 'more griddy' or 'more labyrinthine' configurations. The measurement of axial fragmentation will be given in the context of the current investigation by the ratio between the number of axial lines in each system and the metric area of the system. This measurement might also be taken as a way of assessing the degree of permeability of each system.

Another way of describing this same phenomenon seems to be in terms of the 'degree of tension' of the urban grid. From this standpoint the more labyrinthine configurations can be seen as a 'loose' fabric, while the more griddy configurations are 'stretched' fabrics. The character of 'tension' in urban systems has also been noticed in the work of Hillier and Hanson: 'Muker and Middlemoor are both variants on the beady ring form, but differ from the French examples in having several small clumps rather than a single large clump, in having larger and less well-defined spaces, and in general appearing more loosely constructed than their French counterparts'. Visual comparison of these examples (Fig 4.13) seem to indicate that the 'more loosely constructed' character of the English settlements observed might be described in terms of their higher degree of axial fragmentation as compared with their French counterparts. Visual inspection clearly suggests that this higher degree of axial fragmentation is made up by a decrease in the length of each axial segment. In the same way as the 'stretchedness' of the French examples is made up of longer axial segments.

These metaphors seem to be all clearly concerned with the description of distinct 'degrees of tension' in the grid and, insofar as visual observation is reliable, the length - average length - of the axial segments that

---

1 Hillier, B. and Hanson, J. *The Social Logic of Space*, op. cit., p. 84.
Fig. 4.14 Ranks of axial fragmentation and tension

A Bar Chart for column: $X_1$ Ax Fragm

Table 4.04 Measurements for axial fragmentation and tension

<table>
<thead>
<tr>
<th>Syst Code</th>
<th>Ax Fragm</th>
<th>Tension</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR145</td>
<td>25.99</td>
<td>.52</td>
</tr>
<tr>
<td>SR60</td>
<td>23.26</td>
<td>.79</td>
</tr>
<tr>
<td>SR30</td>
<td>25.64</td>
<td>.59</td>
</tr>
<tr>
<td>SR34</td>
<td>23.81</td>
<td>.54</td>
</tr>
<tr>
<td>SR77</td>
<td>31.97</td>
<td>.45</td>
</tr>
<tr>
<td>SR99</td>
<td>41.55</td>
<td>.45</td>
</tr>
<tr>
<td>SR121</td>
<td>39.82</td>
<td>.58</td>
</tr>
<tr>
<td>SR16</td>
<td>32.65</td>
<td>.67</td>
</tr>
<tr>
<td>SR120</td>
<td>170.87</td>
<td>.18</td>
</tr>
<tr>
<td>SR118</td>
<td>102.95</td>
<td>.26</td>
</tr>
<tr>
<td>SR299</td>
<td>73.28</td>
<td>.26</td>
</tr>
<tr>
<td>SR71</td>
<td>71.00</td>
<td>.25</td>
</tr>
<tr>
<td>SR22</td>
<td>68.90</td>
<td>.20</td>
</tr>
<tr>
<td>SR106</td>
<td>108.16</td>
<td>.27</td>
</tr>
<tr>
<td>SR194</td>
<td>127.76</td>
<td>.16</td>
</tr>
<tr>
<td>SR69</td>
<td>47.02</td>
<td>.34</td>
</tr>
<tr>
<td>SR199</td>
<td>33.21</td>
<td>.45</td>
</tr>
<tr>
<td>SB62</td>
<td>52.12</td>
<td>.38</td>
</tr>
<tr>
<td>SB30</td>
<td>46.60</td>
<td>.33</td>
</tr>
<tr>
<td>SB69</td>
<td>38.66</td>
<td>.41</td>
</tr>
<tr>
<td>SB295</td>
<td>52.40</td>
<td>.31</td>
</tr>
<tr>
<td>SB54</td>
<td>35.76</td>
<td>.34</td>
</tr>
<tr>
<td>SB44</td>
<td>35.77</td>
<td>.34</td>
</tr>
<tr>
<td>SB127</td>
<td>56.70</td>
<td>.35</td>
</tr>
<tr>
<td>SB96</td>
<td>65.50</td>
<td>.24</td>
</tr>
<tr>
<td>SB45</td>
<td>48.91</td>
<td>.35</td>
</tr>
<tr>
<td>SB83</td>
<td>60.14</td>
<td>.24</td>
</tr>
</tbody>
</table>
compose an urban area play a decisive role in the 'looseness' or 'stretchedness' of the system. Grids composed of long axial lines will have high tension values while axially fragmented curvilinear systems tend to have a low tension value. Yet both 'axial fragmentation' and 'tension' are descriptions concerned with the same phenomenon, the variables taken into account for their respective calculations are rather distinct. The measure of axial fragmentation, as it is proposed here, takes an areal reference in order to relativise the amount of axial segments counted for each system. It might then be said that axial fragmentation is to be measured in terms of the 'density' of axial lines. By contrast the 'degree of tension' of each system is to be read through the average or mean length of the axial lines that compose the system. Both measurements are syntactic by origin, for both are based upon properties of the axial map. Axial fragmentation considers number of axial lines (and not the number of streets) while the measurement of tension is based upon the length of each axial segment (and not of streets as well). Hence, as the process of measurement has suggested, both measures link metric properties to the syntactic character of the area of interest.

Visual observation (and intuition) suggests that these two features - axial fragmentation and tension - tend to perform in opposition, i.e. insofar as axial fragmentation increases tension tends to decrease. This is to a large extent confirmed in the way the current sample of grid configurations is distributed in bar charts A and B (Fig 4.14). The more orthogonal part of SA west contains the systems at the bottom of the rank of axial fragmentation.1 The four local areas lowest in the rank are all different parts or decompositions of SA143 (SA west). That is to say, SA60 is the local area with the lowest degree of axial fragmentation amongst all systems derived from second order decompositions.2 If this system is further decomposed (third order) the two parts then produced (SA30 and SA34) will remain amongst the least

---

1 Compare the ranks given in the barcharts and the distinct degrees of axial fragmentation that can be detected in the reference map (decomposition diagrams).

2 See reference map.
fragmented in the rank. SA77 follows SA60 in the rank of axial fragmentation. It complements the west part of SA (SA143). If SA77 is further decomposed the parts brought about by such division will then decrease in the rank of axial fragmentation. This is rather distinct from what happens to SA60 where a rather even degree of axial fragmentation is homogeneously spread throughout the system.\textsuperscript{1}

The observed more griddy parts of sector B - SB62 and SB54 - are the next systems in the rank of axial fragmentation. From SA69 onwards (to the right in the barchart) the amount of axial fragmentation increases strongly and includes all the so called labyrinthine systems. SA128 is at the top as the most fragmented system within the current sample. This system is also the lowest in the rank of intelligibility. This might be taken as a significant coincidence between a topological description - the syntactic measurement of intelligibility - and a measurement based upon the 'perceptual' dimension of the urban space such as axial fragmentation. The four systems at the right end of the rank - before SA128 - are the four local areas belonging to the east part of sector A, whose high degree of axial fragmentation had already been noticed during the syntactic analysis.

Amongst the systems higher in the rank of axial fragmentation SB127 will provide a case where a further decomposition produces a system - SB45 - that from the axial fragmentation standpoint is distinct from its system of origin. That is to say SB45, despite the lump of short axial lines at its south part, is much less fragmented on average than SB127. These observations show that as described by axial fragmentation there are distinct parts within the local areas derived from the second order decomposition. These distinct degrees of axial fragmentation seem to provide another standpoint for an assessment of the pertinence of the proposed third order decompositions. In the case of SA127 the fact that the decomposition has brought about systems that are rather distinct in terms of axial fragmentation seems to support the third order decomposition.

\textsuperscript{1} It is noteworthy that SA60 is a large urban area with more than one and a half square miles.
\( R = -0.934 \) \((p = 0.0001)\)

\( R = -0.997 \) \((p = 0.0002)\)

\( R = 0.677 \) \((p = 0.0001)\)

\( R = 0.849 \) \((p = 0.0001)\)

\( R = -0.828 \) \((p = 0.0001)\)

\( R = -0.946 \) \((p = 0.0001)\)
decomposition proposed. By contrast in the case of SA60, the even degree of axial fragmentation observed throughout the system seems to indicate that a third order decomposition in this specific case, is not supported by the spatial character of that system – at least from the standpoint of its axial fragmentation – since the same regular grid spreads through SA30 and SA34. In other words, the even degree of axial fragmentation seems to stand against the further decomposition of SA60, as it has been proposed.

The rank of tension – as measured by the average length of the axial lines of each local area – put things to a large extent the other way around (Fig 4.14 B). SA184 and SA128, the two systems that are at the top in the rank of axial fragmentation, are at the lower part of the tail in the rank of tension. On the other hand the systems that have presented the lowest degrees of axial fragmentation (both in sector A and B) are at the top in the rank of tension. Here again the rank ordering of tension values seems to perform from the more labyrinthine (or more fragmented) towards the more griddy (or less fragmented) systems. The correlation between axial fragmentation and tension, as expected from the inspection of the barcharts, is high. The coefficient is -.934 (p=.0001) (Fig 4.15 A).1 Tension increases steadily throughout the sample insofar as axial fragmentation decreases. This plot includes the larger areas of embedding. If just local areas are computed the correlation remains stable at -.929 so showing that the correlation stays and even increases insofar as size is taken into account. If only the larger areas of embedding are computed the correlation becomes almost perfect: -.997 (p=.0002) so confirming the conjecture raised at the outset that these two measures, yet distinct in nature, are both descriptions of the same phenomenon (Fig 4.15 B).

Both axial fragmentation and tension are strongly correlated with integration. All systems computed, axial fragmentation is .677(p=.0001)

---

1 Both measurements are negatively skewed in their linear form. The logtransformation of average length will bring the distribution close to the normal. For tension, the logtransformation will bring about a more rectangular distribution.
correlated with RRA (Fig 4.15 C). In this plot each system has its RRA measured as detached from its surroundings. The correlation is not higher for two particular systems that stand as outliers in the scattergram. These systems are SA128 and SA184. Both are exceptional cases where a high degree of axial fragmentation is coupled with low integration values (if compared with the standard set up by the most fragmented systems where the RRA values oscillate between .70 and .90 as given in scattergram C). In fact these two systems are right at the middle of the RRA rank, either as embedded or as locally measured (Fig 4.02). In the case of SA184, as it has been suggested, the high integration value is due to the long axial lines that penetrate right inside the lumps of axial fragmentation.

In respect of SA128 visual observation of its axial map suggests that yet this system is mostly composed of short axial lines these lines tend to perform consistently as a pattern of rings. If ringyness has anything to do with integration, it is likely that systems so configured - even if the pattern of rings is axially fragmented - would be from the syntactic standpoint fairly integrated systems.1 If SA128 and SA184 are not computed the correlation between axial fragmentation and integration increases to .849 (p=.0001) (Fig 4.15 D). If just the systems of interaction are computed the correlation between RRA and axial fragmentation will go even higher to .908 (p=.328), which is a rather high coefficient despite the low probability consequent upon the small number of observations.2

Tension, as expected, performs with respect of integration in the opposite direction if compared with the performance of axial fragmentation. That is to say, the higher the average length of the axial lines the more integrated (lower RRA) the system tends to be. The correlation coefficients in this case are even higher than the ones

---

1 A further clarification on this issue is provided in next section where grid configuration is described in terms of the measurements of 'ringyness' observed for the different systems.

2 This correlation includes just the larger areas produced out of the proposed first order decomposition, that are SA143, SA148 (and SA299), SB89 and SB295.
Graph A: $R = 0.751 \ (p = 0.0001)$

Graph B: $R = -0.799 \ (p = 0.0004)$

Graph C: $R = -0.636 \ (p = 0.0003)$

Graph D: $R = -0.658 \ (p = 0.0002)$

Graph E: $R = -0.820 \ (p = 0.0001)$
observed when integration and axial fragmentation are matched. All systems computed tension is -.828 (p=.0001) correlated with RRA (Fig 4.15 E). SB184 and SA128 remain as outliers, same as when measured for axial fragmentation. If these two systems are not computed the correlation between integration (given by mean RRAs locally measured) and tension (given by average length) is -.946 (p=.0001)(Fig 4.15 F).

These results indicate that although both the measurements of axial fragmentation and tension might be regarded as good guides for identifying the extent to which an urban system is integrated (as the strong correlation between the two measurements and integration has suggested) there is a certain level of subtlety in the configuration of urban grids that is captured by the measurement of integration which seems to be missed when the sample is described in terms of either axial fragmentation or tension. This level of subtlety is revealed precisely in the performance of systems such as SA184 and SA128 which however strongly fragmented systems are relatively well integrated (as compared with the integration values observed for other systems high in the rank of axial fragmentation).

If, instead of local integration, axial fragmentation is matched with mean RRA values observed for systems as embedded - the correlation goes higher to .751 (p=.0001) (Fig 4.16 A).\textsuperscript{1} The opposite happens in respect of tension that now is -.799 (p=.0001) correlated with RRAemb (Fig 4.16 B).\textsuperscript{2} These figures suggest that axial fragmentation is more associated with patterns of integration as globally measured while tension tends to perform the other way around by being more strongly associated with local integration. In other words the role played by the average length of the axial lines in the pattern of integration is more effective at the local level than at the global level. Insofar as integration is globally measured the role of length as an integrating factor decreases. This result seems to confirm what has already been

\textsuperscript{1} For local RRA the correlation with axial fragmentation, all systems computed, is .677 (p=.0001).

\textsuperscript{2} For local RRA the correlation was -.828 (p=.0001).
observed during the syntactic description given in chapter three. When systems are analysed as detached from their systems of interaction there are axial lines - sometimes short axial lines - that are in a peripheral position. These same lines might become rather integrated lines when the system is analysed as embedded in the system of interaction. The other way around is also true with respect of the longer lines, which can be well integrated locally, yet segregated globally. In other words at the global scale of the urban grid axial length seems to be less effective as an integrating factor than it is at the local scale.

These strong relationships between mean RRA values and average length has raised the question as to whether mean choice values are also strongly associated with average length, especially if the high correlations observed between the two measurements - when values assigned for each axial line were compared during the previous chapter - are taken into account. Nevertheless the same does not happen if mean choice values are compared with axial fragmentation and tension. Both these measurements are hardly correlated with the mean choice values observed for the current sample of grid configurations.

Unlike choice, the intelligibility values observed for different systems are strongly associated with axial fragmentation. The correlation between local intelligibility and axial fragmentation is \(-0.638\) (p=0.0003) (Fig 4.16 C). If instead of local intelligibility, axial fragmentation is compared with global intelligibility - which has already been conjectured as a more reliable way of describing syntactic intelligibility - the correlation increases just marginally to \(-0.658\) (p=0.0002) (Fig 4.16 D). Although the coefficients are similar, it is significant that for local intelligibility the distribution of points in the scattergram is rather dispersed while for global intelligibility the distribution of points is as a whole more homogeneous and closer to the regression line. The fact

---

1 These results are in tables 3.09 and 3.10 (p.197).
2 The correlations are .100 and .181, for axial fragmentation and tension respectively.
3 Local intelligibility, as it has been proposed here, is calculated on the basis of RRA values for the systems as detached from their surroundings.
that correlation is not higher is explained by the performance of just two particular outliers (SA34 and SA184).

Some interesting phenomena emerge out of the relationship between axial fragmentation and intelligibility. SA60 - the orthogonal grid at west in sector A and also one of the least fragmented of all local areas - appears in scattergram C (Fig. 4.16) as a system with a rather low degree of intelligibility. In effect the intelligibility of SA60 is not low with relation to the average intelligibility of the sample, yet it is low if compared with the intelligibility of the systems at the bottom of the rank of axial fragmentation which are all closer to the regression line at the top left in the scattergram. Nevertheless this same SA60, that is an outlier in scattergram C, comes rather close to the regression line in scattergram D, where axial fragmentation is matched with global intelligibility values instead of the local ones.

Some conjectures raised earlier in this chapter are brought back into discussion by the distribution of points observed in scattergram D (Fig 4.16). One refers to the much higher intelligibility of SA60 when it is analysed at the global level, i.e. as embedded in the proposed systems of interaction. The reason for that was already noticed and discussed when the current sample of grid configurations was described in terms of syntactic intelligibility. That is to say the standard orthogonal grid becomes more intelligible insofar as it interacts with surrounding systems. The scattergram also shows that SA34 - a system that is, in effect, a third order decomposition of SA60 - drops down strongly in the rank of intelligibility if global values are considered and, as a consequence, this system will appear as an outlier in scattergram D (Fig 4.16). These variations in intelligibility, both in relation of size and also in relation of scale, clearly indicate (this time from the standpoint of axial fragmentation) that SA60 tends to perform as a whole and when it is decomposed, the parts produced out of such decomposition (especially SA34) will lack the intelligibility of the whole or, in other
words, the intelligibility they have when measured as a part of the whole.

The other outlier in scattergram D (Fig 4.16) is SA184. The performance of this system indicates that for this particular case axial fragmentation is not a reliable indication to detect global intelligibility. This follows what has already been noticed for this same system in respect of the relationship between axial fragmentation and integration. SA184 is a highly fragmented system yet highly integrated and intelligible at the same time. It is significant that for SA128 (the other system together with SA184 whose high mean integration value was not captured by the measure of axial fragmentation as given in Fig 4.16 A) intelligibility remains low so following the high degree of axial fragmentation of this system. This result suggests that the conspicuous 'ringyness' already observed for SA128 (despite its high degree of axial fragmentation) might make it a relatively well integrated system but it does not help to make SA128 intelligible or, in other words while axially fragmented rings may integrate a system, they cannot make it more intelligible.

For the remaining systems the distribution of points is rather homogeneous along the regression line. If the two outliers (SA34 and SA184) are removed the correlation between axial fragmentation and global intelligibility increases to -0.820 (p=.0001) showing clearly that in general axial fragmentation can be regarded as a fair parameter in order to depict the syntactic intelligibility of the urban grid (Fig 4.16 E).

The performance of tension against local intelligibility is virtually symmetric to what was observed in respect of axial fragmentation. Even the 'outlying' performance of SA60 is repeated here, the other way around (Fig. 4.17 A). The correlation although goes slightly higher to

---

1 As it has been suggested, this follows the pattern of long and integrated lines that go into the lumps of axial fragmentation located at south in this system.

2 Compare performances of SA128 and SA184 in relation to local and global intelligibility as given in scattergrams C and D (Fig 4.16).
Fig. 4.17 Correlation analysis for axial fragmentation and tension
.724 (p=.0001). Nevertheless if tension is matched against global intelligibility the correlation will decrease to .587 (p=.0013) (Fig 4.17 B). The description given by the scattergram shows that the part of the sample that includes the systems with lowest average length - the more fragmented systems - tend to perform as a separate group. These seem to be exactly the so called 'labyrinthine' systems whose precise identification and specification has been proceeded in terms of degrees axial fragmentation and tension. These systems are represented by the black dots in scattergram B (Fig 4.17 B). Remarkably if this group is accounted as a separate sample the correlation between tension and intelligibility will increase to .973 (p=.0001) (Fig 4.17 C). For the other part of the sample, which includes the systems where the average length of the axial lines goes higher (which are also the most integrated), tension is hardly related to intelligibility at all. The correlation is -.159 (p=.3942) (Fig 4.17 D).

These results seem to confirm what visual observation and intuition have suggested. For the systems at the top of the rank of tension (which are in fact a specification of the so called more 'griddy' systems) the variations of length take place within a smaller range, i.e. in systems such as SA16 or SA60 the length of the axial lines varies for most observations within a much narrower range than for the more fragmented systems where the number of short axial lines increases dramatically, yet long axial lines also remain scattered here and there, so enlarging (widening) the range of length for these cases. What scattergrams B, C and D express is that in orthogonal grids, such as SA16 and SA60, length is hardly related to intelligibility, while in the case of more fragmented configurations the role of length in the performance of intelligibility is important. It is significant that these characteristics are only captured if global intelligibility values are used. For local intelligibility values

1 The black dots represent twelve out of the twenty six systems that constitute the whole sample, i.e. almost fifty per cent of the systems.
2 SA184 is not included in this test, yet SA69 - the same system having the short housing estates axial lines deleted - is. SA184 repeats here its performance when global intelligibility was matched against axial fragmentation (Fig 4.16 D). Tension, same axial fragmentation, is unable of describing the relatively high intelligibility of this system.
the average length of the axial lines is well correlated with intelligibility throughout the sample, so providing an even and probably distorted picture of the way in which the two measurements are actually associated, especially if the conjectures produced out of the evidence given by global intelligibility values are accepted.

The experiments carried out during this section have shown that to a large extent the measurements of axial fragmentation and tension, as proposed here, provide an accurate and yet visual reference for the identification of the more abstract patterns of integration and intelligibility in urban systems. This is particularly significant for the patterns of integration where axial length, as depicted both in the measurement of axial fragmentation and tension, seems to play a major role.

With respect to intelligibility the situation seems to be more ambiguous. While axial fragmentation and tension are descriptions of the same phenomenon - as it has been suggested here - when both these measurements are matched with intelligibility they perform in a distinct way. The effects of variations in length upon the performance of intelligibility has already been investigated in experiments with theoretical piles of randomly generated axial lines carried out by Professor Bill Hillier and Alan Penn (UAS, Bartlett School). These experiments have demonstrated that intelligibility varies with such factors as the length of the axial lines and the 'compactness' of the pile (a feature that is parallel to the property of axial fragmentation as proposed in the current investigation). In respect of these experiments Hanson has pointed out: 'Short random line piles are found to be relatively unintelligible and long random line piles are correspondingly more intelligible, because the longer the lines the more concentrated the relation becomes between connectivity and integration which is the basis of the measure of intelligibility'.

The cases examined by the current investigation have shown that 'compactedness' - as given by the observed degrees of axial fragmentation - and the length of the axial lines are related to intelligibility in two distinct ways. While the association between average length and intelligibility is restricted to one precise set of systems (the systems at the bottom of the rank of tension), the role of axial fragmentation in intelligibility is consistently observed throughout the sample (Fig 4.16 E). The measurement of axial fragmentation takes length into account in an indirect way, namely through the number of axial lines and its variation with relation to the area of the system, and it is this rather particular way of describing length that is consistently associated with global intelligibility.

By contrast when average length is directly matched with intelligibility - as it has been proposed in the measurement of tension - the correlation will drop, so suggesting that length in itself is not that preponderant in the performance of intelligibility as axial fragmentation seems to be. Besides the highest correlation between length and intelligibility is observed precisely for the cases where long axial lines are mixed with short axial lines (Fig 4.17 B and C) showing that the increase in average length does not necessarily mean an increase in intelligibility. On the contrary, for the part of the sample where tensions are higher the association between intelligibility and average length as given in Fig 4.17 D collapses, showing that the increase in length is not in itself a guarantee of a higher intelligibility.

The urban grid as a pattern of rings

The second of the 'immediately graspable' or 'visually observable' feature of the street grid, as proposed at the outset of this chapter, is the

1 If global intelligibility is simultaneously regressed against both axial fragmentation and tension, the observed coefficient will virtually keep the standard set up by axial fragmentation (.662 p.=.001).
**A** Bar Chart for column: $X_1$ Ringyn

![Bar Chart](chart.png)

- **Observations**

**B** $y = -1.165x + 1.088$, $R^2 = .724$

![Graph](graph.png)

**C** $y = -0.876x + 1.027$, $R^2 = .54$

![Graph](graph.png)

**Table 4.05**

<table>
<thead>
<tr>
<th>Syst Code</th>
<th>Ringyn</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB143</td>
<td>3.36</td>
</tr>
<tr>
<td>SB60</td>
<td>4.05</td>
</tr>
<tr>
<td>SB30</td>
<td>4.30</td>
</tr>
<tr>
<td>SB34</td>
<td>3.92</td>
</tr>
<tr>
<td>SB77</td>
<td>2.27</td>
</tr>
<tr>
<td>SB50</td>
<td>2.27</td>
</tr>
<tr>
<td>SB21</td>
<td>2.45</td>
</tr>
<tr>
<td>SB16</td>
<td>2.88</td>
</tr>
<tr>
<td>SB120</td>
<td>2.39</td>
</tr>
<tr>
<td>SB418</td>
<td>2.07</td>
</tr>
<tr>
<td>SB299</td>
<td>2.22</td>
</tr>
<tr>
<td>SB71</td>
<td>1.80</td>
</tr>
<tr>
<td>SB72</td>
<td>2.22</td>
</tr>
<tr>
<td>SB106</td>
<td>2.52</td>
</tr>
<tr>
<td>SB184</td>
<td>1.81</td>
</tr>
<tr>
<td>SB69</td>
<td>2.86</td>
</tr>
<tr>
<td>SB89</td>
<td>2.46</td>
</tr>
<tr>
<td>SB62</td>
<td>2.65</td>
</tr>
<tr>
<td>SB50</td>
<td>1.93</td>
</tr>
<tr>
<td>SB69</td>
<td>2.16</td>
</tr>
<tr>
<td>SB295</td>
<td>2.00</td>
</tr>
<tr>
<td>SB54</td>
<td>2.90</td>
</tr>
<tr>
<td>SB44</td>
<td>3.15</td>
</tr>
<tr>
<td>SB127</td>
<td>1.80</td>
</tr>
<tr>
<td>SB96</td>
<td>1.80</td>
</tr>
<tr>
<td>SB45</td>
<td>1.71</td>
</tr>
<tr>
<td>SB83</td>
<td>1.81</td>
</tr>
</tbody>
</table>

$R = -.854 (p = .0004)$

$R = -.735 (p = .0004)$
characteristic of configuring itself as a pattern of urban blocks. Hillier and Hanson have termed this property the 'ringyness' of urban systems and have proposed its measurement through the ratio between the number of links and the number of axial lines counted for an urban area. These authors suggest that the measurement of ringyness of an axial system will describe the degree of 'distributedness' of the system. A system may be regarded as syntactically distributed when it forms rings, as is conspicuous in more orthogonal configurations. A system is non-distributed when it forms a 'tree-like' spatial structure (as this characteristic is described by Alexander). Non-distributedness is conspicuous in the more fragmented configurations. The concept of ring is a syntactic equivalent to the concept of loop or circuit in network analysis where non-distributed systems are named 'branched' networks and distributed systems are 'circuit' networks.

This study will describe ringyness in this same way. In first glance it seems that ringyness will systematically increase with the increase of integration (and tension) while decreasing with the increase of fragmentation. This is what the barchart given in Fig 4.18 suggests. The systems already identified at the top of the rank of tension (those so called more griddy systems) are concentrated at the top left of the barchart. To the right the rank of ringyness drops down as it describes the more fragmented configurations. However this cannot be taken as a general rule. Barchart A indicates that some strongly fragmented configurations are quite ringy at the same time. SA106 and SA128 provide examples of that. These systems are in fact at the middle of the barchart. In both cases a pattern of rings is observed throughout the system, yet many of these rings are composed of a large number of axial segments. These systems are ringy but in a rather distinct way from

1 Hillier, B. and Hanson, J. The Social Logic of Space, op. cit.
2 Hagget P. and Chorley, R Network Analysis in Geography, op.cit. As the networks equivalent for the syntactic measurement of ringyness these authors propose a beta index, i.e. the ratio between the number of edges and the number of nodes of the network.
3 The rank of axial fragmentation is given in Fig 4.14.
4 There is one particular ring in SA106 that is composed of eight axial segments (see reference map).
the ringyness observed in a 'standard' orthogonal grid—such as SA60 or SB54—where rings are systematically performed by four and just four axial lines which define the contour of each urban block. An example in the other direction is provided by SA77, that is the less 'griddy' part of SA west. This system is high in the rank of integration, yet it drops down strongly in the rank of ringyness. That is to say it is an integrated system with a low degree of ringyness.

At any rate, if the whole sample is considered ringyness is strongly correlated with integration. Local integration—mean RRA values for each system measured as detached—is -.851 (p=.0001) correlated with ringyness (Fig 4.18 B). It is significant that the exceptional cases described above (SA106, SA128 and SA77) are not captured through the matching of local RRA and ringyness. The plot shows that all systems are rather homogeneously distributed along the regression line. Nevertheless if ringyness is matched against global integration—mean RRA values of each local area as embedded—the picture changes and the exceptional cases described above will perform in opposition to the general pattern (Fig 4.18 C). SA77 and its two parts produced out of third order decomposition (SA59 and SA21) will perform as outliers in the scattergram, so confirming that their ringyness is much lower than the expected value if ringyness and integration were to be consistently associated. SA 106 provides an example in the other direction. This system is strongly segregated yet its ringyness is much higher than the expected, again, if ringyness and integration were to perform in a more consistent association. As a consequence the correlation between integration—as globally measured—and ringyness drops down to -.735 (p=.0001) (Fig. 4.18 C).

The third situation pointed out as an exception—SA 128—was described in the previous section as a strongly fragmented system yet rather

---

1 The test of normality applied for the distribution of ringyness has shown that this variable is negatively skewed. Logtransformation will just reduce skewness and make the distribution rectangular.
Fig. 4.19 Correlation analysis for ringyness
integrated at the same time. SA128 has been a strong outlier when axial fragmentation was matched with integration.\footnote{This is given in Fig 4.15 C for integration values as 'detached' and Fig 4.16 A for values as 'embedded'}. It was then conjectured that the higher than expected degree of integration observed for this system might be brought about by the conspicuous pattern of rings as visually observed. This seems to be confirmed by the performance of this system in scattergrams B and C (Fig 4.18). Either at the local or at the global level – i.e. either for local or for global integration values – SA128 is consistently close to the regression line so showing an agreement between integration and ringyness for this particular case.\footnote{Further in this section it will be shown that when ringyness is plotted against axial fragmentation, SA128 will become a strong outlier.}

Ringyness, following what has happened with axial fragmentation and tension, is poorly correlated with the mean choice values observed for the different systems. The correlation is .207 (p=.3564) (Fig 4.19 A). Nevertheless, different from axial fragmentation and tension whose performance has been consistently associated with intelligibility, ringyness is also hardly related to this measurement, most especially with global intelligibility. \footnote{This coefficient is obtained when all systems are compared. If the systems of interaction are deleted the coefficient remains rather stable in .458 (p=.0322) so showing that the correlation is not affected by size.} In fact ringyness is somewhat correlated with local intelligibility. The coefficient is .450 (p=.0184) (Fig 4.19 B). Nevertheless the coefficient drops strongly to .167 (p=.4069) when the ringyness of the different systems, as measured by their link/line ratio, is plotted against global intelligibility (Fig 4.19 C). It is also significant that even for local intelligibility the distribution of points in the scattergram is rather dispersed.

When ringyness is plotted against axial fragmentation and tension the correlation coefficients will be much higher than the previous cases, especially if we take into account the low association between ringyness and intelligibility described above. SA106 and SA128 - the two systems at the top of the ranking of axial fragmentation – will stand as outliers.
in these tests so confirming what visual observation had already suggested, namely the conspicuous ringyness of SA106 and SA128, despite their high degree of axial fragmentation (and low degree of tension) (Fig 4.19 D and E).

In short the evidence provided in this section has shown that the ringyness of the urban grid is strongly associated with its pattern of integration, especially when local integration values (measurements of RRA for systems 'as detached') are accounted. In this respect ringyness performs rather similarly to axial fragmentation and tension. Nevertheless if mean integration values are measured as embedded the role of ringyness in integrating the urban grid seems to decrease.1 The explanation for that seems to be straightforward. A ring is a local feature in the configuration of the street grid, and as such ringyness seems to be more likely to affect integration at the local level than at the global.

The high correlations observed between ringyness and integration are not strong enough to set up an association between ringyness and intelligibility. The performance of the urban grid as a pattern of rings, although it is consistently associated with its pattern of integration and with its degree of fragmentation as well, seems to play a minor role in the intelligibility of the different systems. The conjecture here is that there is a correspondence between the way urban systems are intelligible from the perceptual standpoint, as studied by Lynch, and the syntactic concept of intelligibility. It is suggested here that axial length or fragmentation are influential in the way urban systems are perceived and used, whereby intelligibility is well correlated with both axial fragmentation and tension. By contrast the fact that the street grid performs or not as a pattern of rings is less perceived by an actual

---

1 The coefficient drops from - .85 (for local RRA) to - .735 (for global RRA). This is given in Fig 4.18 B and C.
observer (unless from a bird's eye view) and this is reflected in the poor association between intelligibility and ringyness.¹

The urban grid as a pattern of connectivities

The third of the 'visually observable' qualities proposed at the outset of this chapter is the frequency (or density) of intersections observed for each system which might also be described as the character of the system as a patterns of connectivities. This characteristic will be measured in two distinct ways. The first is the mean connectivity of each system, that is to say the mean given by the connectivities of all lines inside the system of interest. The other is the density of intersections (or connections) per unit of area. This measurement was originally developed by Borchert (1961) in his study on density of transport channels for the Minneapolis-St.Paul area (US).² Borchert evolved a simple measure of counting all the road junctions on the map. His findings include a very strong association between population density, as measured by number of single family dwellings, and 'network density', as measured by the ratio between the number of intersections and the area of the system.

These two measurements - mean connectivity and density of intersections - complement the each other by providing two distinct descriptions for the pattern of connectivities, one from the standpoint of the frequency axial lines intersect the each other, other from the standpoint of the intensity the pattern of intersections spreads in relation to the area of the different systems.

The rank of mean connectivities reproduces to a large extent a distribution already noticed for other variables, i.e. the sample here again seems to be explicitly ordered from the more 'griddy' or orthogonal

¹ A fair account on such perceptual dim ension of the 'pattern of paths' is given in Lynch, K. The Image of the City, op.cit.
² Borchert, J. The twin cities urbanized area: past, present and future, op.cit.
Below correlation analysis for mean connectivity and density of intersections:

**Table 4.06**

Measurements of connectivity and density of intersections

<table>
<thead>
<tr>
<th>Syst Code</th>
<th>Conn</th>
<th>D Intersec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR135</td>
<td>6.73</td>
<td>84.58</td>
</tr>
<tr>
<td>SR60</td>
<td>6.46</td>
<td>84.10</td>
</tr>
<tr>
<td>SR50</td>
<td>11.80</td>
<td>109.26</td>
</tr>
<tr>
<td>SR34</td>
<td>9.36</td>
<td>89.47</td>
</tr>
<tr>
<td>SR77</td>
<td>5.45</td>
<td>72.54</td>
</tr>
<tr>
<td>SR59</td>
<td>6.20</td>
<td>94.57</td>
</tr>
<tr>
<td>SR21</td>
<td>6.14</td>
<td>90.75</td>
</tr>
<tr>
<td>SR16</td>
<td>7.94</td>
<td>95.80</td>
</tr>
<tr>
<td>SR22</td>
<td>4.70</td>
<td>100.00</td>
</tr>
<tr>
<td>SR418</td>
<td>4.13</td>
<td>111.76</td>
</tr>
<tr>
<td>SR299</td>
<td>4.45</td>
<td>112.99</td>
</tr>
<tr>
<td>SR71</td>
<td>3.01</td>
<td>129.06</td>
</tr>
<tr>
<td>SR72</td>
<td>4.85</td>
<td>129.78</td>
</tr>
<tr>
<td>SR106</td>
<td>4.90</td>
<td>125.02</td>
</tr>
<tr>
<td>SR104</td>
<td>5.79</td>
<td>131.25</td>
</tr>
<tr>
<td>SR66</td>
<td>6.41</td>
<td>108.61</td>
</tr>
<tr>
<td>SR69</td>
<td>6.19</td>
<td>108.65</td>
</tr>
<tr>
<td>SR89</td>
<td>5.44</td>
<td>101.71</td>
</tr>
<tr>
<td>SR62</td>
<td>6.02</td>
<td>114.46</td>
</tr>
<tr>
<td>SR50</td>
<td>5.12</td>
<td>113.55</td>
</tr>
<tr>
<td>SR69</td>
<td>6.19</td>
<td>113.65</td>
</tr>
<tr>
<td>SR295</td>
<td>4.29</td>
<td>109.76</td>
</tr>
<tr>
<td>SR84</td>
<td>6.72</td>
<td>110.73</td>
</tr>
<tr>
<td>SR44</td>
<td>6.97</td>
<td>113.00</td>
</tr>
<tr>
<td>SR127</td>
<td>3.94</td>
<td>102.23</td>
</tr>
<tr>
<td>SR86</td>
<td>5.97</td>
<td>113.67</td>
</tr>
<tr>
<td>SR45</td>
<td>4.69</td>
<td>103.70</td>
</tr>
<tr>
<td>SR83</td>
<td>4.06</td>
<td>108.70</td>
</tr>
</tbody>
</table>

**Correlation Graph**

\[ r = -0.376 \, (p = 0.0529) \]
configurations towards those so called 'labyrinthine' systems (Fig 4.20 A). Insofar as the current analysis advances it has become clear that different descriptions - connectivity, integration, axial fragmentation, tension and ringyness - are strongly associated despite the number of exceptional cases that have been identified. The same does not apply to the distribution observed when configuration is described by density of intersections per unit of area (Fig 4.20 B). The barchart indicates that for this measurement the values assigned for fifteen out of nineteen local areas vary within a relatively small range, while for four particular systems the figures seem to grow exponentially.

Among these four systems are the strongly fragmented SA128, SA106 and SA184, although this is not enough to set up the recurrent 'griddy towards labyrinthine' pattern described above. Low axial fragmentation systems - such as SA30 and SB44 - which are markedly high in the rank of tension are also quite high in the rank of density of intersections per area, next to more fragmented configurations such as SB96 and SB127. In effect the inclusion of an areal dimension in the measurement of connectivity produces a measurement that is hardly related to the topological concept of connectivity. Strongly fragmented systems such as SA128 and SA106 which are the two highest densities of intersections per area will be right at the middle of the connectivity rank. A plot of connectivity against density of intersections per area for the sample as a whole confirms what the observation of the barcharts has suggested. The correlation between the mean connectivity of the different systems and their density of intersections is as low as -.376 (p=.0529) (Fig 4.20 C).

And it has been precisely from the performance of exceptional cases - those systems that tend to perform distinctively from the more general pattern observed - that significant clues on the performance of the different variables have emerged.

The test for normality has shown that both connectivity and density of intersections are negatively skewed in their linear form. Both variables will have a rectangular distribution after logtransformation.
The distinct performance of connectivity and density of intersections per area is made further explicit when both measurements are matched with other syntactic parameters. The mean connectivity of the different systems is well correlated with the mean RRA values as locally measured, i.e. for each system measured as detached. The correlation is -.905 (p=.0001) (Fig 4.21 A). The points are rather homogeneously distributed along the regression line, despite the performance of SA184 (the black dot in the scattergram) that emerges as a unique outlier.¹ When mean connectivity values are matched with mean integration values observed for the different systems as embedded the coefficient will drop to -.833 (p=.0001) (Fig 4.21 B) showing as expected that the performance of connectivity as an integrating factor is more effective at the local level than at the global level, same as it has been observed for ringyness. Despite such a decrease it is significant that the correlation keeps a rather high coefficient even at the global level, so indicating that connectivity, despite its strict local character, is also strongly influential in the pattern of global integration.

Unlike connectivity the measurement of density of intersections per area is scarcely associated with integration (either at the local or at the global level). The correlations are .328 (p=.0946) for RRA and .494 (p=.0143) for RRAemb. The correlations will change direction if compared with the performance observed for mean connectivity in relation to mean RRA. While integration follows the increase of connectivity, it tends to decrease insofar as density of intersections per area increases. Nevertheless the correlation coefficients are much lower and also the probability of the correlations. These low coefficients cannot be seen as provoked simply by the inclusion of an areal dimension (number of intersections per unit of area) which has hardly anything to do with the topological dimension of the street grid. If that was the case

¹ If the general tendency observed in the scattergram were applied for SA184, the quite low mean connectivity observed in this system should correspond to a much higher RRA value. SA184 is the lowest mean connectivity of all sample. Here again it is made explicit the integrating role of the long axial lines that traverse SA184 going straigh inside the lumps of short (and poorly connected) axial lines given by the housing estates. Despite its low mean connectivity SA184 is relatively well integrated.
the proposed measurement of axial fragmentation — that same as density of intersections is a ratio between a syntactic and an areal parameter — would have followed a similar pattern. Nevertheless, as it has been seen during previous analysis, axial fragmentation is consistently well correlated with both integration and intelligibility.

This picture changes when both measurements — connectivity and density of intersections per area — are plotted against intelligibility. Local intelligibility is reasonably well associated with connectivity. The correlation coefficient is .65 (p=.0002) (Fig 4.21 C). The correlation is particularly affected by the performance of the more orthogonal grid at west of sector A (SA60) and its two parts produced out of third order decomposition (SA30 and SA34). These systems although positioned at the top of the connectivity rank are much lower than expected in the rank of intelligibility if the general tendency observed in the scattergram is taken as a parameter. This confirms what was observed when the current sample of grid configurations was described in terms of axial fragmentation and tension. These same systems, despite their low degree of axial fragmentation and high degree of tension, have shown a rather low degree of intelligibility.

In the context of the current test the high mean connectivity observed for SA60 seems to perform against its local intelligibility and this is rather distinct from what is observed for the bulk of the sample, where the increase of local intelligibility seems to follow consistently the increase of connectivity, as the distribution of the remaining points suggest. Nevertheless if global intelligibility values are computed — instead of the local ones — the correlation will drop to .326 (p=.0976) (Fig 4.21 D), showing clearly that the effects of connectivity on intelligibility are restricted to the local level. This is distinct from what was observed for the relationship between mean connectivity and mean integration where, despite the lower correlation given by mean
integration values as embedded, the coefficient remains quite significant.¹

The relationship between intelligibility and density of intersections per area works the other way around. Density of intersections, while hardly associated at all with integration, will be strongly correlated with intelligibility, especially at the global level. It is significant that the correlation for density of intersections changes its direction if compared with the plot of intelligibility against connectivity. Local intelligibility is −0.529 (p = 0.0045) correlated with density of intersections (Fig 4.21 E). The coefficient goes higher to −0.734 (p = 0.0001) if instead global intelligibility values are plotted (Fig 4.21 F).²

These results indicate that insofar as density of intersections per area increases the intelligibility of the system tends to decrease. It may then be said that while the topological measurement of connectivity hardly affects the global intelligibility of the urban grid (Fig 4.21 D), variations in the density of intersections per unit of area might be seen as a possible parameter for detecting intelligible patterns (Fig 4.21 F). Although the number of observations is not large enough to produce a conclusive evidence, the high probability of the correlation plus the somewhat homogeneous distribution of points along the regression line produces at least a fair hypothesis for further research on this specific topic.

When matched against axial fragmentation and tension the measurements of mean connectivity and density of intersections will have opposite performances. Connectivity will increase strongly following the increase of average length (tension) and the decrease in

¹ These results are given in Fig 4.21 A and B.
² SA184 – a system whose relatively high intelligibility is parallel to a high degree of axial fragmentation – is again an outlier when intelligibility is plotted against density of intersections so indicating that the two measures – axial fragmentation and density of intersections – tend to perform similarly in their relationship with intelligibility.
Fig. 4.22
Correlation analysis for mean connectivity and density of intersections
the density of axial lines per area (axial fragmentation). The correlations are \(-0.752\) \((p=0.0001)\) for connectivity against axial fragmentation (Fig 4.22 A) and \(0.900\) \((p=0.0001)\) for connectivity against tension (Fig 4.22 B). By contrast, density of intersections will increase with axial fragmentation, \(R=0.874\) \((p=0.0001)\) (Fig 4.22 C), and decrease with tension, \(R=-0.696\) \((p=0.0001)\) (Fig 4.22 D).\(^1\) This results indicate that both axial fragmentation and tension are parameters strongly related — yet in different ways — to the pattern of connectivities, either described in its topological expression (mean connectivity) or from the areal standpoint (density of intersections per area). The same cannot be said about ringyness, that is strongly correlated with connectivity; \(R=0.925\) \((p=0.0001)\) (Fig 4.22 E) yet it is virtually uncorrelated with the density of intersections.\(^2\)

This section has shown that although the two parameters proposed here as measurements for the pattern of connectivities are hardly related, they seem to complement the each other for their distinct descriptive potential. This is particularly relevant in their performance with respect of the pattern of global intelligibilities, to which the measurement of mean connectivity is hardly associated while density of intersections per area seems to play a major role. It must be also acknowledged that the syntactic characteristics depicted in the experiments carried out during this section have transcended the ‘visually observable’ features proposed at the outset. In effect the subtle distinction between the topological dimension of connectivity and the measurement of connectivity relativised to the area of each system is not within easy reach of straight visual observation and can only be detected after a proper inspection and subsequent measurement as a way of preventing misleading descriptions.

\(^1\) The high correlation between axial fragmentation and density of intersections confirms the conjecture raised earlier in this section, when the ‘outlying’ of SA184 was identified in the plotting of both these measurements against intelligibility.

\(^2\) The correlation is \(-0.119\) \((p=0.3627)\).
Fig. 1.25: Rank of figure-ground ratios

Bar Chart for column: X1 Fig Ground rt

Observations

Table 4.07: Measurements of figure-ground ratio

<table>
<thead>
<tr>
<th>Sys Code</th>
<th>Fig Ground rt</th>
</tr>
</thead>
<tbody>
<tr>
<td>S9145</td>
<td>14.22</td>
</tr>
<tr>
<td>S960</td>
<td>16.35</td>
</tr>
<tr>
<td>S9850</td>
<td>22.90</td>
</tr>
<tr>
<td>S9854</td>
<td>17.24</td>
</tr>
<tr>
<td>S977</td>
<td>14.44</td>
</tr>
<tr>
<td>S9859</td>
<td>17.92</td>
</tr>
<tr>
<td>S9821</td>
<td>19.74</td>
</tr>
<tr>
<td>S9816</td>
<td>21.71</td>
</tr>
<tr>
<td>S9128</td>
<td>20.02</td>
</tr>
<tr>
<td>S9418</td>
<td>26.59</td>
</tr>
<tr>
<td>S9299</td>
<td>18.69</td>
</tr>
<tr>
<td>S9771</td>
<td>17.82</td>
</tr>
<tr>
<td>S9772</td>
<td>22.89</td>
</tr>
<tr>
<td>S98106</td>
<td>23.57</td>
</tr>
<tr>
<td>S98104</td>
<td>20.95</td>
</tr>
<tr>
<td>S9669</td>
<td>16.45</td>
</tr>
<tr>
<td>S9889</td>
<td>14.78</td>
</tr>
<tr>
<td>S9862</td>
<td>16.19</td>
</tr>
<tr>
<td>S9850</td>
<td>14.88</td>
</tr>
<tr>
<td>S9869</td>
<td>18.60</td>
</tr>
<tr>
<td>S9295</td>
<td>16.83</td>
</tr>
<tr>
<td>S9854</td>
<td>18.45</td>
</tr>
<tr>
<td>S9844</td>
<td>18.29</td>
</tr>
<tr>
<td>S9127</td>
<td>14.12</td>
</tr>
<tr>
<td>S9896</td>
<td>15.13</td>
</tr>
<tr>
<td>S945</td>
<td>17.12</td>
</tr>
<tr>
<td>S9883</td>
<td>15.93</td>
</tr>
</tbody>
</table>

R = .766 (p = .0004)

R = -.990 (p = .0095)

R = .502 (p = .0077)
Figure-ground ratios

This section describes the current sample of grid configurations from the point of view of the 'figure-ground ratio' observed for each system. The measurement of 'figure-ground' as it is proposed here might be regarded as an axial version of Peterson's 'proportion of solids and voids'. This characteristic will be measured through the ratio between the total length of all axialities and the area of the system. A similar description has been utilized in network analysis, mostly as a way of measuring drainage density. The measure was first defined by Horton (1932) as the total length of stream channel within a basin per unit of area. Once adapted to the urban field this measurement seems to be a reasonable way of assessing density of public open space, which might be seen as parallel, if not coincident, with the degree of permeability of an urban area.

Just as it happened for density of intersections per area the rank of figure-ground ratios, as given in Fig 4.23 A, bears hardly any relationship with the pattern observed for the current sample of grid configurations, when it is described according to most of the measurements so far dealt with. For most measurements the same set of systems (those initially qualified as more griddy systems) tend to be at the top of the ranks of integration, tension, connectivity and to some extent intelligibility. At the same time, another set of systems (those initially qualified as more 'labyrinthine' systems) tend to occupy the bottom of these same ranks as the least integrated, the least connected,

---

1 The description of grid configuration according to Anderson (1979) is part of the review of literature given in chapter one. In Peterson, S. Urban Design Tattics, op.cit. Anderson proposes a series of examples which compare 'traditional' and 'modern' figure-ground configurations in terms of their 'proportion between solids and voids' as a visually observable feature. Peterson has not made any attempt of measuring this property for distinct grid configurations for comparative purposes.


3 probably more accurate than if 'voids' were to be measured in terms of their areal dimension - same as it is proposed for the 'solids' - for if this was the case the axial dimension of the routes would not be captured and as a consequence the measurement would have lost its syntactic feature.
the lowest degrees of tension (the highest degrees of axial fragmentation) and the less intelligible systems. In effect the set of measurements referred to above seems to perform as distinct descriptions for the same phenomena.

The same cannot be said about figure ground ratios. In fact the pattern already observed in the rank of density of intersections per area is to a large extent reproduced in the rank of figure ground ratios. This follows, on the one hand, the fact that both these measurements are relativised to the area of the different systems and, on the other hand, the strong correlation between connectivity (upon which the measure of density of intersections is based) and length (upon which the measure of figure-ground ratio is based). The comparison of Fig 4.23 A (for figure-ground ratio) and Fig 4.20 B (for density of intersections) shows that, in general, the same set of systems will appear at the top and bottom of both ranks. This applies both for SA128, SA106 and SA72 (systems that are at the top of both ranks) and also for SA77 and SB30 (systems that are at the bottom of both ranks). Nevertheless the performance of systems such as SA16, SB127 and SB69 (which perform more independently) will radically contradict this model. At any rate the correlation between figure-ground ratio and density of intersections is as high as .766 (p=.0001) (Fig 4.23 B).

Both measurements also perform similarly when plotted against the mean integration of the different systems and their intelligibilities. That is to say figure-ground ratio is virtually uncorrelated with mean integration - either locally or globally measured - and also with local intelligibility. Nevertheless when figure-ground is matched with global intelligibility the correlation increases, but to a much lower extent than the increase observed for density of intersections when matched with the same global intelligibility figures. The correlation coefficient for figure-ground plotted against intelligibility will be -.49 (p=.0095) (Fig 4.23 C). The correlation is not high, although it seems to be significant.

1 These results are in table 3.09 and 3.10 (p.194).
for the distribution of points in the scattergram is rather homogeneous so providing an indication that the increase of 'voids' (as given by the aggregate of axial lengths) in relation to the 'solids' (as given by the area of the system) tends to bring about a decrease in the syntactic intelligibility of the urban grid.

Figure-ground ratio is as expected better correlated with axial fragmentation for - as visual observation suggests - the increase in the number of axial segments in an urban system seems to be naturally attached to an increase in the total length of axial lines. Nevertheless the coefficient is lower than expected; \( R = 0.502 \) (\( p = 0.0077 \)) showing that the conjecture produced out of straight visual observation is somewhat misleading (Fig 4.23 D). The correlation is higher than when figure-ground is matched with intelligibility, but the scattergram shows that for the current test the systems at the top of the rank of axial fragmentation (black dots in the scatter diagram) are strong outliers in relation to the bulk of the distribution. If these systems are deleted figure-ground ratio will be virtually uncorrelated with axial fragmentation.

In relation to other measurements - tension, ringyness and connectivity - figure-ground ratio is totally uncorrelated. In effect, apart from its association with global intelligibility, the description given by figure-ground ratios, as it is currently proposed is hardly associated to other syntactic parameters examined during this chapter.

The descriptions of grid configuration given during this chapter have made an effort to enlarge the range of possible descriptions instead of limiting the descriptive potential of the different systems. It might be said that the descriptive potential of each system has been enlarged in terms of the range of measurements applied - integration, intelligibility, axial fragmentation, density of intersections, etc. - in so far as these
descriptions of the configuration of each system have added weight and clarification to the decompositions and compositions proposed.

This range of measurements and decompositional propositions will be matched in the next two chapters with the performance of land use distributions for these same systems. In what follows all axial lines - and thus all different systems - are loaded with the frequency of location of the different use categories as given by the constitution criterion (already stated during chapter two). Beside the investigation of the relationships between grid configuration and land use distribution the comparison of syntactic and functional parameters may also bring further clarification to the different propositions which have emerged from the syntactic analysis, namely the different decompositional alternatives, the performance of different measurements, the problem of scale and, most of all, the extent to which the range of parameters utilized as spatial descriptions (syntactic parameters) will respond to inputs coming from the socio-economic dimension of the urban phenomenon as embodied in the distribution of uses.
CHAPTER 5
Syntactic Descriptions for
the Distribution of Productive Activities

It is likely that a number of grid effects upon the distribution of uses - which are picked up by syntactic descriptions in the analysis that follows - could be also explained by other reasons given by the socio-cultural, political and historical nature of the two areas of study; reasons that reflect the will of individuals, groups and institutions, at different times of the city's history, in laying the grid and setting up a pattern of land use in one way or another. This study does not enter into the analysis of historical factors which have affected the development of each part of the grid. Instead it concentrates strictly in the statistical assessment of syntactic regularities in the compared performance of grid configuration and land use distribution. The original reasons why the street grid came to be as it is and why the pattern of land use stands as it stands - however these reasons might for sure have provoked innumerable morphological outcomes - is not amongst the concerns of this investigation.¹

Besides however this thesis acknowledges that the timing given by the historical development of the city - in the sense of the chronology according to which different parts of the grid were laid out - is associated to morphology and also to the initial distribution of uses and its earlier development, the proposed method of analysis implies that the current sample of grid configurations is large and diversified enough to include and go beyond the historical effect, so allowing for the identification of regularities which, by going beyond the historical factor, recur throughout the selected sample. These regularities may be termed as grid effects.

¹ Despite the fact that the socio-cultural factors that have affected the historical development of the city of Porto Alegre are to a large extent printed in the way land uses are distributed and if this is accepted the distribution of uses is in itself a historical record.
In fact the two areas of study include portions of the grid coming from different periods of the history of the city and the chronology observed in the development of sectors A and B has not followed the centre towards periphery rule to all extent. A number of urban voids along sectors A and B have remained unused for many years. Some of these areas have been developed after the urbanization of more peripheral parts of these systems. This is the case of a large number of blocks in the east part of SA60 which have been developed more than twenty years after the development of the remainder of that system and even after the development of a large part of SA77, the adjacent part of the grid at east. This also applies to a large part of SA72 which has been the last of all SA systems to be entirely developed despite its more central position in relation to the whole sector A. That is to say, the two vectors of urban growth - which include sectors A and B - does not correspond to a linear chronology. This characteristic of both sectors A and B reinforce the conjecture that the pattern of land use developed in different parts of the grid might be naturally associated to grid effects given by the syntactic character each area.

It is also noteworthy that the proposed local areas - which in many cases correspond to one particular kind of grid configuration - do not correspond as a whole to one development, all carried out at the same time. In fact the grid configuration observed within each local area has been in most cases produced by different developments occurred at different times and in some cases including adjacent areas with a distinct grid configuration. The way in which the east part of sector A was developed illustrates this point. Fig 5.01 shows that SA106 is a product of three different developments. One of them also includes part of SA184 the adjacent local area. The same applies for most of the conjectured local areas.\footnote{SA128 is the exception. This part of the grid is as a whole produced by one development.} The complex character observed in the way in which the grid was laid out is very much in tune with the purposes of this study, which implies that both the configuration of the grid and the distribution of land uses - in both areas of study - are products of a
spontaneous or natural process of development instead of a process artificially produced, i.e. emerged out of public policies oriented towards the modern concept of urban space coupled with zoning strategies.¹

In fact the zoning ordinance proposed by the masterplan of Porto Alegre for the two areas of study have to a large extent embodied a pre-existing pattern of land use distribution. Areas where the mixture of uses has been predominant such as the west part of sector A and the north and west parts of sector B had their mixed status confirmed by the masterplan. Areas that are more residential such as SA106 and SB96 had also their residential status confirmed yet in these cases the plan does not conceal an aim of 'purifying' further these areas - although in a less radical way if compared with the residential purity of more peripheral parts of the city where recent developments have occurred. In any case, since the areas under investigation might be regarded both of them as parts of the central Porto Alegre and since the masterplan is so recent as 1979 the effects of legislation on the patterns of distribution of uses in the proposed areas of study are rather marginal.

In what follows, this research investigates the interface between the distribution of productive activities and the configuration of the urban grid in sectors A and B as given by the range of syntactic parameters delivered in the two previous chapters.² The distribution of productive activities will be measured in two distinct ways; two distinct measurements of density it might be said. The first considers the density of each one of the proposed categories of productive activities - shops, offices and industries - at the level of each system. This measurement aims to identify system effects which might recur in the

¹ Despite the fact that the current sample also includes some areas like that, such as the parts of the grid where housing estates predominate inside SA184 and SB45.
² The concept of productive activity in the context of the current investigation same as for all land use categories to be utilized in what follows - chapters five and six - have been presented and discussed in chapter two of this thesis.
association between the configuration of the grid and the distribution of productive activities. In other words *mean densities* observed for each use category within the different systems, will be compared with the set of syntactic measurements investigated during the last chapter so allowing for the investigation of the relationship between grid configuration and distribution of productive activities. This is the object of next section where the procedure for measuring *mean densities* of land use is fully explained.

In the following step the analysis shifts towards *density* values observed at the level of each individual axial line. This measurement - which is concerned with *line effects* - brings back into the analysis the set of syntactic parameters which gave rise to the proposed syntactic decompositions in chapter three. This procedure, by inverting the analytical strategy adopted during the two previous chapters will complete what might be termed as an analytic cycle. That is to say, the analysis developed during chapter three - which gave rise to the proposed decompositions - has been most of it based upon the syntactic identity of each individual axial line, i.e. it has been mostly based on *line effects*. In the subsequent step - chapter four, the analysis has shifted towards the description of the different *systems* in terms of the mean values observed for the set of proposed syntactic measurements. That is to say, *system effects*. The description of the syntactic characteristics of land use distributions will be proceeded the other way around. It starts from the analysis of *system effects* and advances towards the analysis of *line effects*.

The analytical strategy structured in this way allows for a further testing out of the proposed decompositions. It is conjectured here that variations in the correlation coefficients between syntactic parameters and patterns of land use distribution may be utilized as an instrument for assessing the pertinence of the proposed boundaries and systems of interaction as well. In other words, if a set of *possible decompositions* for the same area is to be compared the alternative for which the
correlation coefficient between syntactic and land use measurements is the highest is likely to be the \textit{area of syntactic reference} for that particular use inside that particular portion of the street grid. Whether or not the concept proposed here of area of syntactic reference coincides with the concept of \textit{catchment area} is in fact beyond the scope of this research. Nevertheless since the concept of catchment area - as the literature reviewed has suggested - has been utilized in a rather broad and vague way, the concept of area of syntactic reference as it is proposed here might be seen as a possible way of providing an objective character for the catchment area description.

\textbf{Grid configuration and the densities of productive activities}

The distribution of productive activities will be measured in two distinct ways in what follows. One is the ratio between the sum or aggregate of constitutions related to each one of the proposed categories - shops, offices and industries - within each system and the area of the system (dPA/A). The second measurement is the mean value - for all lines inside each system computed - given by the \textit{frequency of location} of each land use category inside each particular axial line. As it has already been explained, such a frequency of location is measured in terms of the number of constitutions related to each land use category per unit of length (axial length). Thus this measurement can also be regarded as describing the \textit{density} of each land use category inside each particular system or, in other words, the mean given by the \textit{densities of use} observed at the level of each axial line inside each system (dPA/Ln).

Both measurements are syntactic in origin by virtue of their commitment with the axial map.\footnote{Axial lines \textit{loaded} by \textit{qualified constitutions}.} Nevertheless while the first measurement has also an areal concern - for the aggregate of constitutions is relativised to the area of the system - the second is conspicuously attached to the
### Table 5.01
Measurements for densities of productive activities

<table>
<thead>
<tr>
<th>Sgnt Code</th>
<th>dPA/A</th>
<th>dPA/Ln</th>
</tr>
</thead>
<tbody>
<tr>
<td>5A105</td>
<td>840.45</td>
<td>36.15</td>
</tr>
<tr>
<td>5A114</td>
<td>1176.14</td>
<td>61.14</td>
</tr>
<tr>
<td>5A150</td>
<td>1423.90</td>
<td>64.29</td>
</tr>
<tr>
<td>5A341</td>
<td>1846.87</td>
<td>58.81</td>
</tr>
<tr>
<td>5A77</td>
<td>454.70</td>
<td>26.25</td>
</tr>
<tr>
<td>5A59</td>
<td>556.47</td>
<td>23.75</td>
</tr>
<tr>
<td>5A21</td>
<td>158.40</td>
<td>28.41</td>
</tr>
<tr>
<td>5A118</td>
<td>773.40</td>
<td>37.89</td>
</tr>
<tr>
<td>5A120</td>
<td>382.67</td>
<td>9.69</td>
</tr>
<tr>
<td>5A410</td>
<td>591.46</td>
<td>14.87</td>
</tr>
<tr>
<td>5A929</td>
<td>386.86</td>
<td>18.35</td>
</tr>
<tr>
<td>5A71</td>
<td>445.82</td>
<td>20.83</td>
</tr>
<tr>
<td>5A72</td>
<td>657.50</td>
<td>25.89</td>
</tr>
<tr>
<td>5A106</td>
<td>412.21</td>
<td>16.24</td>
</tr>
<tr>
<td>5A104</td>
<td>365.32</td>
<td>7.68</td>
</tr>
<tr>
<td>5A69</td>
<td>371.54</td>
<td>13.55</td>
</tr>
<tr>
<td>5A140</td>
<td>411.34</td>
<td>28.91</td>
</tr>
<tr>
<td>5A62</td>
<td>508.40</td>
<td>24.53</td>
</tr>
<tr>
<td>5A50</td>
<td>316.60</td>
<td>14.14</td>
</tr>
<tr>
<td>5A69</td>
<td>712.80</td>
<td>30.69</td>
</tr>
<tr>
<td>5A295</td>
<td>418.17</td>
<td>12.22</td>
</tr>
<tr>
<td>5A54</td>
<td>784.60</td>
<td>38.42</td>
</tr>
<tr>
<td>5A44</td>
<td>713.80</td>
<td>30.78</td>
</tr>
<tr>
<td>5A127</td>
<td>219.64</td>
<td>9.56</td>
</tr>
<tr>
<td>5A96</td>
<td>231.79</td>
<td>9.99</td>
</tr>
<tr>
<td>5A45</td>
<td>408.71</td>
<td>17.68</td>
</tr>
<tr>
<td>5A85</td>
<td>506.72</td>
<td>14.49</td>
</tr>
</tbody>
</table>
syntactic character of the street grid - for the aggregate of constitutions is in this case relativised to the number of axial lines. The simultaneous use of these two parameters allows for a systematic match of areal oriented and topologically based measurements. Despite the distinct procedures behind the calculation of these two measurements, intuition suggests that these two ways of assessing land use density might be strongly related. The conjecture here is that the parts of the street grid, as given by the proposed decompositions, where the density of an x land use category per area is higher will probably be the ones where the mean density observed for this same use category per number of axial lines will be higher as well.

The rank ordering of the current sample of grid configurations for these two density modes, as given in bar charts A and B will confirm to a large extent what intuition has suggested (Fig 5.01). Either for measurements per unit of area (dPA/A) or for measurements per number of axial lines (dPA/Ln) the orthogonal grid at west of sector A carries the highest concentration of productive activities of all sample. This also stands for second and third order decompositions. Second in the rank is the more orthogonal part of sector B, either configured as SB54 or reduced to SB44. This is followed by SA16, the small orthogonal grid at the centre of sector A, and SB69, that is the star shaped centre of the initially given whole sector B. Although a similar order is observed both for dPA/Area and dPA/Line at the top level of the rank, some differences are noticed insofar as the lower part of the rank is reached.

This is the case of SA21, that is the system lowest in the rank of measurements of productive activities per area yet it is rather high in the rank of measurements per number of axial lines. The opposite applies.

---

1 The information given in the barchart shall be complemented by the simultaneous observation of the proposed decomposition diagram (Fig 3.61) and the land use maps of the two areas of study presented in chapter two (Figs 2.12 and 2.13). Both the decomposition diagram and the land use maps can be opened from the back cover of this volume in order to allow the reader a simultaneous access to maps and text.

2 The three systems at the top of both ranks are either a second order decomposition (SA60) or third order decompositions (SA30 and SA34) of the same SA west (see reference map).
for SA184, the system that carries the largest amount of short housing estate axial lines of all sample. Most of these lines are totally bare of either shops, offices or industries. SA184 will be the system lowest in the rank of measurements of productive activities per number of axial lines yet it goes higher close to the middle of the rank if the density of productive activities is measured per area. For the remaining twenty systems despite minor irregularities it can be said that the mean density of productive activities relativised to the number of axial lines (dPA/Ln) is an effective guide for assessing the density of productive activities per area (dPA/A).

The sample of 'productive activities' has been disaggregated in three distinct categories: shops, offices and industries. The measurements proceeded for this further level of disaggregation have been produced on the basis of the mean density observed for each of these categories per number of axial lines (dPA/Ln). As suggested above the measurements relativised to the number of axial lines beside their explicit syntactic basis (and as such in tune with the descriptive tools under investigation) seem to provide a fair representation of areal distribution. The ranks observed for densities of shops, offices and industries will confirm to a large extent the ranks already observed for their aggregate as productive activities (dPA). The systems belonging to the more orthogonal portions of both sectors A and B tend to be at the top of these ranks yet some exceptions occur.1 SA21 for instance is outstanding for its density of offices, mostly brought about by a large quantity of houses (residential use) that have been converted for office purposes inside that particular area (Fig 5.02 B). SA34 is outstanding in the rank for industrial densities. In effect the concentration of industries in that particular system will also affect the measurement for SA60 (Fig 5.02 C). Nevertheless for the rest of the sample the densities of industrial activities will to a large extent match the ranks given by the aggregate of productive activities.

1 In what follows, the codes 'PA' and 'dPA' will stand where necessary for 'productive activities' and 'density of productive activities' respectively.
### Table 5.02
Measurements for densities of shops, offices and industries

<table>
<thead>
<tr>
<th>Sept Code</th>
<th>dSHP/Ln</th>
<th>dOFC/Ln</th>
<th>dIND/Ln</th>
</tr>
</thead>
<tbody>
<tr>
<td>51143</td>
<td>33.19</td>
<td>2.25</td>
<td>2.79</td>
</tr>
<tr>
<td>51660</td>
<td>46.49</td>
<td>2.52</td>
<td>1.91</td>
</tr>
<tr>
<td>51312</td>
<td>54.33</td>
<td>4.44</td>
<td>5.61</td>
</tr>
<tr>
<td>52324</td>
<td>35.89</td>
<td>0.85</td>
<td>21.21</td>
</tr>
<tr>
<td>50773</td>
<td>23.43</td>
<td>2.81</td>
<td>4.1</td>
</tr>
<tr>
<td>50799</td>
<td>23.14</td>
<td>1.25</td>
<td>7.8</td>
</tr>
<tr>
<td>50130</td>
<td>24.94</td>
<td>2.81</td>
<td>1.4</td>
</tr>
<tr>
<td>51162</td>
<td>35.59</td>
<td>1.80</td>
<td>2.07</td>
</tr>
<tr>
<td>51210</td>
<td>9.69</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>50410</td>
<td>11.88</td>
<td>0.8</td>
<td>1.61</td>
</tr>
<tr>
<td>50299</td>
<td>15.21</td>
<td>0.84</td>
<td>2.6</td>
</tr>
<tr>
<td>50771</td>
<td>15.23</td>
<td>0.81</td>
<td>4.18</td>
</tr>
<tr>
<td>50772</td>
<td>21.46</td>
<td>1.51</td>
<td>5.23</td>
</tr>
<tr>
<td>50106</td>
<td>14.18</td>
<td>0.87</td>
<td>1.89</td>
</tr>
<tr>
<td>50104</td>
<td>6.84</td>
<td>0.85</td>
<td>3.5</td>
</tr>
<tr>
<td>51100</td>
<td>13.83</td>
<td>0.83</td>
<td>1.08</td>
</tr>
<tr>
<td>50199</td>
<td>19.01</td>
<td>1.82</td>
<td>1.28</td>
</tr>
<tr>
<td>50422</td>
<td>22.99</td>
<td>1.81</td>
<td>1.13</td>
</tr>
<tr>
<td>50330</td>
<td>12.71</td>
<td>1.26</td>
<td>1.17</td>
</tr>
<tr>
<td>50469</td>
<td>27.72</td>
<td>1.34</td>
<td>1.13</td>
</tr>
<tr>
<td>50295</td>
<td>15.82</td>
<td>0.87</td>
<td>1.15</td>
</tr>
<tr>
<td>50544</td>
<td>33.08</td>
<td>2.50</td>
<td>2.73</td>
</tr>
<tr>
<td>50494</td>
<td>35.89</td>
<td>2.81</td>
<td>1.4</td>
</tr>
<tr>
<td>51127</td>
<td>6.64</td>
<td>0.89</td>
<td>1.42</td>
</tr>
<tr>
<td>50906</td>
<td>6.94</td>
<td>0.19</td>
<td>0.4</td>
</tr>
<tr>
<td>50455</td>
<td>15.77</td>
<td>1.72</td>
<td>1.10</td>
</tr>
<tr>
<td>51635</td>
<td>12.25</td>
<td>0.35</td>
<td>1.29</td>
</tr>
</tbody>
</table>

### Observations
It is also noteworthy that the range allowed for the rank of densities of industry is rather small - especially if SA34 is not computed - when compared with the much wider range observed for offices and especially for the density of shops. The variations in the mean density of shops from one system to another are in effect much stronger than the variations for offices and industries whose densities seem to be more evenly spread throughout the sample. The consistent 'pattern of ranking' that was described during the previous chapter as performing 'from the griddy towards the labyrinthine configurations' seems to be here again strongly present especially in the ranks for shops and offices. Whether or not this agreement between ranks of land use density - as represented in the bar charts - and the conjectured 'pattern of ranking' is also reflected in the correlations between these same use densities and the range of descriptions of grid configuration observed for the different systems is what remains to be seen. In order answer this question the ranks of land use density presented above are plotted in what follows against the set of syntactic descriptions of grid configuration proposed during the previous chapter.

This exercise shows for start that patterns of integration - as described by the mean RRA values observed for different systems - are remarkably associated with the variations in the density of productive activities from one system to another. This applies for both ways of measuring density proposed at the outset, although the extent of the conjectured association will vary significantly when 'productive activities' is further disaggregated in shops, offices and industries. The correlation between the two measurements is higher for local integration values

---

1 These 'ranges' may be compared in the three bar charts given in Fig 5.02.
2 For industries there are some exceptions. SA71 and SB83 are rather fragmented systems, yet both are high in the rank for the density of industries.
3 In what follows the matching of densities of productive activities with the proposed set of descriptions of grid configuration will be proceeded in the same order as this same set of measurements was presented in chapter four, namely: integration, choice, intelligibility, axial fragmentation and tension, ringyness, mean connectivity and density of intersections and, finally, figure-ground ratio.
of productive activities (shops, offices and industries).

A \( R = -0.685 \) 
\((p = 0.0001)\)

B \( R = 0.506 \) 
\((p = 0.0074)\)

C \( R = -0.759 \) 
\((p = 0.0001)\)

D \( R = -0.697 \) 
\((p = 0.0001)\)

E \( R = -0.790 \) 
\((p = 0.0001)\)

F \( R = -0.717 \) 
\((p = 0.0001)\)

G \( R = -0.659 \) 
\((p = 0.0003)\)

H \( R = -0.65 \) 
\((p = 0.0003)\)

I \( R = -0.298 \) 
\((p = 0.1388)\)

J \( R = -0.449 \) 
\((p = 0.0663)\)
(for systems measured as detached from surrounding areas) than for global integration values (for systems measured as interacting with surrounding areas). Local integration is -.685 (p=.0001) correlated with the density of productive activities per area (dPA/A) (Fig 5.03 A). If the density of productive activities is measured per line (relativised to the number of axial lines) the correlation increases further to -.759 (p=.0001)(Fig 5.03 B).

The coefficients are high and suggest that insofar as the mean integration value observed for the different systems increases, the mean density of productive activities inside these same systems will increase as well. The highest correlation is the one observed for the measurement of density of PA per number of lines, which is ratified by the also high coefficient observed for the measurement per area. In the first case (measurements per number of axial lines) SA21 is a unique outlier; in fact the only system that contradicts the homogeneous distribution of points given by the bulk of the sample (scat A). In the second case two other outliers emerge. They are SA128 and SA184 (scat B).

The 'outlying' of these two systems can be explained. Both these areas are crowded with large housing estates. SA128, in particular, is one large housing estate in itself. The buildings that compose that area are most of them strictly housing purpose built and however they have been built during the thirties and forties they remain very much the same. Those morphological and functional transformations which are inherent to 'naturally evolved' urban areas have not happened there or, at least, they have been allowed to a much lesser extent. Most buildings and entire streets still remain largely attached to the residential use (Fig 5.04).

---

1 The density values of the current sample of PA (as given in tab 5.01 and 5.02) are all logtransformed as the tests for normality have recommended. In effect these distributions present just a slight negative skewness in their linear form and their logtransformation will bring all distributions rather close to the normal.

2 These physically homogeneous neighborhoods - built all at once - have been a particular target of the work of Jane Jacobs. These places, she suggests, 'have been handicapped in every way, so far as generating diversity is concerned. It seems that one cannot blame their poor staying power and stagnation entirely on their most obvious misfortune: being built all at once. Nevertheless, this is one of the handicaps of such neighborhoods, and unfortunately its
Fig. 5.04 Housing estates in SA128 and SA184
Nevertheless the range of syntactic transformations happened in view of the development of the surrounding areas, after these estates were first built, have made SA128 a rather integrated system from the syntactic point of view. In other words, the typological character (the building typology) has been a strong constraint for the functional transformation of the 'neighbourhood'.\(^1\) This seems to explain why the current pattern of syntactic integration for that system - same as for SA184 - is hardly followed by a corresponding degree of density of productive activities, as it happens for the bulk of the sample.\(^2\)

If the productive activities category is further disaggregated in shops, offices and industries some significant variations will occur in the plot against the mean integration values. The correlation coefficient for the density of shops goes higher to -0.790 (p=0.0001) (Fig 5.03 C). For offices the correlation decreases to -0.659 (p=0.0003) (Fig 5.03 D). For industries the correlation drops markedly to -0.298 (p=0.1388) (Fig 5.03 E). The weakening in the correlation seems to match to a large extent what intuition might suggest in respect of the association between these three land use categories and integration or, in other words, in respect of the distinct extents to which these three land use categories are affected by the pattern of integration. Commercial locations are strongly

---

\(^1\) In fact some commercial activity has emerged at the ground floor of these housing estates. Nevertheless the scale of this transformation is too small to affect the performance of SA128 and SA184 in terms of the proposed measurements of density of productive activities.

\(^2\) In respect of the urban schemes 'built all at once', it is worth to mention that authors that have analysed the same issue from a distinct standpoint - commercial oriented schemes instead of residential projects - have put forward a contrasting opinion in relation to Jacobs': Barnett (1982) in his analysis of the Battery Park City scheme in New York (Cesar Pelli Architects) has suggested that the key to the 'success' of that new commercial development is that it has all been designed and built at one time: 'A crucial factor in the success of the Battery Park City plan has been Olympia & York's (the developers') willingness to develop the commercial core all at once. So many large scale architectural plans have failed because they were carried out by different architects, for different clients over a period of time long enough for development conditions to change'. In Barnett, J. An introduction to urban design, Harper and Row Publishers, New York 1982, p.121.
dependent on integration for the conspicuous public character of this activity. The increase in the density of shops in more integrated areas seem to follow directly the explicit public nature of this particular use.

Unlike for shops, the density of offices is less associated with patterns of integration, yet the correlation remains strong (-.659). Office buildings seem to carry to a large extent the same public character inherent to shops, although the lower coefficient suggests - if mean integration values are accepted as a parameter for measuring the public character of an urban area - that offices are less dependent on that character than shops. The way in which shops distribute themselves in an urban area might in fact be seen as a way of describing the set of spaces with the strongest public character. For industries the correlation collapses (-.298) so to a large extent reenforcing what was suggested above in respect of the performance of shops and offices. Industries are for their 'introverted' character less dependent on the public dimension of the street grid which, so far as the current investigation has detected, seems to be outstandingly described in the patterns of integration.1

All correlations above are given by the matching of the densities of productive activities with local integration values - mean RRAs observed for each system as detached from its surroundings. If global integration values are computed the correlations get weaker. In this case the statistical tests seem to contradict what intuition suggests, namely that productive activities in general for their predominant public character would be more strongly associated to the global scale of the street grid.2 This is not what the results given by the current sample of grid configurations suggest. Both the aggregate of productive activities (either per area or per line) and also the disaggregated categories - shops, offices and industries - are more strongly correlated with local integration values than with global integration values, i.e. integration

1 especially for the way in which integration depicts the distribution of shops.
2 Despite those more locally oriented commercial activities such as local shops and services.
values measured for each system as a part of the proposed systems of interaction.¹

If on the one hand this result defies what intuition suggests on the other hand it is very much in tune with the performance of integration analysed in the previous chapter especially when it is matched with intelligibility. Integration and intelligibility are \(-0.646\) \((p=0.0001)\) correlated when both parameters are locally measured. For the systems 'as embedded' the coefficient drops to \(-0.416\).² That is to say, same as for the densities of productive activities, intelligibility is more associated with the patterns of integration at the local than at the global level. It remains to be seen whether the syntactic property of intelligibility plays a part in the way land uses are distributed in the urban grid and moreover which intelligibility (either local or global) is more effective.³

The correlation coefficients presented above include all systems, i.e. the systems of interaction plus the twenty one local areas produced out of second and third order decompositions. If the systems of interaction are not computed the correlation remains stable so indicating that variations in size do not affect the strong association between patterns of integration and the distributions of productive activities. As a whole the statistical tests presented above seem to indicate that the density of productive activities is strongly associated and, from a deterministic point of view, even brought about by patterns of syntactic integration which are inherent to the spatial configuration of the urban grid.

Unlike integration, the mean choice values observed for the different systems are virtually uncorrelated with the density of productive activities and its disaggregations. A series of attempts were made in order to identify some regularity in the performance of the different

¹ The comparison between the two columns of scattergrams - one at left and other at right in Fig 5.03 - shows that dPA in general is also well correlated with global integration values, yet the coefficients for local integration are consistently higher.

² These results are in Fig 4.12 (p. 228).

³ The correlation analysis between intelligibility and the distribution of productive activities is presented further in this section.
Fig. 5.05 Correlation analysis for choice and densities of productive activities

A. $R = .146 (p = .5164)$

B. $R = .29 (p = .4897)$

C. $R = .307 (p = .165)$

D. $R = .32 (p = .4574)$

E. $R = .199 (p = .3873)$
systems from the standpoint of the correlation between choice and PA. Intuition has suggested that since choice and integration values - as given for each axial line - are strongly correlated, choice should also be, same as integration, be strongly correlated with the densities of PA. The scattergrams given in Fig 5.05 show the opposite. Mean choice values are hardly related to the densities of PA. One possible explanation for these low coefficients is that the correlations between choice and integration will be consistently higher at the core level (as the syntactic analysis presented in chapter three has shown). Choice presents systematically a strong negative skewness and at the lower tail of the distribution the correlation with integration has collapsed consistently for all cases. This happens even for values logtransformed or square rooted. As a consequence the fact that choice is strongly correlated with RRA at the core level does not necessarily mean that the mean choice values will follow mean RRA values in their strong relationships with the densities of productive activities.

Unlike choice, and following to a large extent what has been observed for integration, the measurement of syntactic intelligibility will be significantly well correlated with variations in the density of productive activities. Same as it has happened for integration the local measurement of intelligibility - based upon the mean RRA values observed for each system as detached from its surroundings - is the one that will provide the highest correlations. It is significant that the different densities of PA - and its disaggregations - will be as a whole less correlated with intelligibility than they were with integration. The correlations are .489 (p=.0209) for dPA/A and .592 (p=.0037) for dPA/Ln (Fig 5.06 A and B). SA60, SA34 and SB30 will be strong outliers in both scattergrams. For the first two - SA60 and SA34 - low intelligibility values are counterparty a strong density of productive activities. For SB30 it happens the other way around. This system is high in the rank of intelligibility yet it has a rather low density of PA. Apart from these irregularities, the distribution of points observed for the bulk of the sample is rather homogeneous along the regression line.
Fig. 5.06 Correlation analysis for intelligibility and densities of productive activities

1) $R = 0.489$ 
   ($p = 0.0209$)

2) $R = 0.329$ 
   ($p = 0.1354$)

3) $R = 0.592$ 
   ($p = 0.0037$)

4) $R = 0.356$ 
   ($p = 0.104$)

5) $R = 0.637$ 
   ($p = 0.0044$)

6) $R = 0.394$ 
   ($p = 0.0694$)

7) $R = 0.550$ 
   ($p = 0.0098$)

8) $R = 0.324$ 
   ($p = 0.1566$)

9) $R = 0.108$ 
   ($p = 0.6397$)
For the density of shops the correlation goes as high as .637 (p=.0014) (Fig 5.06 C). The correlation is strong yet lower than the coefficient observed for integration (-.790). A significant decrease in the coefficients observed for offices and industries - same as it has happened for integration - is also noticed here (Fig 5.06 D and E).\footnote{All these correlations remain rather stable if the systems of interaction are excluded from the plot of intelligibility against dPA, so indicating that size does not affect the association between the two measurements. In effect the coefficients will just drop slightly to .469 and .577, for dPA/A and dPA/Ln respectively.}

Nevertheless if intelligibility values are globally measured - i.e. based upon RRA values for each system as embedded - the correlations will drop remarkably as a whole. This output seems to contradict to some extent the conjecture raised during the previous chapter, according to which global intelligibility values should provide a more accurate or even the 'actual description' for syntactic intelligibility.\footnote{This conjecture has been put forward on the basis of the distinct performance of both intelligibilities - local and global - when matched with the prescribed 'visually observable' features (axial fragmentation, tension, etc.} This does not seem to be the case at least if the way in which productive activities distribute themselves in the street grid is regarded as following the \textit{actual} pattern of syntactic intelligibility. In effect the output given by the correlation analysis indicates that the densities of productive activities observed for the different systems is more associated with local intelligibility values than with global intelligibility. In other words, the intelligibility of each local area in itself is more determinant in the concentration of productive activities, than the intelligibility of local areas measured as a part of a larger whole. In this case the difference in the coefficients from local to global is much higher than in the case of integration. As a whole the coefficients for global intelligibility against the proposed measurements of PA will drop remarkably.\footnote{Compare the two columns of scattergrams in Fig 5.06. The column at left carries the diagrams for local intelligibility. The column at right carries the diagrams for global intelligibility.}
Fig. 5.07 Correlation analysis for axial fragmentation and tension against the densities of productive activities

(A) $R = -0.516$ ($p = 0.0059$)

(B) $R = 0.664$ ($p = 0.0002$)

(C) $R = -0.794$ ($p = 0.0001$)

(D) $R = 0.908$ ($p = 0.0004$)

(E) $R = -0.799$ ($p = 0.0001$)

(F) $R = 0.865$ ($p = 0.0004$)

(G) $R = -0.633$ ($p = 0.0005$)

(H) $R = 0.784$ ($p = 0.0004$)

(I) $R = -0.294$ ($p = 0.4499$)

(J) $R = 0.349$ ($p = 0.0803$)
In the analysis developed during chapter four intelligibility has performed highly correlated with both axial fragmentation and tension. Nevertheless in their association with the density of productive activities these two measurements - axial fragmentation and tension - will overcome intelligibility by far. In effect the coefficients observed for the correlation between dPA and either axial fragmentation or tension will be even higher than the coefficients observed between dPA and integration. For density of PA per unit of area, the coefficient is .516 (p=0059) for axial fragmentation and .664 (p=.0002) for tension (Fig 5.07 A and B). The systems that compose the east part of SA - SA418 and its decompositions - are the highest in the rank of axial fragmentation. These systems are all concentrated at right in the scattergram A (black dots) and their distribution seems to produce a pattern that is distinct from the one observed for the bulk of the sample. That is to say, these systems despite their strong degree of axial fragmentation, are relatively high in the rank of productive activities per area. The same will happen when the measurements of dPA/A are plotted against tension, although inverting the direction of the correlation.

For the measurements of productive activities per number of axial lines these same systems (which have 'outlied' in the plot of PA against axial fragmentation) get closer to the regression line and the correlations will grow remarkably strong. The coefficients raise to -.794 (p=.0001) and .908 (p=.0001) for axial fragmentation and tension respectively (Fig 5.07 C and D). The distribution of points is now remarkably homogeneous - especially for tension values (scat D) so clearly indicating the effective role of tension - as given by the average length of the axial lines - in the performance of densities of productive activities. That is to say the higher is the average length of the axial lines inside each system (or the lower is the degree of axial fragmentation) the higher will be the density of productive activities.

\[ \text{In this case the correlations for RRA is } - .759 (p=.0001). \]
As the 'productive activities' category is disaggregated in shops, offices and industries the correlations get weaker. This follows what has been observed - when these three categories were plotted against integration and intelligibility. A consistent decrease in the coefficients for offices and industries - if compared with the strong correlations observed for shops - was then noticed. Nevertheless for the density of offices the correlation still remains significantly strong especially when densities of offices are plotted against tension values; R = .784 (p = .0001) (Fig 5.07 H). As a whole the coefficients observed for tension, will be stronger than the ones observed for integration.1 In fact the three categories as disaggregated - shops, offices and industries - will be more correlated with integration than they are with axial fragmentation. Although the coefficients observed for tension - as measured by the average length of the axial lines inside each one of the conjectured systems - will be the highest amongst the three measurements (Fig 5.07 F, H and J). These correlations have considered all systems, i.e. inclusive of the systems of interaction. If the systems of interaction are not computed the correlations remain stable showing that variations in size hardly affect the strong association between axial fragmentation, tension and the densities of productive activities.

As the descriptions of grid configuration given during the previous chapter have shown, axial fragmentation and tension are both of them characteristics strongly related to the ringyness of the different systems.2 The strong relationship between these three measurements allows for the conjecture that ringyness - following axial fragmentation and tension - should also be strongly associated with the density of productive activities. The extent and strength of this association is what remains to be seen. A plotting of density of productive activities per unit of area against ringyness provides a .785 (p = .0001) coefficient

---
1 Compare sequence of scattergrams for RRA (Fig 5.03) and axial fragmentation/tension (Fig 5.07).
2 That is the character of the urban grid in configuring itself as a pattern of urban blocks or as a pattern of 'rings'. As it has already been explained this property has been measured during the current investigation by the link/line ratio of the different systems.
Fig. 5.08 Correlation analysis for ringyness and densities of productive activities

A $R = .785 \ (p = .0001)$

B $R = .863 \ (p = .0001)$

C $R = .859 \ (p = .0001)$

D $R = .668 \ (p = .0002)$

E $R = .601 \ (p = .0012)$
between the two measurements that is the highest correlation coefficient with dPA/A amongst all syntactic measurements so far analysed (Fig 5.08 A). For density of productive activities per line the correlation goes even higher to .86 (p=.0001) (Fig 5.08 B).

This high degree of association between dPA and ringyness remains steady after the proposed disaggregation in shops, offices and industries is proceeded (Fig 5.08 C, D and E). These coefficients are higher than the ones observed for integration and axial fragmentation and almost levelled with the outstandingly high coefficients observed for tension. The evidence suggests that the characteristic of the urban grid of configuring itself as a pattern of rings or urban blocks is – together with tension – the two most effective measurements in describing from the syntactic standpoint how the 'ups and downs' in the densities of productive activities are arranged in the street grid. Here again the correlations are hardly affected by variations in size, since the exclusion of the systems of interaction will have just a marginal effect in the coefficients.1

The relationship between the densities of productive activities and the pattern of connectivities has been measured in two distinct ways, i.e. both against the mean connectivity of the axial lines inside each system and also against the density of intersections per unit of area. When matched with the densities of productive activities these two distinct ways of measuring connectivity will perform in opposite directions. While the density of productive activities will increase consistently insofar as the mean connectivity of the different systems increases, these same measurements of PA will decrease insofar as the density of intersections increases. This is what the set of scattergrams presented in Fig 5.09 indicate. The diagrams in the left column show that the increase in the mean connectivity is consistently followed by an increase in the concentration of productive activities. While the

1 If the systems of interaction are not computed the correlation for dPA/Ln will decrease marginally from .863 to .857. The same happens for dSHP/Ln (density of shops) that decreases from .859 to .851.
diagrams in the right column show that the increase in the density of intersections is consistently associated with a decrease in the density of productive activities.

While the correlation coefficients observed for mean connectivity are outstandingly high, the coefficients for density of intersections per unit of area will be much lower yet the systematic change in the direction of the correlation can be taken as a significant warning in respect of the subtlety of the relationships between the syntactic character of the urban grid and land use distributions. The analysis of the mean values observed for the proposed set of syntactic measurements (as developed during chapter four) has shown that mean connectivity and density of intersections per area are hardly correlated yet it has also shown that when these measurements are matched with intelligibility both will show a strong degree of association. Intelligibility has consistently increased with the increase of mean connectivity and has decreased for increases in the density of intersections.\(^1\) In a subsequent step this section has shown that intelligibility is fairly correlated with the density of productive activities.

Analysed altogether this set of observations seems to indicate that it is not the increase of connectivity 'in general' that will make urban systems more intelligible and also strongly 'populated' with productive activities. In effect the straightforward increase in the density of intersections will have the opposite effect. This is clearly expressed in the set of scattergrams displayed in Fig 5.09. The straightforward increase in the density of intersections will be systematically correlated with a decrease in the density of productive activities as for the categories produced out of the proposed disaggregation.\(^2\)

By contrast the topological property of connectivity - as measured by the mean connectivity relativised to the number of axial lines given in each

---

\(^1\) This is shown in chapter four, Fig 4.21 C and D, p.250.

\(^2\) See the right column of scatter diagrams in Fig 5.09.
Fig. 5.09 Correlation analysis for connectivity and density of intersections against the densities of productive activities.

A) \( R = 0.781 \)  
\( (p = 0.0001) \)

B) \( R = 0.164 \)  
\( (p = 0.415) \)

C) \( R = 0.909 \)  
\( (p = 0.0001) \)

D) \( R = -0.469 \)  
\( (p = 0.0436) \)

E) \( R = 0.918 \)  
\( (p = 0.0001) \)

F) \( R = -0.447 \)  
\( (p = 0.0119) \)

G) \( R = 0.746 \)  
\( (p = 0.0001) \)

H) \( R = -0.364 \)  
\( (p = 0.0673) \)

I) \( R = 0.470 \)  
\( (p = 0.0154) \)

J) \( R = 0.065 \)  
\( (p = 0.7532) \)
system will be strong and positively associated to the densities of productive activities. The correlation between dPA/A and mean connectivity is .781 (p=.0001) (Fig 5.09 A), while for dPA/Ln the coefficient increases remarkably to .909 (p=.0001) (Fig 5.09 C). The corresponding coefficients for density of intersections are -.164 (p=.415) and -.469 (p=.0136) respectively (Fig 5.09 B and D). The disaggregation of density of productive activities in shops, offices and industries will keep the pattern observed for the other measurements so far discussed, that is to say, shops will present the strongest coefficients, offices are less correlated (with both measurements) and industries still less.

Two other aspects are worth to mention in respect of the performance of connectivity. The first is that the correlation coefficients observed between the mean connectivity of the different systems and the densities of productive activities are the highest amongst all measurements analysed even if compared with the high coefficients observed for tension and ringyness. The correlation between mean connectivity and the density of shops is particularly high (R=.918 p=.0001) (Fig 5.09 E). The second aspect is that even the densities of industry, that have been virtually uncorrelated with other measurements, is somewhat associated with the mean connectivity of the different systems (Fig 5.09 I). This correlation includes two strong outliers - SB30 and SA21.1 These two systems are relatively well connected yet the density of industries in that 'portions' of the street grid is exceptionally low if compared with mean density values observed for the bulk of the sample.2

The last measurements to be plotted against the density of productive activities are the figure-ground ratios observed for different systems as given by the ratio between the total length - all axial segments in each

1 If these two systems are not computed the correlation between the density of industries and mean connectivity gets even stronger to .655 (p=.0005).

2 This is given in Fig 5.02 C.
Fig. 5.10 Correlation analysis for figure-ground ratios and densities of productive activities

\[ F_6 \times PA \]

\[ g = 2.55x + 0.356, R^2 = 0.54 \]

\[ R = 0.285 \]

\( (p = 0.0004) \)

\[ F_6 \times PA \text{ (most ax fragm at)} \]

\[ g = 2.95x + 0.359, R^2 = 0.54 \]

\[ R = 0.748 \]

\( (p = 0.0004) \)

\[ F_6 \times PA \]

\[ g = 1.95x - 2.39, R^2 = 0.15 \]

\[ R = 0.357 \]

\( (p = 0.0026) \)

\[ F_6 \times PA \]

\[ g = 2.39x - 2.36, R^2 = 0.18 \]

\[ R = 0.280 \]

\( (p = 0.0193) \)
system computed - and its area. For this measurement the correlations will drop remarkably pointing out at least in a first moment that the figure-ground ratios observed for the different systems are hardly related to the densities of productive activities. For the measurement of dPA per unit of area the correlation will be .285 (p=.1985) (Fig 5.10 A). For the measurement per line (dPA/Ln) the correlation will decrease further to .102 (p=.6522) and low it remains for dSHP/Ln (R=.129 p=.567) (Fig 5.10 B and C). Yet these figures suggest that figure ground ratios are hardly related to the densities of productive activities if the distribution of points in the scattergram is taken into account this does not seem entirely the case.

In effect two distinct tendencies seem to coexist inside the sample. One seems to express that the two measurements are somewhat correlated (Fig 5.10 C) the other (given by the systems carrying the highest figure-ground ratios) is represented by points totally dispersed throughout the right part of the scattergram and suggest that the two measurements are totally uncorrelated. These more scattered points include both systems with a marked low degree of axial fragmentation such as SA30 and SA16 and also strongly fragmented systems - such as SA72, SA126, SA106 and SA184 - which are the four most fragmented systems inside the current sample.

The explanation of this phenomenon is not straightforward yet it allows for some conjectures. Figure-ground ratio is largely affected by the size of the blocks that compose each system. That is to say the smaller the size of the blocks the higher will be the proportion between 'voids' in relation to 'solids'. At least this is what visual observation suggests and if this is the case the degree of fragmentation can hardly be taken as a parameter for the assessment of figure ground ratios. SA30 and SA16 are almost perfect orthogonal grids with a very low degree of axial fragmentation, but since in average the size of their blocks is small their figure-ground ratios will be high, same as it is for strongly fragmented systems such as SA126 or SA106. The correlation analysis
for axial fragmentation and figure-ground ratio has shown a relatively high correlation between the two measurements so at least in principle contradicting the conjecture above. Nevertheless, as it has already been shown, the correlation coefficient then observed is strongly biased by the systems at the top of the axial fragmentation rank. If these systems are not computed axial fragmentation and figure-ground ratio will be virtually uncorrelated.

If the most fragmented systems - the ones that are dispersed throughout the right part of the scattergram C (Fig 5.10) - are deleted the extent of the association between figure-ground ratios and the densities of productive activities will increase remarkably. For the density of shops the correlation will be .748 (p=.0004) (Fig 5.10 D), showing that for this particular part of the sample the higher is the proportion of 'voids' in relation to 'solids' the higher will be the density of shops. For offices the correlation remains high at .613 (p=.0068) (Fig 5.10 F). For industries it drops to .361 (p=.1398) so confirming once again the conjectured detachment of industries in relation to the syntactic character of the street grid, at least if the mean values observed for industrial densities (which is criterion adopted throughout this section) is followed (Fig 5.10 H). At any rate these coefficients - observed after deleting the most axially fragmented systems - do not improve the relationship between figure-ground ratios and dPA to the standard reached by the set of measurements that have more effectively described the syntactic performance of the densities of productive activities; that are mean connectivity, tension and ringyness.

As a whole this section has shown that three particular descriptions of grid configuration - connectivity, tension and ringyness - are the syntactic parameters most strongly associated with the distribution of productive activities. The correlation coefficient drops from .502 to .174. This result is in Fig 4.23, p. 254.

1 This coefficient includes SA30 and SA16 which despite the high figure-ground ratios are low in the rank of axial fragmentation.

2 Mean connectivity is the only measurement to some extent correlated with the density of industries.
productive activities in the urban grid. It has also shown that the extent of this association will be particularly outstanding for the density of shops, yet decreasing for density of offices and virtually collapsing in so far as industries are measured on their own. This confirms to a large extent the conjecture raised at the outset with respect of the distinct 'spatial requirements' demanded for these three land use categories. Shops are consistently well correlated with different measurements, so reflecting the conjectured strong association between locational requirements for commercial activities and the syntactic character of the street grid. For offices the conjectured syntactic 'locational requirements' still stand yet the 'office purpose' does not seem to be so dependent on such 'locational facilities' as shops are. By contrast industries have shown consistently higher degree of 'independence' in relation to the syntactic character of the urban grid. It is not suggested here that the conspicuous concentration of particular uses at certain 'portions' of the street grid is brought about by the syntactic factor. Nevertheless the evidence presented has shown that the performance of specific spatial variables (of syntactic nature) is strongly and systematically associated with the socio-economic dimension of the urban phenomenon as given by the densities of land use proposed above.

Since these results have been produced at the level of mean values observed for each system, a further inquiry is necessary in order to assess how these same land use categories - shops, offices and industries - will perform when measured at the level of each axial line and matched with syntactic measurements also given by each line inside the different systems. This is precisely the object of what follows for the remainder of this chapter. Instead of dealing with 'mean densities' observed at the level of each system, as so far proceeded, the analysis now shifts towards the comparison of the densities observed for each use category at the level of each axial line (the proposed 'frequency of location') and syntactic measurements also observed at the level of each axial line.
Table 5.03
Distribution of shops and syntactic measurements
in SA west: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA143</th>
<th>SA143 core</th>
<th>SA60</th>
<th>SA30</th>
<th>SA34</th>
<th>SA77</th>
<th>SA59</th>
<th>SA21</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 dSHP x RRA</td>
<td>-0.219</td>
<td>-0.363</td>
<td>-0.109</td>
<td>-0.031</td>
<td>-0.064</td>
<td>-0.051</td>
<td>-0.055</td>
<td>-0.097</td>
</tr>
<tr>
<td>2 dSHP x RRA/143</td>
<td>*</td>
<td>*</td>
<td>-0.404</td>
<td>-0.416</td>
<td>-0.054</td>
<td>-0.154</td>
<td>-0.270</td>
<td>-0.014</td>
</tr>
<tr>
<td>3 dSHP x CHC</td>
<td>0.028</td>
<td>*</td>
<td>0.363</td>
<td>0.408</td>
<td>0.231</td>
<td>0.100</td>
<td>0.181</td>
<td>0.023</td>
</tr>
<tr>
<td>4 dSHP x CON</td>
<td>0.275</td>
<td>*</td>
<td>0.051</td>
<td>0.229</td>
<td>0.081</td>
<td>0.168</td>
<td>0.301</td>
<td>0.033</td>
</tr>
<tr>
<td>5 dSHP x LEN</td>
<td>0.223</td>
<td>*</td>
<td>0.025</td>
<td>0.008</td>
<td>0.054</td>
<td>0.066</td>
<td>0.155</td>
<td>0.127</td>
</tr>
</tbody>
</table>
This procedure will allow for a further exploration and discussion on the concept of 'area of syntactic reference' - as proposed at the outset of this chapter. The discussion will focus on variations in the correlation coefficients emerged out of measurements taken for distinct spatial compositions and decompositions proposed for the same area. The conjecture here is that the decompositions (or compositions) for which the highest correlations - between land use distributions and syntactic measurements - are observed will be in probabilistic terms the ones in relation to which the given sample of land uses is distributed. That is to say, that particular system produced out of one specific decomposition would be the area of syntactic reference for that particular use.  

A syntactic description for the distribution of shops

The assessment of the performance of patterns of land use distribution inside each system is made by two distinct and subsequent steps. The first is the observation of how the relationship between each category of land use and different syntactic measurements happens inside the same system, i.e. inside the same area of syntactic reference. Table 5.03 gives an example. It shows that inside each of areas of syntactic reference proposed for SA west (SA143, SA60, SA30 and so on) the association between the distribution of shops and the proposed syntactic measurements (RRA, RRA emb, CHC and so on) varies. For instance, if SA34 is taken as the area of syntactic reference for the distribution of shops it happens that syntactic and functional parameters will be virtually uncorrelated. For RRA and RRAemb the correlations are -.064 and -.054 respectively. The correlation will increase marginally for choice (.231) and decreases again for connectivity and length. This procedure is expected to clarify which syntactic measurement or measurements is more efficient or more 'in tune' - with each pattern of land use distribution having all areas of syntactic reference compared.

1 Or 'catchment area' if the similarity between the two concepts is accepted.
2 This is 'example 1' in tab 5.03.
Fig. 5.11 Areas of syntactic reference for SA west
The second step identifies in which of the proposed areas of reference these 'more efficient' parameters are more strongly correlated with each pattern of land use distribution. Table 5.03 also gives an example. The correlation between the distribution of shops and connectivity is .275 when the area of reference is SA143.1 When SA143 is decomposed in SA60 and SA77 (second order decomposition) the correlation between dSHP and CON drops to .051 and .168 for SA60 and SA77 respectively. Table 5.03 also provides the correlations for the third order decompositions (SA30, SA34, SA59, SA21). It is conjectured here that the system (or systems) where the correlation coefficient is the highest - or the systems where there are significant increases in the degree of correlation observed for a certain syntactic measurement - are the ones that in probabilistic terms will perform as the 'area of syntactic reference' for that particular use distribution.

The five syntactic measurements to be dealt with in what it follows are precisely the ones whose syntactic performance, as discussed during chapter three, have produced the decomposition strategy under scrutiny. These measurements are: RRA, that is the integration value of each axial line when the system is measured as detached from its surroundings; RRA emb, that is the integration value for each line measured as embedded (in the example given by table 5.03 the system of interaction for all local areas is SA143); CHC, that is the choice value of each axial line; CON, that is the connectivity of each line and finally LEN, that is the length of the axial line. The analysis starts from the sector A (west and east) to the sector B (west and east). The systems (or decompositions) to be tested out in what follows are presented in Fig 5.11. They are the west part of sector A (SA143) and the set of conjectured local areas emerged out of its second and third order decomposition.

The distribution of shops measured for the whole SA west as the area of syntactic reference is low correlated (or virtually uncorrelated) with

---

1 This is 'example 2' in tab 5.03.
### Table 5.03 Distribution of shops and syntactic measurements in SA west: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA143</th>
<th>SA143 core</th>
<th>SA60</th>
<th>SA30</th>
<th>SA34</th>
<th>SA77</th>
<th>SA59</th>
<th>SA21</th>
</tr>
</thead>
<tbody>
<tr>
<td>dSHP x RRA</td>
<td>-.219</td>
<td>- .363</td>
<td>-.109</td>
<td>-.031</td>
<td>-.064</td>
<td>-.051</td>
<td>-.055</td>
<td>-.097</td>
</tr>
<tr>
<td>dSHP x RRA/143</td>
<td>•</td>
<td>•</td>
<td>-.404</td>
<td>-.416</td>
<td>-.054</td>
<td>-.154</td>
<td>-.270</td>
<td>-.014</td>
</tr>
<tr>
<td>dSHP x CHC</td>
<td>.028</td>
<td>•</td>
<td>.363</td>
<td>.408</td>
<td>.231</td>
<td>.100</td>
<td>.181</td>
<td>.023</td>
</tr>
<tr>
<td>dSHP x CON</td>
<td>.275</td>
<td>•</td>
<td>.051</td>
<td>.229</td>
<td>.081</td>
<td>.168</td>
<td>.301</td>
<td>.033</td>
</tr>
<tr>
<td>dSHP x LEN</td>
<td>.223</td>
<td>•</td>
<td>.025</td>
<td>.008</td>
<td>.054</td>
<td>.066</td>
<td>.155</td>
<td>.127</td>
</tr>
</tbody>
</table>

**Fig. 5.12** Distribution of shops in SA west.
most syntactic measurements (Tab 5.03).\(^1\) The picture does not change much when the integration core of SA143 is compared, as a separate sample, with the distribution of shops.\(^2\) In effect the correlation between the distribution of shops (dSHP) and RRA will improve in this case to -.363 (p=.0577), yet such an improvement in the coefficient is very much brought about by two strong outliers, that are precisely the two most integrating lines in that system. If these lines are not computed RRA and dSHP will decrease to -.163 (p=.2139) even at the core level.

When SA143 is decomposed in SA60 and SA77 the picture changes. Inside SA60 the correlation between dSHP and RRA/143 (integration values for each axial line measured as a part of the system of interaction) will increase to -.404 (p=.0027) (Fig 5.12 A).\(^3\) Nevertheless for the other system emerged out of the second order decomposition of SA west - that is SA77 - the density of shops will be virtually uncorrelated with RRA emb (-.154).\(^4\) In effect the distribution of shops in SA77 is hardly correlated with any of the five proposed syntactic measurements. But if SA77 is further decomposed the coefficient with RRA emb inside SA59 (one of the parts given by its third order decomposition) goes slightly higher again to -.270 (Fig 5.12 B).\(^5\) The coefficient is not high yet it gets significance inside the current context, i.e. as compared with the standard of rather low correlations presented in Tab 5.03.\(^6\) It is also worth to mention that the correlation

---

\(^1\) Connectivity is the only measurement that will present a hint of correlation (.275).

\(^2\) In order to improve the statistical significance of the test the core has been regarded as expanded to 20%, so providing twice the number of observations (if compared with the 'standard' 10% core).

\(^3\) The distribution of shops in SA60 is normal in its linear form, while RRAemb will come close to the normal distribution after logtransformation.

\(^4\) The coefficients under discussion are highlighted in table 5.03.

\(^5\) Both variables are logtransformed.

\(^6\) The standard of correlations that will be observed between land use distributions measured and syntactic measurements at the level of each axial line and syntactic measurements is consistently lower than the correlations already observed between 'densities' of land use and 'mean values' of syntactic measurements, as described in the previous section. Nevertheless the significance of the coefficients observed for the current tests tend to be higher in view of the much higher number of observations. That is to say, the number of observations for the 'density' values - as discussed in the previous section - was the total number of
with connectivity inside SA59 is marginally higher than it is for RRAemb yet connectivity is in general a less consistent parameter if the coefficients observed for the other areas of reference are also taken into account.

If SA60 is further decomposed the correlation between dSHP and RRAemb values for SA30 - one of the parts emerged out the proposed third order decomposition - will be the highest amongst all SA west decompositions; $R=-0.416$ (p=0.0223) (Fig 5.12 C). For this test the integration values assigned to each axial line inside SA30 are measured as a part of whole SA west (RRA emb or RRA/143). Yet the probability of the correlation is out of the proposed acceptable standards the distribution of points in the scattergram is more homogeneous than it is for SA60 (scat A), where the three lines that concentrate the highest dSHP outlier from the bulk of the distribution. For the other system given by of the third order decomposition of SA60 (that is SA34) the correlation with RRA emb will collapse (-0.054). It is noteworthy that if local RRA values are plotted against shops in SA30 these measurements will be virtually uncorrelated.

As a whole the results presented above indicate that the density of shops inside SA west increases following the increase of the integration value of the axial lines. That is to say, for the whole SA west (SA143) the correlations are weak. Nevertheless when this system is decomposed the distribution of shops will become more strongly correlated with syntactic measurements (especially integration) within the systems (or local areas) given by second and third order decompositions, that are SA60, SA30 and SA59. The consistent increase in the coefficients in so far as global integration values are plotted indicates that the distribution of shops is systematically referred to the global scale of

---

1 Both variables are logtransformed.
2 In effect the correlations with local RRA are very low for all areas of reference. (Tab 5.03)
Fig. 5.13 Areas of syntactic reference for SA east
the street grid, while for locally oriented measurements the correlations are consistently lower (Tab 5.03).

In other words the distributions tend to happen within the set of proposed local areas but the 'scale of measurement' that delivers the highest coefficients is the global scale. That is to say all axial lines inside each one of the conjectured local areas regarded as a part of the larger SA west. This global oriented tendency is ratified by the higher correlations observed for choice especially in the case of SA60 and SA30 (the coefficients are .363 and .408 respectively), while for connectivity and especially for axial length - that are locally oriented parameters - the coefficients will be consistently lower (Tab 5.03).

The systems to be tested out as a syntactic basis for the current sample of shops inside SA east - the more fragmented part of sector A - are presented in Fig 5.13. These areas are the large SA418 and its four second order decompositions that are SA106, SA72, SA184 and SA71. Apart from these two other alternative systems will be examined. These are SA299 that as already explained is the same SA418 yet having the 'lumps' of short housing estates axial lines deleted, and SA69, that is SA184 also having the same housing estates deleted. The distinct core configurations observed for SA418 and SA299 have allowed for the conjecture that the core description given by measurements that have taken into account these lumps of short axial lines might have been 'distorted' or 'biased' by such an outstanding increase in the density of axial lines in that rather small portion of the street grid. The current analysis allows for a further testing out of the hypothesis raised above in so far as both configurations - one including and other deleting the housing estates - will be matched with the current sample of land use

1 As it has already been shown, the southeast part of SA418 is 'crowded' of short axial lines given by housing estates. Most of these are located inside SA184. The integration core of SA east tends to concentrate inside the eastern part of the system, i.e. precisely inside SA184. Although if the lumps of short axial lines given by the housing estates are not computed (SA299) the core will lose this eastward 'bias' and will become a globally integrated core, then reaching the interior of the four proposed local areas in a rather 'balanced way'. These distinct core configurations are given in Fig 3.30 (p.169).
2 The conjectured syntactic reasons for that have already been discussed in chapter three.
<table>
<thead>
<tr>
<th>Table 5.04</th>
<th>Distribution of shops and syntactic measurements in SA east: correlation analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Correlation</strong></td>
<td><strong>SA184</strong></td>
</tr>
<tr>
<td>dHSHP H ARA</td>
<td>-.024</td>
</tr>
<tr>
<td>dHSHP H ARAemb</td>
<td>-.157</td>
</tr>
<tr>
<td>dHSHP H CIC</td>
<td>-.446</td>
</tr>
<tr>
<td>dHSHP H CIN</td>
<td>-.446</td>
</tr>
<tr>
<td>dHSHP H LEN</td>
<td>-.446</td>
</tr>
</tbody>
</table>

**Fig. 5.14** Distribution of shops in SA east

- **A** SA148 R = -.483 (p = .0028)
- **B** SA299 R = -.256 (p = .0001)
- **C** SA299 core R = -.474 (p = .0082)
- **D** SA184 R = -.089 (p = .5049)
- **E** SA69 R = -.407 (p = .0057)
- **F** SA106 R = -.164 (p = .1174)
- **G** SA71 R = -.496 (p = .0006)
- **H** SA72 R = -.305 (p = .0449)
distributions. This might allow for an exploration on the extent to which the concentration of axial lines in that particular portion of the grid will affect (or not) the measurements taken for the grid as a whole and their relationships with the distribution of uses as well.

The correlation analysis for SA east shows at the outset that the distribution of shops in SA418 - the system analysed as a whole - is hardly correlated with any of the proposed syntactic measurements. The highest correlation is observed for integration. The coefficient is \(-.183\) (p=.0028) (Fig 5.14 A). If the lumps of housing estates are deleted (SA299) the coefficient for integration will improve to \(-.256\) (p=.0001)(Fig 5.14 B). The coefficients are not high yet in view of the large number of observations the probabilities for both correlations are rather high. These figures indicate that the distribution of shops inside SA east hardly takes into account the lumps of short housing estates axial lines concentrated at the east part of the system. On the contrary, the distribution seems to be more referred to the pre-existing grid (SA299) if the evidence given by the coefficients above is accepted.

When the correlations are measured at the core level both coefficients will improve strongly especially for SA299 - the system measured as having the housing estates deleted. For the 10% integration core of SA299 the coefficient will improve to \(-.474\) (p=.0082) (Fig 5.14 C). This output seems to be in tune with what has already been observed in respect of the performance of intelligibility in SA299. The intelligibility figure for this system measured as a whole is .48. But when intelligibility is measured at the core level it increases strongly to .71.\(^1\) The combination of these results has allowed for a further conjecture which seems to follow what intuition suggests. The conjecture is that the pattern of distribution of shops in an urban area tends to follow the pattern of syntactic intelligibility given by the configuration of the street grid itself.\(^2\) When the intelligibility of SA299 increases

\(^1\) This is given in table 3.09 (p. 194).
\(^2\) And expressed in the relationship between connectivities and integration values for all axial lines.
conspicuously at the core level such an increase is followed by a marked improvement in the association between the distribution of shops and the pattern of integration at the core level as well (Fig. 5.14 C).

The comparison of these results with the output given by the analysis of SA west (as given in Tab 5.03) seems to confirm to a large extent the conjecture above. In that case the variation of intelligibility will perform the other way around, i.e. it decreases from .80 when it is measured for all lines to .35 when it is measured for the core level. At the same time the correlation observed at the core level for the distribution of shops will decrease. This output seems to be supportive of the conjectured ‘intelligible distribution of shops’ as stated above. In SA east the increase of intelligibility at the core level has produced an increase of the correlation between the distribution of shops and the different syntactic measurements at that level, while in SA west the syntactic configuration of the system is the less intelligible at the level of the core and, as a consequence, the distribution of shops will be in general less correlated with syntax at that level. These conjectures are further tested out and discussed during the analysis of the distribution of shops in sector B.

When SA east is decomposed the correlations between the distribution of shops and the set of proposed syntactic measurements will increase as a whole (Tab 5.04). Here again the coefficients observed for integration will be consistently the highest, as it has happened for the larger systems of interaction (SA418 and SA299). The supposedly ‘distorting effect’ brought about by the lumps of housing estates are noticed here again. If the local area more at southeast is measured having the housing estates computed (SA184) the distribution of shops will be virtually uncorrelated with integration and all other syntactic measurements. The coefficient for integration is -.084 (p=.5049) (Fig 5.14 D). Although if

---

1 This output is also part of table 3.09 (p.194).

2 Integration is the only measure where a marginal increase can be noticed. See SA143 core (Table 5.03).
the axial lines given by the housing estates are not computed (SA69) the coefficient goes higher to -.407 (p=.0037) (Fig 5.14 E). This output seems to confirm the 'misleading' role of the lumps of housing estates in the description of the 'effective' syntactic configuration of that area, that is to say, in describing the set of spaces (or lines) that actually affect (or is related to) the distribution of shops in that area. SA106 will be an exception in the observed pattern of increase of coefficients noticed when SA east is decomposed in its four local areas. For this system the correlation between integration and the distribution of shops remains low at -.164 (p=.1171) (Fig 5.14 F). For the two remaining systems - SA71 and SA72 - the correlations will improve significantly to -.446 and -.305 respectively (Fig 5.14 G and H).

These figures seem to provide some clues in respect of the systems or local areas according to which the distribution of shops in SA east takes place. On the one hand the distribution is well correlated, especially with integration, at the core level. The distribution for this part of the sample is globally oriented, i.e. it describes the global core lines where insofar as integration increases the concentration of shops increases as well. If the sample is expanded to all lines - the whole SA east computed - the correlation collapses. On the other hand for the local areas produced out of the decomposition of SA east the correlations increase, indicating that if all the sample is computed - and not only the core lines - the distribution of shops will take place in agreement with the proposed local areas instead of referring to the system described as a whole (SA418/299). The current sample has not been disaggregated to a point where it is possible to detect what might be termed as 'globally oriented' and 'locally oriented shops' (if this distinction is possible after all). Nevertheless this output suggests that part of the sample is clearly oriented towards the global scale while other part is more referred to each one of the local areas produced after decomposition.

The correlations for the local areas are not particularly high in themselves yet they get significant as compared with the coefficients...
Fig. 5.15 Areas of syntactic reference for sector B

Table 5.05
Distribution of shops and syntactic measurements for the whole sector B: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SB355</th>
<th>SB351 core</th>
<th>SB295</th>
<th>SB295 core</th>
<th>SB54</th>
<th>SB44</th>
<th>SB127</th>
<th>SB96</th>
<th>SB65</th>
<th>SB83</th>
<th>SB99</th>
<th>SB99 cor99</th>
<th>SB99 cor351</th>
<th>SB62</th>
<th>SB30</th>
<th>...</th>
<th>SB69</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 distHP x ARA</td>
<td>-.334</td>
<td>-.413</td>
<td>-.160</td>
<td>.017</td>
<td>-.076</td>
<td>-.016</td>
<td>-.249</td>
<td>-.224</td>
<td>.003</td>
<td>-.217</td>
<td>-.416</td>
<td>-.097</td>
<td>+</td>
<td>-.116</td>
<td>-.123</td>
<td>+</td>
<td>-.463</td>
</tr>
<tr>
<td>2 distHP x ARAamb1</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3 distHP x ARAamb2</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>4 distHP x CIC</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>5 distHP x CON</td>
<td>.259</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>6 distHP x LEN</td>
<td>.186</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
observed for SA east - either SA418 or SA299 - measured as a whole. Here again the highest coefficients are given by RRAem, i.e. RRA values for each axial line measured as a part of the larger SA east. For the plots of local RRA values (lines measured inside the local areas) the correlations will collapse as a whole (tab 5.04). This shows that the distribution of shops inside SA east - following what has already been noticed for SA west - is markedly referred to the global scale of the street grid (referred to RRA values as embedded), despite the fact that all distributions are 'configured' according to or within particular 'syntactic zones' (the four conjectured areas of syntactic reference). This might be taken as a syntactic way of describing the balance and interweaving of local and global scales in 'naturally' evolved urban environments.

The analysis, of the distribution of shops in sector B, by following the proposed 'from the wholes to the parts' strategy, starts from the initially given SB351 whole and develops through the range of proposed decompositions. The 'areas of reference' for the SB whole are presented in Fig 5.15. Three amongst these systems are also large areas of embedding or interaction. These areas are the whole SB351 and its two first order decompositions that are SB295 and SB89. This is distinct from the analytical strategy applied for sector A as presented above. For sector A the observed patterns of 'differences', 'definitions' and 'overlaps' had made it clear that in syntactic terms SA west and SA east are virtually independent or autonomous systems. Following this observation, the analysis of the distribution of uses in sector A has taken from the outset the two first order decompositions - SA143 and SA418/299 - as the two systems of interaction.1

---

1 This has not prevented the correlation analysis considering the whole sector A as the large area of embedding from being carried out. This procedure has consistently shown that different land use distributions are virtually uncorrelated to all syntactic measurements when sector A is measured in its entirety. This analytical procedure is part of Aguiar, D. Space, Land Use and Design, working paper n°3, UAS, Bartlett School, 1989, pp. 22-31.
Fig. 5.16 Distribution of shops in sector B

- **A** 58354
  \[ r = -0.334 \] \[ p = 0.004 \]

- **B** 58354 Core
  \[ r = -0.413 \] \[ p = 0.047 \]

- **C** 58295
  \[ r = -0.160 \] \[ p = 0.0387 \]

- **D** 58295 Core
  \[ r = 0.047 \] \[ p = 0.9313 \]

- **E** 5854 DSHP x RRA
  \[ r = -0.076 \] \[ p = 0.6172 \]

- **F** 5854 DSHP x RRA/295
  \[ r = -0.28 \] \[ p = 0.0599 \]

- **G** 5854 DSHP x RRA/354
  \[ r = -0.253 \] \[ p = 0.0693 \]
By contrast in the case of the whole sector B the syntactic output has suggested that for this case all local areas should be checked both as a part of the proposed first order decompositions - SB89 and SB295 - and also as a part of the whole sector B. Following this analytical strategy, table 5.05 shows in the 'correlation' column that apart from the coefficients observed for the distribution of shops against 'RRA' (that are RRA values measured considering each local area in itself as the 'scale of measurement') two other RRA modes will be considered. These are 'RRAemb1' that gives the correlation observed when the scale of measurement is enlarged to the proposed SB west and east (SB89 for the western systems and SB295 for the eastern systems) and 'RRAemb2', that is the coefficient observed when the scale of measurement is further enlarged to SB351.

The distribution of shops when the whole sector B is taken as the area of syntactic reference is fairly correlated (at least for the current standards) with the pattern of integration (table 5.05). The coefficient is \(-.334 (p=.0001)\) (Fig 5.16 A). Although the coefficient is not high the correlation is significant for the large number of observations. It indicates that for the system as a whole the density of shops tends to increase in so far as the integration value of the axial lines increases (decrease in RRA). The correlation as measured at the core level increases further to \(-.413 (p=.017)\) (Fig 5.16 B). The correlation observed at the core level corresponds to a lesser extent to what intuition has suggested, i.e. that in a globally integrated core such as the one verified for the whole sector B the concentration of commercial activities ought to be along the most integrated axial lines. Yet this is somewhat the case the strength of such a relationship is below the expected. More significant than that seems to be the coefficient observed for 'all lines compared' which, especially for the large number of observations, indicates a significant relationship between integration and the distribution of shops at all levels of the integration rank. This

---

1 This is fully discussed in chapter three (pp. 199-201).
2 The integration core observed for the whole Sector B is given in Fig 3.17 (p.150).
result gets still more significant when compared with the coefficients observed between integration and the distribution of shops for the two SA larger areas of embedding already examined, that are -.219 for SA west (SA143) and -.183 for SA east (SA418). For both these cases only after a second order decomposition some more significant association between the distribution of shops and syntactic measurements could be identified.

For SB295 - the system at east after the first order decomposition of the whole sector B - the correlation between shops and integration drops to -.160 (p=.0387) (Fig 5.16 C). At the core level of SB295 the two measurements will be virtually uncorrelated (Fig 5.16 D). The conjectured relationship between the intelligibility of the core and the distribution of shops can be again tested out for the current case. In SB295 the intelligibility value for the system measured 'all lines' is .56, while at the core level intelligibility drops sharply to .27.¹ As this figures indicate here again, same as it has been observed for the SA systems, there is a strong association between the intelligibility of the core and the distribution of shops at the core level. That is to say, SB295 is hardly intelligible at the core level and the distribution of shops is virtually uncorrelated with integration when the set of core lines is measured as a separate sample.

This seems to provide a further support for the conjectured 'intelligible distribution of shops at the core level', as proposed during the analysis of the SA systems. In other words, the integration core observed when SB295 is taken as the area of syntactic reference is hardly intelligible and this lack of intelligibility is paralleled by a total lack of relationship between integration and the distribution of shops, in the same way as in the case of SA east (SA299) the 'intelligible cores' have displayed a strong association between the distribution of shops and the pattern of integration. Apart from that the overall decrease in the correlations observed from the whole sector B to SB295, its east part,

¹ This is given in Tab 3.10 (p.194).
as observed in tab. 5.05 seems to provide further evidence in support of the whole sector B as the system of interaction for all SB local areas, at least as far as the distribution of shops is concerned. Nevertheless, as it has been already explained, all SB local areas will be tested out both as a part of SB east and west and also as a part of the whole sector B.

Following this strategy, the correlations between syntactic measurements and the distribution of shops were analysed for the set of systems produced out of the decomposition of SB295 (Fig 5.15). The results given by the measurements taken for SB54 do not agree with the conjecture raised above.\(^1\) That is to say the highest coefficient between the distribution of shops and integration is obtained when SB54 is measured as a part of SB east, and not as a part of the whole sector B (Fig 5.16 F and G). This result also contradicts the syntactic autonomy of SB54 as conjectured on the basis of the high 'definition' observed for that system.\(^2\) If such an autonomy were to be translated into the distribution of commercial activities (as given by the current sample of shops inside that system) it is likely that such a distribution should have followed the pattern of local integration, i.e. RRA values for the system measured as detached from its surrounding areas.

This is not what the results suggest. The correlation between dSHP and RRA is virtually nil; \( R = -.076 \) (\( p = .6172 \))(Fig 5.16 E). When SB54 is measured as a part of SB295 (RRAemb1) the coefficient goes higher to -.28 (\( p = .0599 \))(Fig 5.16 F). And if the system of interaction is further enlarged to the whole sector B (RRAemb2) the correlation will drop to -.253 (\( p = .0893 \))(Fig 5.16 G).\(^3\) The correlations are low yet in view of the distinct coefficients observed for local RRA in relation to both embeddings they become significant. In other words, from the standpoint

---

\(^1\) The conjectured syntactic indivisibility of the whole sector B.

\(^2\) This is in table 3.08 (p.193).

\(^3\) Following the pattern observed for the distribution of shops in SA the highest coefficients are the ones observed for integration. The coefficients for choice, connectivity and for axial length are consistently lower (table 5.05).
**Fig. 3.14** Distribution of shapes in sector 2

(A) $R = -0.249$ ($p = 0.0591$)

(B) $R = -0.224$ ($p = 0.1339$)

(C) $R = 0.003$ ($p = 0.9792$)

(D) $R = -0.121$ ($p = 0.5828$)

(E) $R = -0.644$ ($p = 0.0018$)

(F) $R = -0.217$ ($p = 0.1969$)

(G) $R = -0.410$ ($p = 0.0118$)

(H) $R = -0.327$ ($p = 0.0482$)
of the distribution of shops SB54 is not an autonomous system at all. On the contrary, the distribution of shops is very much referred to the syntactic organization of the surrounding systems.

Similar performance has been observed for the more orthogonal part of sector A - SA60 and its decompositions. Same as for the current SB54 - that is the more orthogonal part of sector B - the distribution of shops inside that orthogonal grid is also carried out according to syntactic rules coming from global scale of the street grid, as given by its measurement as a part of the large area of embedding. The proposed alternative configuration for SB54, that is its reduction to SB44 as shown in Fig 5.15 (third order decomposition), has also been tested out. The outcome of the correlation analysis has shown that for all syntactic measurements the correlations against the distribution of shops are consistently higher for SB54 than for SB44. That is to say, from the standpoint of the distribution of shops SB54 is more likely to be the local area of reference, than its reduction to SB44.

For the local area right beside, that is SB127, the picture changes. Inside this system the highest correlations will be observed for local RRA values. The coefficient is \(-.249\) (p=.0591) (Fig 5.17 A). The correlation for RRAemb1 - integration values measured for SB127 as a part of SB east - is virtually nil (\(R=0.099\)). These results seems to follow the strong overlap (0.50) observed for SB127 in relation to the integration core of SB295. That is to say same as it has happened for SB295 at the core level, the measurement of integration for SB127 as a part of SB295 will be virtually uncorrelated with the distribution of shops.

---

1 For SA60 the correlation \(d_{SHP} \times RRA\) is \(-.109\), while for RRAemb the coefficient will increase to \(-.404\) (table 5.03).

2 This configuration (SB44) was proposed in view of the ambiguity of the 'traverse permeability' criterion when applied to define the east boundary of that system, so generating two distinct configurations: SB54 and SB44. Despite the fact that, as it has been explained during chapter four, the strongest rupture in the traverse permeability happens in effect for the boundary as it is defined for SB54. These results are in Fig. 3.08 (p.128).

3 The correlations for integration are the strongest as for the previous cases.
Although when SB127 is further decomposed (Fig 5.15) the performance of the two resulting parts is contrasting. SB96 tends to follow the same performance given by the system of origin (SB127). The correlations are just marginally lower yet, same as for SA127, the coefficient gets stronger when shops are matched with local RRA. On the other hand, for SB45 - the other system produced out of the third order decomposition of SB127 - the correlation for local RRA against the distribution of shops virtually collapses (Fig 5.17 C). If SB45 is measured as a part of SB295 the coefficient will increase marginally to -.121 (p=.5826) (Fig 5.17 D). But when SB45 is embedded into the whole sector B the coefficient will go as higher as -.614 (.0018) (Fig 5.17 E).

It could be argued that SB45, apart from being a result of the decomposition of SB127, has also incorporated part of the star-shaped centre of the SB whole (Fig 5.15) and that this particular set of lines would be responsible for the high correlation observed for global RRA values. This does not seem to be the case. The scatter diagram suggests that the high correlation between the distribution of shops and global integration observed for SB45 cannot be regarded as a result of the inclusion of this particular set of lines.1 The distribution of points in the scattergram is as a whole rather homogeneous along the regression line and not a product of particular outliers (Fig 5.17 E). If the lines given by the star-shaped centre of the whole system are not computed the coefficient will just drop marginally to -.594 (p=.0041). What these results in fact seem to suggest is that SB127 can hardly be regarded as just one local area (as a whole). In effect this has already been noticed during the syntactic analysis.2 The decomposition of SB127 has revealed two systems with diametrically opposed patterns of distribution of

1 In fact just three out of the nine lines taken from the star-shaped centre of the system will carry shops.
2 SB127 is less ‘defined’ as a local area than the two systems produced out of its decomposition. The definition figure for SB127 is .94, while for SB96 and SB45 definition increases for 1.06 and 1.00 respectively. This is in table 3.08 (p.188). Apart from that it is worth to remind the high value choice lines that separate the two systems. This is in Fig 3.53 (p. 193).
shops. While the eastern part - SB96 - is much locally oriented, in the western part - SB45 - the distribution is totally referred to the global scale. That is to say inside this particular fragment of the street grid (SB45) the distribution of shops is explicitly referred to syntactic features given by the whole sector B (RRA/351), the largest system of interaction.

The heterogeneity and the specific character of each one of the SB local areas is confirmed when the analysis shifts its focus towards SB83 the last of the second order decompositions emerged out of the decomposition of SB295 (Fig 5.15). This system brings back a pattern of correlations similar to the one observed for SB54. That is to say, the distribution of shops will be neither locally oriented nor referred to the whole sector B. Instead, the highest coefficient is observed for RRAemb1, i.e. for the integration values observed when SB83 is measured as embedded in SB295. In other words, same as it has happened for SB54 the 'most effective' system of interaction for SB83 is produced just after the first order decomposition of the SB whole. The coefficient is - .410 (p=.0118) (Fig 5.17 G). Both for the system measured as detached from the surrounding areas and also for its interaction within the whole sector B the coefficients will be lower (Fig 5.17 F and H).

The analysis of the distribution of shops for the local areas inside SB east - local areas produced out of the second and third order decompositions of SB295 - has shown three distinct situations. Inside the two local areas at north and south - SB54 and SB83 - the distribution of shops is organized according to syntactic rules coming from SB295. That is to say, the 'most effective' area of embedding is given by SB295 or, in other words, the distribution of shops is referred to the syntactic character of the 'immediate surroundings'. On the other hand, inside the local area more at east (SB96) shops are more locally oriented, the higher correlation is observed for local RRA. A third situation is given by SB45. For this case the distribution is markedly governed by global rules, given by the syntactic character of the whole sector B. It is noteworthy
Fig. 2.44: Distribution of shops in sector B

(A) 5869 R = - .567 (p = .0001)

(B) 5869 core 89 R = -.097 (p = .7144)

(C) 5869 core 351 R = -.769 (p = .0013)

(D) 5830 R = -.123 (p = .6273)

(E) 5830 R = -.608 (p = .0095)

(F) 5830 R = -.027 (p = .9185)

(G) 5869 R = -.463 (p = .0003)

(H) 5869 R = -.390 (p = .0027)
that for all cases the distributions plotted for integration will consistently provide the highest coefficients. That is to say at the local level the correlations measured for local integration will be systematically higher than for connectivity and length while at the global level the correlations for RRA as embedded will be consistently higher than the ones observed for choice.¹

For the systems at the west part of sector B - SB89 and its two decompositions - the correlations will show once again the effects coming from the whole sector B upon the distribution of commercial activities. The coefficient for the distribution of shops in SB89 against local RRA is −.416 (p=.0009) (table 5.05). Nevertheless when SB89 is measured as a part of the whole Sector B the coefficient will increase to −.567 (p=.0001)(Fig 5.18 A). If on the one hand this output can be regarded as in agreement with the low ‘difference’ and ‘definition’ values observed for SB89, it seems to contradict strongly the lack of ‘overlap’ between the integration core of the whole sector B and the integration core of SB89 which has suggested, following Peponis’ proposition, that SB89 is a rather autonomous local area.² Yet such a lack of overlap may recommend SB89 as a rather autonomous system (in relation to the whole sector B), it is precisely by regarding the whole sector B as the larger area of embedding that the highest correlation will be produced.

In other words despite the lack of overlap the syntactic effects coming from the global scale of the street grid are quite effective in the distribution of shops inside SB89. This result seems to contradict the ‘autonomy’ criterion as stated by Peponis based upon the degree of overlapping of local and global cores. The extent of the syntactic effects coming from the whole sector B upon the performance of SB89 are further stressed when the correlations are measured at the core level. If

¹ The correlations for choice have in effect provided a quite inconsistent pattern for the global description of the distribution of shops. In this respect the case of SB45 provides a limiting case. Despite the strong correlation between shops and global integration inside this system this same distribution will be virtually uncorrelated with choice values (.075) (Tab 5.05).

² These results are in Fig 3.43 (p.181).
the core lines of SB89 are measured as a separate system the plot of integration against the distribution of shops will show that the two measurements are virtually uncorrelated; \( R = -0.097 \) (Fig 5.18 B). If instead the distribution of shops inside SB89 is plotted against the most integrated lines at the global level - that is to say in relation to the whole sector B - the coefficient will go as high as -0.769 (p=0.0013) (Fig 5.18 C).

When SB89 is decomposed the two resulting parts - SB62 and SB30 - will perform in distinct ways, yet eventually the observed results seem to be supportive of the conjectures raised above upon the 'syntactic effects' coming from the global scale. For SB62 the correlation with integration will collapse so suggesting that the decomposition of SB west has deprived that system from its 'syntactic logic' or at least from the logic according to which the distribution of shops tend to perform when the system is analysed in its entirety (tab 5.05). For the other system given by the decomposition of SB west - that is SB30 - the global character of the distribution is noticed again. Fig 5.18 D, E and F show the performance of shops in SB30 as matched against the three proposed RRA modes, i.e. for the system measured as a separate system and also for two distinct embeddings, one as interacting with the immediate surroundings (SB89) and other as a part of the whole sector B. As matched against local RRA values the distribution of shops in SB30 is virtually uncorrelated. The coefficient is -0.123 (p=0.627) (Fig 5.18 D). For SB30 measured as a part of SB89 the coefficient increases sharply to -0.608 (p=0.0045) (Fig 5.18 E). While for SB30 measured as a part of SB351 the correlation gets weaker again; \( R = 0.027 \) (p=0.9165) (Fig 5.18 F).

These results indicate that despite the conspicuous dependence noticed for the SB west as a whole upon syntactic effects coming from the whole sector B - as it the performance of SB89 has suggested - the part of the

---

1 Both correlations have considered a 15% integration core, instead of the standard 10%, in order to improve the statistical significance of the test.
sample of shops that is located inside SB30 will perform in a distinctive way. The distribution of shops inside that particular portion of the street grid is also globally oriented, yet such a global orientation instead of referring to the whole sector B, will refer to global oriented rules given by its interaction within SB89, i.e. its immediate surroundings. The lack of correlation with RRAemb2 shows clearly that this specific part of the street grid is hardly affected by the global interaction of SB west with the whole sector B.

Finally there still remains SB69, that is the system that carries the centre of the star-shaped core of the whole sector B (Fig 5.15). The syntactic analysis has shown that for this system the 'overlap' between the global core lines (SB351 core) and local core lines (SB69 core) is remarkably high (.65).1 Such a strong overlap seems to suggest that the distribution of shops ought to be markedly referred to the global scale for this particular system. Nevertheless, this is not what happens when the distribution of shops is compared with both local and global integration values (Fig 5.18 G and H). For local RRA the coefficient will be -.463 (p=.0003) while for RRA values as embedded in SB351 the coefficient drops to -.390. By contrast with the initial conjecture, these figures suggest that despite the conspicuous assimilation of global syntactic characteristics (the strong overlap) inside this particular part of the grid, this system (SB69) still keeps its local character according to which the distribution of shops tends to refer, even to a larger extent than it refers to the global scale. It is noteworthy that by contrast with the previous cases both correlations are high (as compared within the current standard) so suggesting, it might be conjectured, that the syntactic performance of the distribution of shops in SB69 takes place by superimposing and interweaving locations given by the local and the global scale of the grid.

In general the results observed for the SB systems have confirmed to a large extent what has been observed for the SA systems, namely a

---
1 This result is given in table 3.08 (p.188).
consistent association between the distribution of shops and patterns of syntactic integration as described by the proposed RRA modes. Despite the occasional predominance of the whole sector B as the 'area of syntactic reference', the different parts of the street grid inside that system tend to perform in quite distinctive ways and, moreover, according to quite specific and complex syntactic rules which seem to prevent the observation of a more standardized or generalized performance. Shops located at west (SB89) and the ones located inside the geometric centre of the whole system (SB45) are organized according to global rules coming from SB351 (the whole sector B). Shops located inside SB54, SB83 and SB30 are distributed according to rules coming from the immediate surroundings.\(^1\) A third situation is given by the sample of shops that is located inside SB96. These shops tend to be more locally oriented. The analysis has also shown, also confirming what was observed for sector A, that in general the local areas given by the proposed decomposition strategy have described in a rather effective way not only the subtle variations in the syntactic configuration of the street grid but especially the consequences of such configurational factors upon the distribution of commercial activities.

A syntactic description for the distribution of offices

The distribution of offices will to a large extent perform the other way around in comparison with the performance of shops. As a whole the density of offices tends to increase in so far as integration value of the axial lines (increase of RRA) decreases. Besides the highest correlations are observed for RRA instead of RRA embedded. That is to say the distribution as a whole becomes more locally oriented. This output is in a first look unexpected yet it seems to reflect at least to some extent the fact that a large proportion of the current sample of office buildings are originally single family dwellings (in Chapin's terms) or houses (in terms of the current classification) which have been adapted for offices

\(^1\) These 'immediate surroundings' are SB295, for the first two, and SB89, for SB30.
**Fig. 5.19** Distribution of offices in SA west

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA143 core</th>
<th>SA30</th>
<th>SA34</th>
<th>SA30</th>
<th>SA34</th>
<th>SA77</th>
<th>SA77</th>
</tr>
</thead>
<tbody>
<tr>
<td>dOFC x RRA</td>
<td>-297</td>
<td>.249</td>
<td>.410</td>
<td>.415</td>
<td>.543</td>
<td>.543</td>
<td>.543</td>
</tr>
<tr>
<td>dOFC x RRA/143</td>
<td>-341</td>
<td>.348</td>
<td>-392</td>
<td>-392</td>
<td>-392</td>
<td>-392</td>
<td>-392</td>
</tr>
<tr>
<td>dOFC x CCHC</td>
<td>-325</td>
<td>-323</td>
<td>-323</td>
<td>-323</td>
<td>-323</td>
<td>-323</td>
<td>-323</td>
</tr>
<tr>
<td>dOFC x LEN</td>
<td>-357</td>
<td>-357</td>
<td>-357</td>
<td>-357</td>
<td>-357</td>
<td>-357</td>
<td>-357</td>
</tr>
</tbody>
</table>

(A) SA30 dOFC x RRA $R = .410$ (p = .0336)

(B) SA34 dOFC x RRA $R = .415$ (p = .3549)

(C) SA77 dOFC x RRA $R = .543$ (p = .0049)
purposes. If the residential use is in effect more locally oriented - as intuition recommends - it is likely that offices located in adapted residential premises will also carry this same locally oriented tendency.

In SA west the correlation between the distribution of offices and integration - as locally measured - gets stronger when measured for three particular local areas. These are SA30, SA34 and SA77 (Tab 5.06). The correlation inside SA30 is .410 (p=.0336) (Fig 5.19 A). For SA34 the coefficient goes higher to .415 (p=.3549), yet the probability of the correlation is low in view of the small number of observations, i.e. the small number of lines with offices in that system (Fig 5.19 B). Nevertheless, inside SA77 the number of observations will increase and the points in the scattergram will be more homogeneously distributed. The coefficient gets stronger to .543 (p=.0049) (Fig 5.19 C). These figures suggest - once the conjectured local areas are accepted - that for the purpose of the distribution of offices the whole SA west (SA143) is divided in these three distinct systems. The correlations are higher for SA30 and SA34 yet they will drop for SA60 (.249), that is precisely the system where SA30 and SA34 are measured as interacting. The opposite happens to the other half of SA west. In this case the correlation is stronger for SA77 yet it drops for the third order decompositions (SA59 and SA21). For the more globally oriented measurements - RRAemb and choice - the correlations will be consistently lower, yet increasing again for the other two local parameters, connectivity and axial length (but always lower than local RRA). These figures as a whole have suggested that the distribution of offices inside SA west is mostly arranged in relation to SA30 and SA77 as two clearly identified local areas to which the distribution is spatially referred (Fig 5.19 A and C). Inside the other conjectured

---

1 This phenomenon has already been referred in chapter two (section 'On land use classification') as a characteristic that is common to most systems inside the current sample.

2 The performance of a sample of residential uses against syntactic measurements is the object of next chapter.
Table 5.07

Distribution of offices and syntactic measurements in SA east:

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA106</th>
<th>SA69</th>
<th>SA184</th>
<th>SA299</th>
<th>418 core</th>
<th>SA418</th>
<th>SA299 core</th>
<th>SA106core</th>
<th>SA71</th>
<th>SA72</th>
</tr>
</thead>
<tbody>
<tr>
<td>dOFC H RRA</td>
<td>-5.84</td>
<td>-5.71</td>
<td>-1.53</td>
<td>-1.73</td>
<td>0.57</td>
<td>0.091</td>
<td>-0.632</td>
<td>-0.342</td>
<td>-0.459</td>
<td>-0.336</td>
</tr>
<tr>
<td>dOFC H CHC</td>
<td>-2.73</td>
<td>-2.43</td>
<td>-1.51</td>
<td>-1.28</td>
<td>0.889</td>
<td>0.319</td>
<td>-0.424</td>
<td>-0.424</td>
<td>-0.342</td>
<td>-0.336</td>
</tr>
<tr>
<td>dOFC H CON</td>
<td>-2.54</td>
<td>-2.47</td>
<td>-1.609</td>
<td>-1.17</td>
<td>-1.11</td>
<td>0.201</td>
<td>-0.557</td>
<td>-0.557</td>
<td>-0.557</td>
<td>-0.557</td>
</tr>
<tr>
<td>dOFC H LEN</td>
<td>-3.00</td>
<td>-3.34</td>
<td>-0.609</td>
<td>-0.609</td>
<td>0.460</td>
<td>0.340</td>
<td>-0.340</td>
<td>-0.191</td>
<td>-0.191</td>
<td>-0.191</td>
</tr>
</tbody>
</table>

**Fig. 5.20** Distribution of offices in SA east

Table 5.07

Distribution of offices and syntactic measurements in SA east:

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA106</th>
<th>SA69</th>
<th>SA184</th>
<th>SA299</th>
<th>418 core</th>
<th>SA418</th>
<th>SA299 core</th>
<th>SA106core</th>
<th>SA71</th>
<th>SA72</th>
</tr>
</thead>
<tbody>
<tr>
<td>dOFC H RRA</td>
<td>-5.84</td>
<td>-5.71</td>
<td>-1.53</td>
<td>-1.73</td>
<td>0.57</td>
<td>0.091</td>
<td>-0.632</td>
<td>-0.342</td>
<td>-0.459</td>
<td>-0.336</td>
</tr>
<tr>
<td>dOFC H CHC</td>
<td>-2.73</td>
<td>-2.43</td>
<td>-1.51</td>
<td>-1.28</td>
<td>0.889</td>
<td>0.319</td>
<td>-0.424</td>
<td>-0.424</td>
<td>-0.342</td>
<td>-0.336</td>
</tr>
<tr>
<td>dOFC H CON</td>
<td>-2.54</td>
<td>-2.47</td>
<td>-1.609</td>
<td>-1.17</td>
<td>-1.11</td>
<td>0.201</td>
<td>-0.557</td>
<td>-0.557</td>
<td>-0.557</td>
<td>-0.557</td>
</tr>
<tr>
<td>dOFC H LEN</td>
<td>-3.00</td>
<td>-3.34</td>
<td>-0.609</td>
<td>-0.609</td>
<td>0.460</td>
<td>0.340</td>
<td>-0.340</td>
<td>-0.191</td>
<td>-0.191</td>
<td>-0.191</td>
</tr>
</tbody>
</table>

**Fig. 5.20** Distribution of offices in SA east

Table 5.07

Distribution of offices and syntactic measurements in SA east:

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA106</th>
<th>SA69</th>
<th>SA184</th>
<th>SA299</th>
<th>418 core</th>
<th>SA418</th>
<th>SA299 core</th>
<th>SA106core</th>
<th>SA71</th>
<th>SA72</th>
</tr>
</thead>
<tbody>
<tr>
<td>dOFC H RRA</td>
<td>-5.84</td>
<td>-5.71</td>
<td>-1.53</td>
<td>-1.73</td>
<td>0.57</td>
<td>0.091</td>
<td>-0.632</td>
<td>-0.342</td>
<td>-0.459</td>
<td>-0.336</td>
</tr>
<tr>
<td>dOFC H CHC</td>
<td>-2.73</td>
<td>-2.43</td>
<td>-1.51</td>
<td>-1.28</td>
<td>0.889</td>
<td>0.319</td>
<td>-0.424</td>
<td>-0.424</td>
<td>-0.342</td>
<td>-0.336</td>
</tr>
<tr>
<td>dOFC H CON</td>
<td>-2.54</td>
<td>-2.47</td>
<td>-1.609</td>
<td>-1.17</td>
<td>-1.11</td>
<td>0.201</td>
<td>-0.557</td>
<td>-0.557</td>
<td>-0.557</td>
<td>-0.557</td>
</tr>
<tr>
<td>dOFC H LEN</td>
<td>-3.00</td>
<td>-3.34</td>
<td>-0.609</td>
<td>-0.609</td>
<td>0.460</td>
<td>0.340</td>
<td>-0.340</td>
<td>-0.191</td>
<td>-0.191</td>
<td>-0.191</td>
</tr>
</tbody>
</table>
local area - that is SA34 - the density of offices is rather low so affecting the statistical significance of the test (Fig 5.19 B).

The correlations for the distribution of offices in SA east will confirm to a large extent what was observed for this category in SA west, that is to say the distribution of offices will consistently perform the other way around as compared with the distribution of shops. Here again the density of offices will increase insofar as the integration value of the axial lines decreases (increase of RRA). The coefficients will be in general higher than the coefficients observed for shops, even when the large SA east is measured as a whole (SA418) (Tab 5.07). The highest coefficients in this case are obtained when offices are matched with connectivity (R=-.454 p=.0001) (Fig 5.20 A), yet the coefficient observed for integration (.336) is also significant for the current standards.1

When the measurement is taken at the core level the correlation with connectivity will collapse, while the coefficient for integration will increase and, significantly, change its direction. This phenomenon is outstanding when the coefficients are measured for SA299 - that is the same system having the housing estates deleted. For this larger system of interaction the coefficient for all lines compared is .319 (p=.0253) (Fig 5.20 B). Yet when the measurement is taken at the core level the coefficient will both increase and change its direction to -.632 (p=.0152) (Fig 5.20 C).2 What the change in direction observed for this correlation shows is that, as a whole, the concentration of offices tends to decrease in so far as the integration value of the axial lines increases. Nevertheless if the core lines are measured as a separate sample, for that specific set of lines (the thirty most integrating lines inside SA299) the concentration of offices will increase strongly following the increase of integration. The probability of the correlation is low

1 Density of offices increases with the decrease of connectivity and with the increase of RRA (segregation).

2 Here again the coefficients observed for RRA will be outstandingly higher than for the other syntactic measurements (Tab 5.07).
(p=.0152), but both the distribution of points in the scattergram and, most of all, the change in direction, as observed for the correlation, seem to provide a significant description for the syntactic performance of the distribution of offices, not only in SA east but also in SA west. In effect this same phenomenon has already been noticed during the analysis of SA west, yet for that case the correlation is weaker.¹

This syntactic output - the strengthen of the correlation coupled with a change in its direction - has depicted two distinct types of offices inside the sample, performing according to distinct syntactic rules. One is the type already described as offices that tend to occupy adapted residential spaces. These offices are distributed throughout the more secluded lines and this precise distribution will be responsible for the correlation coefficient observed for all lines, which shows that the concentration of offices tend to decrease with integration. Other is the part of the sample that is composed by office buildings which have been built for office purposes which to a large extent tend to be located at main routes, or at one axial step from a main route. The density of these office purpose buildings, as depicted in the correlation observed at the core level, will consistently increase insofar as the axial lines become more integrated.

When SA east is decomposed the correlations observed for the four second order decompositions will present four distinct performances. In SA184 the distribution of offices is virtually uncorrelated with the different syntactic measurements (Tab 5.07). The correlation for offices against integration in this particular system is -.091 (p=.2136) (Fig 5.20 D). The 'deleting' of the lumps of housing estates does not alter at all the syntactic performance observed for the distribution of offices. The correlations for SA69 will remain rather low showing that for offices, by contrast with what happens for shops, this system can hardly be regarded as an area of syntactic reference for the distribution.

¹ For SA143 the correlation for all lines (dOFC x RRA) is .302, while at the core level the coefficient will also change its direction to -.297 (Tab 5.06).
Inside SA106 the distribution will become more local oriented if the higher correlation with RRA, instead of RRA emb, is taken as a parameter (Fig 5.20 E). A third situation is presented by SA71. Inside this system the distribution of offices will follow the tendency already observed at the core level, i.e. the concentration of offices increases in so far as integration increases. In this case the correlations goes higher (especially for RRAemb and connectivity) yet the probability of the correlation will be lower in view of the smaller number of observations for that system (few lines carrying offices) (Fig 5.20 F). A fourth situation is given by SA72. Inside this system the distribution of offices will correlate positively with RRA and negatively with RRAemb (Fig 5.20 G).

The four distinct performances presented above seem to indicate that, apart from SA184/69, each of the proposed local areas has its own specific way of arranging the distribution of offices inside itself and moreover that the global scale is here again, same as it has happened for SA west, less effective in describing office distribution than the local scale - the correlations for RRA are in general higher than the ones observed for RRA as embedded. Besides, the correlations observed for SA east as decomposed are systematically higher than the coefficients observed for the whole system. This seems to be in tune with the change in the direction of the correlation from 'all lines' to 'core lines' when SA east is syntactically described in its entirety. For this set of lines - and just for the particular set of core lines - the density of offices will increase following the increase of integration (Fig 5.20 C). In other words for a specific part of the sample the density of offices increases following the increase of the integration value of the axial lines despite the fact that for the largest part of the sample, offices tend to distribute according to local rules inside the local areas produced out of the decomposition of SA east.

The exception for this rule is given by SA71 a local area inside which the concentration of offices also follows the increase of integration, same
as for the core. This can be explained. From the set of seven lines axial lines that carry offices inside SA71, four are lines that belong to the global integration core. This strong overlap of core lines and office lines inside SA71 seems to be to a large extent responsible for the tendency observed in that system in following the same performance observed for the core lines, i.e. an increase in the density of offices in so far as integration increases. Although the probability of the correlation is low (p=.2343), especially for the small number of lines carrying offices in that particular system, the distinct direction of the correlation as compared with the other local areas is what counts for the purpose of this argument (Fig 5.20 F).

The results observed for the sample of offices in SA east confirm to a large extent what has been observed for offices in SA west. Here again for three out of the four local conjectured local areas (SA104/69 is the exception in the current case) the coefficients will be significantly higher than the ones observed for SA416 or SA299, i.e. the two versions of SA east described as a whole. Also following the pattern observed for SA west, the direction of the correlation will also change at the core level that is to say the concentration of offices will increase with integration only at the level of the core.

In sector B the densities of offices and industries are even lower than the ones observed for the SA systems. The ranks of densities of productive activities in the sector A (as given in Fig 5.02) have shown that both for SA east and SA west the densities of offices are consistently lower than the density of shops all systems compared.1 This has been noticed not only for the densities of these activities at the level of each one of the axial lines but mostly in respect of the number of axial lines, in absolute terms, that carry either offices or industries inside each system. In effect the number of axial lines inside each different system that carry offices or industries is consistently smaller than the number of lines that carry shops. Yet such lower

---

1 The densities of industries will be even lower (Fig 5.02 C).
densities have to some extent affected the probability of the coefficients observed for both offices and industries inside the SA systems - east and west - it has not prevented the comparative analysis on the performance of the different local areas. However the probability of some correlations is low the distribution of points in the scattergrams has proved itself a useful guide upon which to base the argument when necessary. ¹

In sector B the densities of offices and industries are even lower than the ones observed for the SA systems and thus the number of observations left for the conjectured local areas will be as low as for the SA limiting cases exemplified above. This decrease in the number of observations for offices and industries in sector B reflects in effect the distinct functional character of that area, as compared with sector A, where despite the predominance of commercial activities, both offices and industries are strongly present. As a consequence the analysis of the distribution of offices in sector B will focus on the two systems of interaction - SB west and SB east - where the significance of the statistical tests is consistently higher - in view of the larger number of observations - than when the conjectured local areas are tested as detached. Yet the smaller number of observations for offices in sector B has affected the statistical output at the level of each one of the proposed local areas (so affecting the power of comparative tests) it has not prevented interesting observations both at the level of the systems of interaction - the whole sector B and the two systems given by its decomposition - and at the level of the cores, all to a large extent contributing to the argument set up during the analysis of the distribution of offices in sector A. ²

¹ SA34 (Fig 5.19 B) and SA71 (Fig 5.20 F) provide examples of limiting cases where the significance of the statistical tests is rather affected by the small number of observations.
² The same might be said about the sample of industries inside sector B whose low densities left for each of the conjectured local areas after second and third order decompositions will affect strongly the significance of the statistical tests.
### Table 5.06
Distribution of offices and syntactic measurements for the whole sector B: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SB351</th>
<th>SB351 core</th>
<th>SB295</th>
<th>SB295 core</th>
<th>SB89</th>
<th>SB89 cor89</th>
<th>SB89 cor351</th>
</tr>
</thead>
<tbody>
<tr>
<td>dOFC x RRA</td>
<td>.063</td>
<td>.018</td>
<td>.396</td>
<td>-.012</td>
<td>.448</td>
<td>-.629</td>
<td>-.114</td>
</tr>
<tr>
<td>dOFC x RRAemb1</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>dOFC x RRAemb2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>.095</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>dOFC x CHC</td>
<td>-.106</td>
<td>●</td>
<td>-.374</td>
<td>●</td>
<td>-.081</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>dOFC x CON</td>
<td>-.024</td>
<td>●</td>
<td>-.419</td>
<td>●</td>
<td>-.323</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>dOFC x LEN</td>
<td>-.094</td>
<td>●</td>
<td>-.380</td>
<td>●</td>
<td>-.374</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

Fig. 5.21 Distribution of offices in sector B
When the distribution of offices is matched with the syntactic measurements taken for the whole sector B, the two parameters are virtually uncorrelated (Fig 5.21 A). Neither of the 'regularities' observed for the SA systems can be identified here.¹ What the coefficients suggest is that the distribution of offices has nothing to do with syntactic measurements taken for 'all lines'. This applies for the different syntactic measurements.² A similar pattern is maintained at the core level, where offices and integration are also virtually uncorrelated (Fig 5.21 B). Nevertheless, for the systems produced out of the first order decomposition of SB351 the picture changes and the performance of the two resulting parts - SB295 and SB89 - will, to a large extent, approximate the performance observed for the sample of offices located inside the SA systems.

The distribution of offices in SB295, will be .396 correlated with integration (p=.0044) (Fig 5.21 C). The coefficient observed for connectivity is marginally higher (-.419) but, as for the previous cases, integration tends to be more consistent in its overall performance (tab 5.08). This output is very much in tune with what has been observed for the SA systems. Here again when the system is measured 'all lines' the density of offices buildings will decrease in so far as the integration value of the axial lines increases (decrease of RRA).³ For the previous cases it has been observed that when the correlation is measured at the core level there is a consistent change in direction in the coefficients, which suggests that for the part of the sample that is located along the core lines the degree of concentration of offices tend to increase in so far as integration increases, i.e. the more integrated lines tend to be the ones where the density of offices buildings increases.⁴ The measurement

¹ The 'regularities' referred to here are the increase in the density of offices with the decrease of integration when the systems are measured 'all lines', and the change in direction observed for the coefficients when the correlations are measured at the core level.
² Yet for the choice coefficient there is a marginal increase (Tab 5.08).
³ The same was observed for SA143 (.302), SA418 (.336) and SA299 (.319). These coefficients are presented in tab 5.06 and 5.07.
⁴ In SA143 the coefficient observed for 'all lines' is .302. For the core level it changes to
of SB295 at the core level seems, in a first look, to contradict the pattern described above observed for the previous systems. The correlation is not positive as it is for 'all lines', yet it does not change its direction as it does for the previous cases either. In effect offices and integration will be virtually uncorrelated for SB295 at the core level \( R = -.012 \ p = .9697 \) (Fig 5.21 D).

The number of observations is small. There are just 13 lines carrying offices amongst the 30 lines of the SB295 core. Nevertheless, despite the small number of observations, the distribution of points in the scattergram shows clearly that two particular lines are strong 'outliers' which, to a large extent, are responsible for the lack of correlation.\(^1\) Both these points represent lines which are too integrated for the low concentration of offices they carry if compared with the tendency observed for the bulk of this small sample. If these two lines are not computed the correlation gets stronger. The coefficient improves to \( - .439 \ (p = .1764) \) (Fig 5.21 E). This indicates, despite the low probability of the correlation, that there is at least a tendency in the core of SB295 which seems to confirm what has been observed for the two SA larger areas. If the evidence given in scat D is accepted it might be said that at the core level of SB295 the increase in the density of offices tends to follow the increase of integration as well (decrease of RRA) same as for the SA cases.

For the other system produced out of the decomposition of the whole sector B - that is SB89 - the correlation between the distribution of offices and integration, as measured for all lines, is \( .448 \ (p = .0321) \) (Fig 5.22 A). The coefficient is relatively high (for the current standards) yet the probability of the correlation is low. Not for the small number of observations but, in this particular case, reflecting the distribution of points in the scattergram where the performance of two particular lines tend to bias the correlation. These two lines (black dots in the}

\(^{-.297.}\) For SA418 the coefficient is \( .336 \) (all lines) and changes into \( -.459 \) for the core. For SA299 the change is the most dramatic (from \( .319 \) to \( -.632 \) (Tables 4 and 7).

\(^1\) These lines are represented in the two black dots (Fig. 5.21 D).
Fig. 5.22 Distribution of offices in sector B

(A) 5889
\[ R = 0.448 \ (p = 0.032) \]

(B) 5889 cor.89
\[ R = -0.629 \ (p = 0.083) \]

(C) 5889 cor.354
\[ R = -0.414 \ (p = 0.788) \]
scattergram) are exceptional situations which carry a relatively high concentration of office buildings and are rather low in rank of integration. If these two lines are not computed the correlation collapses to .198 (p=.3906) showing that the tendency observed for the previous systems (decrease in the concentration of offices in so far as integration increases) is hardly followed here.

If on the one hand the correlations observed for 'all lines' are not entirely in agreement with what has been observed for the previous systems, for the core level the performance of the current system will be strongly 'in tune' with the results given by the analysis of the previous cases. Fig 5.22 B shows that for SB89 core the distribution of offices is -.629 (p=.0383) correlated with integration. Same as for the previous cases, for the part of the sample of offices located in the core lines of SB89 the increase of integration will be followed by an increase in the density of offices. Here again the probability of the correlation is low but the recurrence of the observed 'change in direction', as noticed with distinct intensities in all four systems of interaction, seems to be by itself significant as a description for the syntactic performance of the distribution of offices at the core level (within the limits of reliability allowed for results given by a sample as large as the current one).

It is also significant, in respect of the performance of office buildings in SB89, that the strong correlation observed at the core level has taken as its core of reference the 10% most integrated lines of SB89 measured as detached from the SB whole, i.e. measured as a separated system. This is distinct from what has happened for the distribution of shops at the core level of this same system (SB89). In the case of shops the distribution is explicitly referred to the global integration core, that are the most integrated lines within SB89 when this system is measured as a part of the whole sector B (Fig 5.18 C). This is not what happens in the case of offices since, as it has been said, the correlation observed in Fig 5.22 B is obtained for the 10% most integrated lines of SB89 measured as
detached from the whole sector B. In effect, if the most integrating lines within SB89 - measuring this system as a part of SB351 - are matched with the distribution of offices, the two measurements will be virtually uncorrelated (Fig 5.22 C). The distinction is subtle yet it seems to reassert the local character consistently observed for the distribution of offices as compared with the distribution of shops.¹

A syntactic description for the distribution of industries

The distribution of industries presents similarities with the distribution of shops in terms of the conjectured areas of syntactic reference. The partition of the SA west in two systems - SA60 and SA77 - will deliver the strongest correlations both of them observed for RRA embedded values. The correlation coefficient for SA60 is .524 (p=.0001) (Fig 5.23 A) while for SA77 the coefficient goes higher to .763 (p=.0004) (Fig 5.23 B).² The direction of these correlations is positive so suggesting that the frequency of location of industries tends to increase in opposite direction if compared with the frequency of location of shops.³ While shops tend to concentrate in the more integrated lines, industries tend to segregate themselves in the street grid. This does not mean that industries will be concentrated in the most segregated lines. This is not the case. There are industries located throughout the whole rank of integration, even at the most integrating lines. What the correlations in effect suggest is that the concentration of industries tends to grow in so far as integration values decrease, having all the lines that carry industries been compared as a separate sample.⁴

¹ For the SA systems as a whole the correlations for the distribution of offices tend to be consistently higher for local RRA values than for RRA emb.
² All values - for both RRAs and dIND - are logtransformed as the normality tests have recommended.
³ 'Frequency of location', as it has been explained in chapter two (section 'Constitution as a land use measurement'), is another way of referring to the land use 'densities' as measured by the constitution criterion.
⁴ If all lines are plotted - that is to say if the lines that do not carry industries are also plotted in the comparison - the distribution of industries (dIND) will be strongly skewed even after logtransformation.
Fig. 5.23 Distribution of industries in SA west

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA60</th>
<th>SA77</th>
<th>SA34</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_{IND} \times RRA$</td>
<td>$R=0.524$</td>
<td>$R=0.763$</td>
<td>$R=0.587$</td>
</tr>
</tbody>
</table>

| $d_{IND} \times RRA/143$ | $-0.470$ | $-0.390$ | $-0.254$ |

| $d_{IND} \times CHC$ | $-0.305$ | $-0.366$ | $-0.443$ |

| $d_{IND} \times CON$ | $-0.470$ | $-0.390$ | $-0.254$ |

| $d_{IND} \times LEC$ | $-0.305$ | $-0.366$ | $-0.443$ |
The global scale is again the 'scale of reference' for the distribution. In fact the correlations for industries will be as a whole higher for global measurements - RRA embedded and choice - and will decrease for the locally oriented measurements (Tab 5.09). That is to say, industries tend to segregate themselves and such pattern of segregation is syntactically referred to the global scale of the street grid, as given by integration values of each axial line (inside each local area) measured as a part of the system of interaction (SA143). Nevertheless one exception will occur and precisely for the system that carries the highest density of industries in all sample, that is SA34. This system is a third order decomposition of SA west and the distribution of industries - if SA34 is considered as the area of syntactic reference - will be strongly correlated with local RRA. The correlation is .587 (p=.001) (Fig 5.23 C). There seems to be no contradiction in these results. What these figures indicate is that although industries located in that more orthogonal part of SA west are distributed according to global RRA values (when SA60 is taken as the area of reference) if the part of the sample of industries that are located inside SA34 are measured in separate these industries will have their own internal or local arrangement which is carried out according to the local RRA values observed for that system (SA34).

In SA east the distribution of industries will perform rather similarly to the distributions observed for SA west. In that case two local areas (SA60 and SA77) produced out of the decomposition of SA143 have shown themselves as the most effective areas of reference for describing the distribution of industries. Here again the correlations observed for the parts will be systematically higher than the correlations observed for the whole. The direction of the correlations will be the same as well so suggesting that industries tend in probabilistic terms to segregate themselves in the street grid and moreover that such a pattern of

---

1 same as it has been observed for shops and in contrast with what was observed for offices where local RRA values have consistently provided the highest coefficients.
### Table 5.1
Distribution of industries and syntactic measurements in SA east: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA418</th>
<th>SA71</th>
<th>SA72</th>
<th>SA106</th>
<th>SA184</th>
<th>SA418 core</th>
<th>SA299 core</th>
<th>SA395 core</th>
<th>SA418 core</th>
</tr>
</thead>
<tbody>
<tr>
<td>dNO x RAH</td>
<td>.597</td>
<td>.322</td>
<td>.565</td>
<td>.622</td>
<td>.628</td>
<td>.599</td>
<td>.640</td>
<td>.621</td>
<td>.650</td>
</tr>
<tr>
<td>dNO x RAHemb</td>
<td>-535</td>
<td>.736</td>
<td>.690</td>
<td>.778</td>
<td>.873</td>
<td>-627</td>
<td>-688</td>
<td>-605</td>
<td>-582</td>
</tr>
<tr>
<td>dNO x CHC</td>
<td>-597</td>
<td>.614</td>
<td>.722</td>
<td>.713</td>
<td>.890</td>
<td>-625</td>
<td>-688</td>
<td>-605</td>
<td>-653</td>
</tr>
<tr>
<td>dNO x CON</td>
<td>-604</td>
<td>-622</td>
<td>-640</td>
<td>-640</td>
<td>-640</td>
<td>-688</td>
<td>-688</td>
<td>-605</td>
<td>-653</td>
</tr>
<tr>
<td>dNO x LEN</td>
<td>-597</td>
<td>-322</td>
<td>-565</td>
<td>-622</td>
<td>-628</td>
<td>-599</td>
<td>-640</td>
<td>-621</td>
<td>-650</td>
</tr>
</tbody>
</table>

### Fig. 5.24
Distribution of industries in SA east

- **A** SA418 $R = -0.604 \ (p = 0.001)$
  - $y = -0.516x + 0.947$, $R^2 = 0.368$

- **B** SA418 core $R = -0.727 \ (p = 0.001)$
  - $y = -0.520x + 1.119$, $R^2 = 0.329$

- **C** SA184 $R = -0.825 \ (p = 0.001)$
  - $y = -0.565x + 1.668$, $R^2 = 0.484$

- **D** SA106 $R = -0.873 \ (p = 0.001)$
  - $y = -0.596x + 1.599$, $R^2 = 0.363$

- **E** SA184 $R = 0.736 \ (p = 0.002)$
  - $y = 0.066x + 0.606$, $R^2 = 0.242$

- **F** SA106 $R = 0.690 \ (p = 0.015)$
  - $y = 0.18x + 0.225$, $R^2 = 0.475$

- **G** SA184 $R = 0.599 \ (p = 0.052)$
  - $y = 0.166x - 0.34$, $R^2 = 0.239$

- **H** SA106 $R = 0.475 \ (p = 0.0465)$
  - $y = 0.18x - 0.309$, $R^2 = 0.225$
segregation tend to organize itself more effectively inside the proposed areas of reference than as a whole set distributed throughout the entire SA east. For industries the coefficients will be particularly higher for connectivity (Fig 5.24).1

For the distribution of industries in sector B the analysis focuses on the two systems of interaction (SB295 and SB89) plus the whole sector B following what has happened for the sample of offices in this same area.2 The output given by these tests seems to be to a large extent, in tune with the results already observed for the SA systems where industries have shown a consistent tendency in concentrating themselves at the more segregated parts of the street grid. The main difference that will be observed for the distribution of industries within the current SB systems, as compared with the previous SA systems, is in respect of their performance at the core level. For the whole sector B industries are .381 (p=.0012) correlated with RRA (Fig 5.25 A). The coefficient is lower than the ones observed for SA east (.597) and SA west (.385).

Nevertheless if the measurements are taken after the first order decomposition - for SB295 and SB89 - the coefficients will improve, especially for the latter. Inside SB295 industries are .459 (p=.0004) correlated with integration (Fig 5.25 C), while for the other part produced out of the decomposition of the whole sector B (SB89) the coefficient will go as high as .682 (p=.0005) (Fig 5.25 E).

More than confirming the 'segregationist' tendency already detected for industries, as shown for the previous cases, the variation in the coefficients observed above (before and after the decomposition) suggests that the distribution of industries in SB is more referred to

---

1 Fig 5.24 presents a set of scattergrams which compare the correlations for integration and connectivity against the distribution of industries for SA184 (scats C, E and G) and SA106 (scats D, F and G).

2 This follows the fact that the low number of industries left for each local area after the decomposition of sector B will to a large extent undermine the significance of the statistical tests. For the two systems of interaction - SB295 and SB89 - in view of the larger number of observations, the significance of the tests will improve strongly.
Table 5.11
Distribution of industries and syntactic measurements in sector B: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SB89</th>
<th>SB295 core</th>
<th>SB295</th>
<th>SB351 core</th>
<th>SB351</th>
<th>dIND x RRA</th>
<th>dIND x RRAemb1</th>
<th>dIND x RRAemb2</th>
<th>dIND x CHC</th>
<th>dIND x CON</th>
<th>dIND x LEN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.682</td>
<td>.030</td>
<td>.459</td>
<td>.048</td>
<td>.381</td>
<td>.021</td>
<td>-.500</td>
<td>-.594</td>
<td>-.685</td>
<td>-.634</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 5.25 Distribution of industries in sector B
each one of the parts as decomposed than to the whole SB351. This seems to be also in tune with what has been observed for the SA systems, where the highest correlations are observed for the local areas instead of for the systems of interaction.\(^1\) Another distinction in relation to the previous cases are the correlations observed at the core level. Both for SB351 and for SB295 industries are virtually uncorrelated with integration at the level of the core.\(^2\) This is the opposite of what happens for the SA systems - especially for SA418/299 - where the observed decrease in the concentration of industries in so far as integration increases will remain constant even when the core lines are measured as a separate sample.\(^3\)

Finally it is worth to mention that the high correlations observed for the plots of connectivity against industries in the SA systems (especially in SA east) is not observed for the SB systems. In effect the analysis of the three 'productive activity' categories - shops, offices and industries - in SB has shown that integration, amongst the four syntactic parameters under scrutiny, has been the most consistent in its performance against any of the proposed land use categories.

Notes on the syntactic distribution of productive activities \(^4\)

As a whole the results presented in this chapter have shown that amongst the set of measurements tested out integration - as measured by RRA and RRAemb values - tends to be the most effective syntactic parameter in describing the distribution of productive activities. The results observed both for sectors A and B have also consistently

\(^1\) The coefficients for industries in SA west and east are shown in tables 5.09 and 5.10 respectively.
\(^2\) For SB89 the concentration of industries observed at the core level is not enough for setting up a minimum of statistical significance for the tests).
\(^3\) This result is given in Fig 5.24.
\(^4\) The results given by the match of the proposed 'descriptions of grid configuration' and 'mean densities of productive activities' have already been discussed at the end of that analytical procedure (pp. 279–280).
suggested that shops tend to locate themselves in a sort of agreement with the pattern of integration. That is to say the frequency of location of shops will increase in so far as the integration value of the axial lines increases. Offices and industries tend as a whole to perform in opposite direction. In so far as the integration value of the axial lines increases the density of offices and industries has decreased. Nevertheless the distribution of offices has also shown a distinct performance for the part of the sample located at the core level whose density has consistently increased following the increase of integration, same as for the sample of shops.

The fact that both offices and industries tend to correlate well with segregation, all lines compared, does not mean that these two categories tend to concentrate in the same axial lines. This is not the case. SA77, for instance, has seventeen lines with offices and twenty four lines with industries, yet just five of these axial lines will carry both offices and industries simultaneously. In other words although both industries and a significant part of the sample of offices tend to avoid integration they also seem to avoid the each other in their pattern of location.

In respect of the proposed scales of measurement the sample of shops has presented a consistent global orientation that is to say the strongest correlations are systematically observed for RRAemb values. The same applies for industries while for offices the distribution is more locally oriented, i.e. the strongest correlations are observed for local RRAs measured for each system as detached. By contrast with the performance of offices, industries will correlate well with segregation even at the core level. This seems to be in agreement with the character of the industrial activity which for its intrinsic nature depend less on the pattern of integration of the urban grid than shops or offices. The contrasting syntactic performances observed for offices and industries - as compared with what was observed for shops - might be conjectured as a possible description of the natural zoning hypothesis based upon the syntactic character of the street grid as conjectured at the outset of
Further research on this specific topic (for other towns and cultures) might provide further clarification on the degree of recurrence of such phenomena and thus on the validity of the syntactic distribution of productive activities as proposed during this chapter.
Chapter 6
Syntactic Descriptions for
the Distribution of Residential Uses

This chapter extends the proposed range of analysis towards the study of the residential use. The analysis focuses initially in the mean densities of the proposed residential categories – houses, blocks of flats, mixed residential, housing estates and their aggregate as well – as observed at the level of each system and moreover on the scrutiny of relationships between this set of use densities and the proposed configurational parameters. These parameters are integration, intelligibility, axial fragmentation and tension, ringyness, connectivity and density of intersections and figure ground ratio. This same set of measurements has already been utilized in the analysis of the densities of productive activities so allowing for a comparison between those results and the results to be observed in what follows.

This exercise is an attempt of testing the extent to which the performance of these configurational parameters of syntactic nature are (or not) associated with the way the densities of the different residential categories change throughout the urban grid. In a second step the analysis shifts towards the study of the distribution of the proposed residential categories within each system so allowing for a further test of the proposed decomposition strategy and resulting areas of syntactic reference as given during chapter three.

The analysis of the syntactic performance of the residential use follows to a large extent - despite its peculiarities - the procedure adopted in the study of 'productive activities' as given in chapter five. Same as there the analytical procedure is initially focused on the densities of the different residential categories within each one of the proposed local areas and moreover on how these residential densities relate to the

1 The method for measuring residential densities follows the procedure adopted for measuring the mean densities of productive activities, as explained at the outset of chapter five (pp.261-263).
configuration of the urban grid as described by the proposed set of syntactic parameters referred to above. In the following step the analysis shifts towards residential densities as described inside each system by the frequency of location of each residential category along each particular axial line.

**Grid configuration and residential densities**

The ranks of the densities of productive activities examined at the outset of the previous chapter have shown that the highest densities - especially in the case of shops - occur in the less fragmented or more 'griddy' systems and moreover that in so far as the configuration of the urban grid changes from the less fragmented towards the more fragmented systems the density of productive activities as a whole tends to decrease consistently.\(^1\) The same cannot be said in respect of the residential use. In fact the pattern referred to above seems to be somewhat inverted when the sample of residential densities - in its aggregate form - is rank ordered (Fig 6.01).

The set of most fragmented systems tend to occupy the highest positions in the ranks of residential densities while the less fragmented systems tend to be the ones at the bottom of both ranks.\(^2\) This happens both for the aggregate of residential densities relativised to the area of the different systems and also for this same aggregate relativised to the number of axial lines inside each system.\(^3\) As contradicting this more

---

1. Similar pattern was observed in the ranks of integration, axial fragmentation, tension and connectivity.
2. Distinct degrees of axial fragmentation seem to be a proper way of specifying 'more griddy' or 'more labyrinthine' patterns.
3. The measurement of residential densities will follow the same process adopted in the assessment of the densities of productive activities. Residential densities are assessed in two ways. One is the total number of residences relativised to the area of the system or, more specifically, the ratio between the aggregate of constitutions related to each residential category inside the system of interest and the area of the system (dRES/A). The second measurement is the mean value - all lines in the system of interest computed - given by the densities of each residential category at the level of each axial line. As it has already been explained, the residential density inside each axial line is measured in terms of the
Bar Chart for column: $X_1$ dRES/A

Bar Chart for column: $X_1$ dRES/Ln

Table 6.01
Measurements for residential densities

<table>
<thead>
<tr>
<th>Spot Code</th>
<th>dRES/A</th>
<th>dRES/Ln</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1291.66</td>
<td>80.64</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1390.74</td>
<td>65.74</td>
</tr>
<tr>
<td>4</td>
<td>1390.74</td>
<td>70.37</td>
</tr>
<tr>
<td>5</td>
<td>785.37</td>
<td>43.75</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1419.84</td>
<td>86.46</td>
</tr>
<tr>
<td>8</td>
<td>1616.26</td>
<td>94.85</td>
</tr>
<tr>
<td>9</td>
<td>1616.26</td>
<td>94.85</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>1487.74</td>
<td>72.26</td>
</tr>
<tr>
<td>12</td>
<td>1209.09</td>
<td>74.57</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>1680.49</td>
<td>75.65</td>
</tr>
<tr>
<td>15</td>
<td>1601.89</td>
<td>92.26</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>1601.89</td>
<td>74.57</td>
</tr>
<tr>
<td>18</td>
<td>2021.54</td>
<td>91.24</td>
</tr>
<tr>
<td>19</td>
<td>2529.81</td>
<td>121.82</td>
</tr>
<tr>
<td>20</td>
<td>1533.84</td>
<td>41.29</td>
</tr>
<tr>
<td>21</td>
<td>1954.16</td>
<td>58.36</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>1144.67</td>
<td>81.52</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>1217.51</td>
<td>77.35</td>
</tr>
<tr>
<td>27</td>
<td>1135.80</td>
<td>86.17</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>1305.64</td>
<td>68.28</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>1592.85</td>
<td>102.83</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>1713.60</td>
<td>96.53</td>
</tr>
<tr>
<td>34</td>
<td>1400.48</td>
<td>93.50</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>1406.24</td>
<td>109.02</td>
</tr>
<tr>
<td>37</td>
<td>1805.35</td>
<td>126.08</td>
</tr>
<tr>
<td>38</td>
<td>1239.11</td>
<td>108.63</td>
</tr>
<tr>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>1519.50</td>
<td>101.69</td>
</tr>
</tbody>
</table>
general tendency some exceptions occur which are worth to mention. Fig 6.01 A shows the rank for residential densities per area. The three systems at the top of the rank are SA106, SA128 and SA72. These systems are amongst the most fragmented (and least integrated) systems in the whole sector A. Nevertheless just shortly down in the rank comes SA59 and SB54, which are amongst the most integrated (and least fragmented) systems inside the current sample. These two systems are strongly residential yet rather dense in productive activities as well.

Nevertheless it might be said that in general the systems at the bottom of the residential rank (carrying the lowest residential densities) tend to be the less fragmented systems. SA184 is the exception. Yet this system carries large lumps of short axial lines its high degree of axial fragmentation is coupled with a low residential density. This seems to follow the layout of that area where the housing estates are (Fig 6.02). In this particular case the residential density tends to be lower than the average observed for the most fragmented systems, yet this cannot be taken as a general rule. Other systems that are high in the rank constitute related to each of the residential categories per unit of length. In other words, each axial line inside a system has a density value assigned for each of the residential categories it carries. This density value is given by the ratio between the total number of constitutions related to each residential category and the length of the line. The mean value produced out of these partial densities – that is the ratio between the aggregate of densities and the number of axial lines – is the second proposed measurement (dRES/Ln).

1 The ranks of integration and axial fragmentation are given in Fig. 4.02 (p. 205) and Fig. 4.14 (p. 233) respectively.
2 The ranks for densities of productive activities are given in Fig. 5.01 (p.263).
3 such as SA34, SA69, SA30 and SA60.
4 The morphological character of the 'constitution' criterion adopted in this study in order to measure land use density does not necessarily mirror the demographic densities of the different systems. Although, as it has been shown in chapter two, the measurement of land use by constitutions is strongly associated with floor area measurements. If it is accepted that insofar as residential floor area increases it is likely to happen an increase in the density of inhabitants – which seems to be a fair conjecture – it is also likely that as a whole the increase of residential constitutions in an urban area is followed by an increase in the density of people. It is precisely in this sense that SA184 seems to perform in a distinct way as compared with the bulk of the sample. In this particular system a pattern of slabs or towers is predominant and the low residential density observed in terms of the density of constitutions does not necessarily mean a low demographic density. What it in effect means is that the density of residential constitutions observed for the axial lines inside system is rather low in comparison with the density of residential constitutions observed for the bulk of the sample.
Fig. 6.02 Fragment of SA184: housing estates 'infilled' in the street grid

Fig. 6.03 SA106: A curvilinear pattern
of axial fragmentation - such as SA106 or SA128 - are mostly composed either by houses or blocks of flats located in 'standard' plots along 'standard' streets and for both these cases the residential density will be rather high (Fig 6.01 A). For these cases the curvilinear or 'garden city' oriented layout comes together with a high residential density (Fig 6.03).

The rank of residential densities per number of axial lines will to a large extent confirm and stress the observations made for the rank per area (Fig 6.01 B). Here again the most fragmented systems are the ones with the highest residential densities, while the less fragmented will be at the bottom of the rank. This rank also shows that sector B as a whole is more residential than sector A.\(^1\) Five amongst the seven highest residential densities (as measured per number of axial lines) are systems that belong to sector B while at the bottom of the rank just two SB systems will be amongst the nine lowest residential densities. The 'exceptional' systems - the ones which perform in contrast with the suggested pattern - remain virtually the same when densities are relativised to the number of lines.\(^2\)

When the sample of residential densities is further disaggregated in the four proposed residential categories - houses, blocks or flats, mixed residential and housing estates - some clues on the specific performance of each one of these categories emerge. The rank for densities of houses will confirm to a large extent what has been said in respect of the residential distribution as a whole (dRES/ln) (Fig 6.04 A).\(^3\) This shows clearly that the single family dwelling - referred to as 'house' under the

\(^1\) The residential densities for SB systems are represented in black bars.

\(^2\) SB54 and SA59 are low fragmented systems yet strongly residential while at the bottom of the rank SA184 and SB45 will perform the other way around, i.e. as fragmented systems with a low residential density (same as it happens when residential densities are relativised to the area of the system).

\(^3\) The code dRES/ln stands for residential density per number of axial lines in the same way as the codes dHOU/Ln, dBFL/Ln, dMIX/Ln and dHES/Ln will stand when convenient for density of houses, density of blocks of flats, density of mixed residences and density of housing estates respectively.
Fig. 3.9.4: Ranks for densities of houses and blocks of flats.

Table 6.02: Measurements for densities of houses and blocks of flats

<table>
<thead>
<tr>
<th>Site Code</th>
<th>dHOU/Ln</th>
<th>dBFL/Ln</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>65.27</td>
<td>11.18</td>
</tr>
<tr>
<td>2</td>
<td>48.82</td>
<td>11.51</td>
</tr>
<tr>
<td>3</td>
<td>46.18</td>
<td>8.17</td>
</tr>
<tr>
<td>4</td>
<td>26.86</td>
<td>0.44</td>
</tr>
<tr>
<td>5</td>
<td>65.67</td>
<td>13.57</td>
</tr>
<tr>
<td>6</td>
<td>72.20</td>
<td>11.67</td>
</tr>
<tr>
<td>7</td>
<td>32.63</td>
<td>10.67</td>
</tr>
<tr>
<td>8</td>
<td>55.92</td>
<td>4.65</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>57.77</td>
<td>2.06</td>
</tr>
<tr>
<td>12</td>
<td>47.55</td>
<td>7.03</td>
</tr>
<tr>
<td>13</td>
<td>109.85</td>
<td>4.46</td>
</tr>
<tr>
<td>14</td>
<td>15.86</td>
<td>2.17</td>
</tr>
<tr>
<td>15</td>
<td>42.62</td>
<td>6.16</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>65.52</td>
<td>16.90</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>55.11</td>
<td>10.06</td>
</tr>
<tr>
<td>20</td>
<td>76.45</td>
<td>13.85</td>
</tr>
<tr>
<td>21</td>
<td>109.85</td>
<td>4.46</td>
</tr>
<tr>
<td>22</td>
<td>51.70</td>
<td>9.82</td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>82.40</td>
<td>4.04</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>75.20</td>
<td>0.39</td>
</tr>
<tr>
<td>27</td>
<td>71.52</td>
<td>9.89</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>46.50</td>
<td>1.47</td>
</tr>
<tr>
<td>30</td>
<td>119.63</td>
<td>1.82</td>
</tr>
<tr>
<td>31</td>
<td>35.52</td>
<td>3.06</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>66.76</td>
<td>4.58</td>
</tr>
<tr>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
current morphologically oriented classification - is the predominant residential 'type' inside the current sample. A comparison between the scales of reference on the left side of bar charts A and B - which correspond to the ranks of houses and blocks of flats respectively - provides a clear account on that \( \text{Fig 6.04} \). While the rank of houses develops from 20 up to 120 constitutions per axial line (average per system), for blocks of flats the highest density will be 18.67, that is the density observed for SA21 \( \text{Tab 6.02}) \).\(^1\) Despite the overall agreement between the rank of densities of houses and the rank for the aggregate of residences one exception will also occur here. This is SA128, a system that is high in the aggregate rank yet it is at the bottom of the rank for density of houses. As it has already been said this system is basically composed of housing estates where a pattern of slabs is predominant.

For the blocks of flats the rank of densities is completely changed \( \text{Fig 6.04 B} \). The densities of blocks of flats tend to perform in a totally distinct way as compared with the densities of houses. The less fragmented systems are predominant at the top of the rank as the ones that concentrate the highest densities of blocks of flats, while the most fragmented systems will be at the bottom of the rank. Nevertheless some exceptions occur which show that the increase in the density of blocks of flats for the less fragmented systems is not so clear cut as it has been for the ranks of productive activities (and most especially for shops). In effect systems such as SA30 and SA16 - which are amongst the less fragmented inside the current sample - are not among the systems at the top of the rank of densities of blocks of flats.

What happens in fact is that the highest densities of blocks of flats occur in systems that although they are parts of the more 'griddy' systems (SA west and SB west), they are not the most orthogonal parts of these systems (where tension is the highest). This seems to be the case of SA21, SB62, SB30, SA59, all systems that are high in the rank of

\(^1\) For mixed residential the densities are levelled with blocks of flats, while for housing estates the densities will be lower \( \text{Fig 6.05 A and B} \).
Table 6.03  Measurements for densities of mixed residential buildings and housing estates

<table>
<thead>
<tr>
<th>Unit Code</th>
<th>dHES/Ln</th>
<th>dMIX/Ln</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.18</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>12.30</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>16.00</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>7.36</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>12.25</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>10.60</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>11.55</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>11.65</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>2.11</td>
<td>72.57</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>12.18</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>6.60</td>
<td>3.05</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>4.45</td>
<td>0.00</td>
</tr>
<tr>
<td>18</td>
<td>9.67</td>
<td>0.00</td>
</tr>
<tr>
<td>19</td>
<td>7.51</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1.82</td>
<td>22.24</td>
</tr>
<tr>
<td>21</td>
<td>5.16</td>
<td>4.42</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>5.53</td>
<td>0.34</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>5.99</td>
<td>0.45</td>
</tr>
<tr>
<td>27</td>
<td>4.47</td>
<td>0.00</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>6.04</td>
<td>0.45</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>6.67</td>
<td>0.62</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>12.26</td>
<td>0.00</td>
</tr>
<tr>
<td>34</td>
<td>12.17</td>
<td>0.00</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>5.29</td>
<td>0.75</td>
</tr>
<tr>
<td>37</td>
<td>5.76</td>
<td>0.48</td>
</tr>
<tr>
<td>38</td>
<td>5.28</td>
<td>15.25</td>
</tr>
<tr>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>6.04</td>
<td>5.69</td>
</tr>
</tbody>
</table>

Observations
densities of blocks of flats.¹ In other words, blocks of flats are located in a sort of adjacency in respect of the more regular parts of the grid. They do not concentrate in the more fragmented systems, yet a certain degree of fragmentation seem to play an effective role in their location.

By contrast the rank for the densities of mixed residences - buildings where the residential use is mixed with either shops, offices or industries - will reproduce to a large extent the ranks observed for the productive activities as a whole (Fig 6.05 A). Same as for the ranks of productive activities whose highest densities are observed for the less fragmented systems, the highest densities of mixed residences will occur inside this same set of systems. The more orthogonal parts of sector A - SA30, SA60 and SA16 - and the more orthogonal part of sector B - either SB54 or the same system reduced to SB44 - are the systems that carry the highest densities of mixed residences. It is also noteworthy that inside sector A are both the systems that carry the highest and also the lowest densities of mixed residences. These systems are SA184, SA128 and SA71 which are all amongst the most fragmented systems inside the current sample.

On the other hand the densities of mixed residences will be consistently lower in the sector B. The high density of mixed residences observed for SB54 (and SB44) is an exception. Even for SB systems that are relatively high in the ranks of productive activities - such as SB69 or SB62 - the density of mixed residences will be lower than the ones observed for the SA systems. This shows a marked distinction in respect of what has been observed for the SA systems where the increase in the density of productive activities is followed by an increase in the density of mixed residences.² In other words the high density of productive activities observed in systems such as SA69 and SB62 is made of activities that tend, for most cases, to avoid mixing with the residential use.

¹ See reference map.
² This can be observed by comparing the ranks of densities of productive activities as given in Fig 5.01 (p. 263) with the current rank of mixed residences (Fig 6.05 A).
Unlike what has been observed for the three other residential categories, the rank for the highest densities of housing estates seems to be explicitly oriented towards the most fragmented configurations (Fig 6.05 B). In effect the sample of housing estates is mostly concentrated inside the part of the sample composed of strongly fragmented systems. To put the other way around it might be said that the configuration brought about by the current sample of housing estates tends to be strongly fragmented.1 Exceptions to this rule are the few housing estates located inside SB62 and SB69. Also an exception for this rule, yet following an opposite direction, is the case of SA106 that despite its strong degree of axial fragmentation is mostly composed of houses.2

In what follows residential densities observed above are matched with the proposed 'descriptions of grid configuration' as given by the set of syntactic measurements introduced in chapter four. The match of residential densities and mean integration values has shown consistently - i.e. both for measurements of residential density per unit of area (dRES/A) and also for the mean densities per line (dRES/Ln) - that insofar as the mean RRA value observed for different systems increases the residential density tends to increase as well. In other words residential density tends to increase in the more segregated parts of the grid. By contrast with the density of productive activities - which tends to increase with integration - residential densities (at least in their aggregate form) tend to decrease insofar as the mean integration value of the system increase (decrease of mean RRA).

This applies both when residential densities are matched with RRA values for each system as detached from the surrounding areas (Fig 6.06 A and C) and for the systems as embedded or interacting with the surrounding areas (Fig 6.06 B and D).3 While for the measurement of

1 The five systems at the top of the rank of the densities of housing estates are also at the top of the rank of axial fragmentation as presented in Fig 4.14 (p.237).
2 SA106 is the second highest system in the rank of densities of houses (dHOU/Ln).
3 Normality tests have shown that the distributions observed for the sample of residential densities are rather close to the normal for most cases and as such these measurements will be
Fig. 6.06 Correlation analysis for integration and residential densities

\[ y = 779.352x + 998.725, \text{ R-squared: .108} \]

\[ R_x = 0.329 \]  
\[ (p = 0.0388) \]

\[ y = 923.144x + 904.506, \text{ R-squared: .127} \]

\[ R_x = 0.357 \]  
\[ (p = 0.0679) \]

\[ y = 29.8x + 20.289, \text{ R-squared: .149} \]

\[ R_x = 0.386 \]  
\[ (p = 0.047) \]

\[ y = 59.48x + 47.444, \text{ R-squared: .129} \]

\[ R_x = 0.348 \]  
\[ (p = 0.0735) \]

\[ y = 66.71x + 18.604, \text{ R-squared: .154} \]

\[ R_x = 0.392 \]  
\[ (p = 0.0432) \]

\[ y = 66.54x + 14.421, \text{ R-squared: .128} \]

\[ R_x = 0.392 \]  
\[ (p = 0.0432) \]

\[ y = 756.673x - 548.352, \text{ R-squared: .734} \]

\[ R_x = 0.856 \]  
\[ (p = 0.0003) \]
residential density per area the highest correlation is for RRAemb, for the measurement per line the highest correlation is observed for the RRA values observed for each system as detached. This is distinct from what happens when the densities of productive activities were matched with mean integration values. In that case both for measurements per area and per number of axial lines the correlations are consistently higher for RRA values observed for the different systems as detached, so indicating that variations in the density of productive activities are more effectively associated with the pattern of local integration than with the pattern of integration observed for systems as embedded.1

The output given by the match of residential densities and mean integration values does not allow for a conclusion in respect of which if the two scales - RRA or RRA emb - is more associated with variations of residential density. Nevertheless the variations in the coefficients - from RRA to RRAemb - are much smaller for residential densities than the ones observed when the aggregate of productive activities is matched against RRA measurements.2 It is also noteworthy that for the aggregate of residential uses the correlations are consistently lower than the ones observed for the aggregate of productive activities, so indicating that the pattern of integration is less influential in residential distribution (at least in terms of its aggregate) than it is for the distribution of productive activities.

Apparently the result observed above - that residential densities (at least in their aggregate form) tend to decrease insofar as the mean integration value of the system increases - despite the low coefficients come to provide an example (given by a 'naturally evolved' urban environment) which embodies much of the prescriptions given by modern urbanism on the 'suitable' or 'appropriate' location for residential use in

plotted in their linear form. The only exception is the sample of densities of housing estates (dHES/Ln) that in view of its negative skewness will be plotted after logtransformation.

1 This output is given in Fig 5.03 (p. 266).
2 In that case while the coefficient for dPA/Ln against RRA is -.759, for RRAemb it drops to -.697.
urban areas which, as far as the modern paradigm is concerned, should concentrate in the quieter parts of the city. Nevertheless the measurements that follow, where the current sample of residential densities is further disaggregated will show that this is not the case. The disaggregation of the data will show that each one of the proposed residential categories has a rather distinctive performance which, for most cases will contradict strongly the conjecture made above.¹

For the sample of houses - the first of the residential categories after the disaggregation of the residential data - the results are still in tune with the results given by the aggregate of residences, as presented above. The coefficient will even improve slightly when the category of 'houses' is measured separately showing that the density of houses tend to increase in the more segregated parts of the grid as well (Fig 6.06 E). In this case the highest coefficient observed for houses will follow the tendency observed for dRES/Ln, i.e. the highest correlation is observed when the different systems are measured as detached from the surrounding areas (RRA). Nevertheless, it will be precisely in relation to the global scale that an interesting phenomenon takes place in a more explicit form. Fig 6.06 F shows that the systems with the highest mean RRA values, as embedded, tend to perform in a distinctive way as compared with the overall distribution of points in the scattergram. These systems - as the strong relationship between RRA and axial fragmentation has shown - tend to be the most fragmented inside the current sample. If these systems are measured in separate, i.e. as a separate sample, the relationship between the density of houses and RRA as embedded will go as high as .856 (p=.0003) (Fig 6.06 G).

This suggests that inside this particular part of the sample - where axial fragmentation is dominant - the density of houses will follow strongly the increase of RRA or, in other words, the increase of segregation.² This does not mean necessarily that the density of houses

¹ on the association between the current sample of residential densities and segregation.
² SA71, that is the system with the highest RRAemb value of all sample, is not computed in this test.
is higher in the most fragmented systems. In effect what the scattergram suggests in this respect seems to be the opposite. Strongly fragmented systems such as SA128 and SA184 are lower in the rank of dHOU/Ln than less fragmented systems such as SB45 and SB127.\(^1\) It is noteworthy that the distribution of this particular set of points will be much more scattered when RRA values are plotted against dHOU/Ln (scat E) instead of the RRA values as embedded (scat F) so indicating that the global scale of the street grid, as depicted by RRA emb values, will be more effectively associated with the densities of houses in this particular part of the sample.\(^2\) For the part of the sample that is composed of more griddy or less fragmented systems the correlation between dHOU/Ln and RRAemb drops to \(R = .555\) (\(p = .0489\)).

These results seem to suggest that the effects of RRA upon the density of houses will be more effective from a certain degree of segregation onwards. The result given by Fig 6.06 G seems to be rather significant. It alternates systems from both sector A and sector B. The correlation cannot be taken as produced by lower densities of houses observed in systems more recently developed. This is not the case. Systems at the top right of the scattergram - such as SA106 and SB96 where the density of houses is outstandingly high - are urban areas whose development took place later than systems such as SB45, SA128 and SA72. That is to say, the correlation cannot be taken as biased by distinct degrees of consolidation of the different systems since the density of houses - as verified - is not at least inside the current sample related to the age of the development.\(^3\)

For the category of 'blocks of flats' - as disaggregated from the sample of residential densities - the performance against the measurements of integration seems to work the other way around if compared with the

---

\(^{1}\) SA128 and SA184 are both the two highest densities of housing estates of all sample and the systems at the top in the rank of axial fragmentation.

\(^{2}\) The correlation for dHOU/Ln against RRA for this same set of points will be \(R = .578\) \(p = .0385\).

\(^{3}\) SA106 and SB96 are districts whose development took place in the late forties, while SA128 and SB45 were developed in the twenties and SA72 in the thirties.
Fig. 6.07 Correlation analysis for integration and residential densities

\[ y = 72.738x - 24.911, \text{ R-squared: } .658 \]

\[ y = -16.855x + 19.433, \text{ R-squared: } .641 \]

\[ y = -20.623x + 23.335, \text{ R-squared: } .314 \]

\[ y = 2.620x - 36, \text{ R-squared: } .101 \]

\[ y = 1.842x - 810, \text{ R-squared: } .001 \]
performance of 'houses' as observed above. The coefficients will change
direction so indicating that the densities of blocks of flats tend to
increase in so far as the mean RRA values of the different systems
increase (Fig 6.07 A and B). Both coefficients will be higher than the
ones observed for the sample of houses; especially for RRA emb (R=-.560
p=.0024). This output suggests that the mean integration values observed
when the system is measured as embedded - taking into account the
effects coming from the global scale - are more associated with the
variation in the density of blocks of flats than the local effects given by
the local RRA of each system as detached. Here again, following what
was observed for the sample of 'houses', one particular set of systems
will perform in a distinctive way as compared with the distribution of
points observed for the bulk of the sample. These systems are
represented by the black dots at left in Fig 6.07 B.

By contrast with the performance of the sample of houses where a
particular part of the sample overstates the general tendency observed
in the distribution of points (Fig 6.06 F), in the case of the blocks of
flats the part of the sample mentioned above performs in opposite
direction as compared with the tendency observed for the bulk of the
sample (Fig. 6.07 B). Besides while in the case of houses the 'outlying'
set is composed of the most segregated systems, in the case of the
blocks of flats the outlying set is composed of the most integrated
systems of all sample.

In other words while in terms of the sample as a whole it can be said
that the density of blocks of flats tends to increase in so far as
integration increases, for the particular part of the sample that is
represented in scat C the density of blocks of flats will be higher in the
more segregated parts of the grid (Fig 6.07). This 'particular part of the
sample' is mostly composed of SA143 and its decompositions.1 This
result seems to be somewhat in tune with what was observed earlier in
the rank of densities of blocks of flats (Fig 6.04 B). The density of

---
1 SB62 is the only exception.
blocks of flats tends to increase in a sort of adjacency in relation to the more integrated parts of the grid and yet the densities of blocks of flats are hardly significant in the most segregated systems, a certain degree of segregation seems to be a requirement for their location.

The performance of the densities of mixed residences in relation to the pattern of integration will be very much in tune with what was observed for the productive activities as a whole. The coefficients are higher than the ones observed for the other residential categories and approximate the high standard observed for the correlations between RRA and the densities of productive activities.\(^1\) The direction of the correlation is the same as well so indicating that the density of mixed residences will increase strongly in the more integrated parts of the grid. Just as it has happened for the productive activities the coefficient is marginally higher for RRA than it is for RRA emb. The difference between the two coefficients is marginal so allowing for the conjecture that both local effects and also the effects coming from the global scale are influential in the concentration of mixed residences yet the local scale might have a slight predominance \((\text{Fig. 6.07 D and E}).\)\(^2\)

Finally the rank of integration measurements was plotted against the sample of densities of housing estates. For this category the output is rather ambiguous. \textbf{Fig 6.07 F and G} show that the density of housing estates tends to increase in the more segregated parts of the grid. Nevertheless not only the probabilities of both correlations are low but the distribution of points in the scattergrams is rather ambiguous, especially for measurements of each system as embedded (RRAemb). The systems that carry both the lowest and the highest densities of housing estates tend to bias strongly the correlation bringing about the positive direction. In effect for the bulk of the distribution where the density of housing estates increases consistently (black dots in the scattergram) the correlation has a distinct direction, it becomes negative and

\(^1\) The coefficient between the densities of productive activities (in aggregate) and RRA is \(-.759 (p=.0001)\). This result is presented in \textbf{Fig. 5.03} (p. 266).

\(^2\) The same can be said about the densities of productive activities.
indicates the opposite of what is recommended by the general tendency observed.

For this part of the sample - which seems to be the most representative since it includes the systems that are more strongly 'loaded' with housing estates - the density of estates will increase in so far as the integration values observed for the different systems increases (decrease in RRA). The coefficient as measured for this particular part of the sample is -.873 (p=.0021). It is noteworthy that such a tendency is more evident for RRA embedded values so indicating the role of syntactic effects coming from the global scale in the increase of the density of housing estates. For local RRA values the distribution of points is more scattered and yet the change in direction in the correlation as described above can also be noticed for a particular set of points it will be much less evident than for RRA values as embedded.

This result is in a first look controversial since it contradicts the generally accepted notion that housing estates tend to occupy the more segregated parts of urban areas, or at least, that the spatial configuration of the housing estates tend to give rise to a pattern of spatial segregation. This is not what the results produced out of the analysis of the current sample have suggested. In effect the syntactic analysis, as proceeded during chapter three, has already shown that in systems such as SA184 and SB45 the lumps of housing estates tend to be consistently connected to the respective global integration cores. This also happens to a large extent in the cases of SA128 and SA71. All these systems are high in the rank of axial fragmentation yet relatively well positioned in the rank of integration. Although this result cannot be taken as a standard for the performance of housing estates in general, it at least indicates that the association between the location of housing

\[1\] SA71 is the system with the highest mean RRAemb value of all sample and its density of housing estates is much lower that the one observed for the systems included in the current test.

\[2\] These ranks are in Fig. 4.02 (p.205) and Fig. 4.14 (p.233) for integration and axial fragmentation respectively.
estates and patterns of segregation cannot be taken for granted as a general rule. On the contrary the performance of the current sample of housing estates has shown that both cases can happen. Despite the general tendency according to which the density of housing estates increases with segregation, for a significant part of the sample integration comes to play a decisive role and for this particular part of the sample in so far as the pattern of integration gets stronger the density of housing estates increases as well.

In the following step of this analysis the proposed measurements of residential density are matched with the syntactic intelligibility of the different systems.\(^1\) The relationship between the intelligibility of the different systems and the current sample of residential densities - in its aggregate form - will consistently happen in an opposite direction as compared with the relationship between productive activities and intelligibility as analysed during the previous chapter. In that case it has been observed a consistent increase in the density of productive activities in so far as the intelligibility of the different systems increases. Following an opposite tendency, the residential densities observed for the current sample will increase consistently in so far as the intelligibility of the systems decreases. In other words in the more intelligible systems the residential density will be in probabilistic terms lower than in the less intelligible systems.

This pattern is observed both for measurements per area and per number of axial lines as well, yet the measurements per area will produce the highest coefficients. It is noteworthy that the coefficient observed for global intelligibility (intelligibility values calculated on the basis of RRA values for each system as embedded) will give the highest

\(^{1}\) This section will not deal with the relationships between residential densities and the mean choice values observed for the different systems. This follows the observation that, same as it has been noticed for the densities of productive activities, the different measurements of residential density are virtually uncorrelated with mean choice values.
Correlation analysis for intelligibility and residential densities

(A) $r = -0.251$ ($p = 0.0279$)

(B) $r = -0.644$ ($p = 0.0006$)

(C) $r = 0.05$ ($p = 0.6948$)

(D) $r = -0.454$ ($p = 0.0226$)

(E) $r = -0.454$ ($p = 0.0226$)

(F) $r = 0.839$ ($p = 0.0007$)
coefficient; $R = -0.641$ ($p = 0.0004$) (Fig 6.08 B). These observations follow to a large extent what has been observed for the relationship between residential densities and integration. As it has been shown previously, residential densities - in their aggregate form - tend to increase in the more segregated parts of the grid, in the same way as these same residential densities will decrease in the more intelligible parts of the grid. This follows the strong association - already discussed during chapter four - between integration and intelligibility.

The fact that the correlation is outstandingly higher for global intelligibility values makes a distinction in relation to what was observed for integration, where local and global values have produced rather similar coefficients. That is to say from the standpoint of the intelligibility of the different systems the variations of residential density as described above are strongly affected by syntactic effects coming from the global scale. In other words residential densities tend to decrease in so far as the intelligibility of each system, measured as interacting with its surroundings, increases. These results, as a consequence, seem to reassert the local character of residential densities which, from the standpoint of the intelligibility of the system, tend to be higher the lower is the degree of interaction of the different systems within their larger surroundings.

When the sample of residential densities is further disaggregated the correlations between intelligibility and the sample of houses will decrease in comparison with the coefficient observed for the aggregate of residential densities, yet some interesting results will emerge. Fig 6.08 C indicates that densities of houses and local intelligibility values are virtually uncorrelated. Nevertheless when the same sample of densities of houses is plotted against global intelligibility values - based upon RRAemb measurements - the correlation increases and assume a negative direction, so indicating that the density of houses

---

1 If the measurements are plotted per number of axial lines instead of per area the coefficients will be lower both for local intelligibility ($-0.118$) and also for global intelligibility ($-0.307$).
decreases with the increase of intelligibility (Fig 6.08 D). Despite the relatively high coefficient the distribution of points in the scattergram is quite dispersed and the probability of such a correlation will be rather low. Nevertheless a closer scrutiny of this scattergram will show that for a particular set of systems - the systems at the top of the rank of intelligibility - the direction of the correlation is virtually the opposite in relation to the general tendency observed in the scattergram.

For this particular set of points (systems whose intelligibility value goes beyond .65) it will be observed an increase in residential density in so far as intelligibility increases. These areas are, for most cases, part of the so called most griddy or less fragmented systems (Fig 6.08 E). Amongst these systems are also the ones where the density of houses are the lowest inside the current sample. If these systems are plotted as a separate sample the density of houses will increase following strongly the increase of global intelligibility. The coefficient is .839 (p=.0007) and indicates that within this particular set of systems the increase of global intelligibility goes hand in hand with the increase in the density of houses. If this result is matched with what was observed for the same set of systems (intelligibilities beyond .65) in respect of the densities of productive activities it becomes clear the mixed character of these areas. That is to say for the set of more intelligible systems both the density of houses and the density of productive activities will increase consistently with the increase of global intelligibility.

In respect of the densities of blocks of flats and its relationship with the intelligibility of the different systems the current sample seems to perform more consistently as a whole set (Fig 6.09 A and B). The distinct performance of a particular sets of systems (as it has been

1 SA184 is an exception. This system despite its high degree of fragmentation is relatively high in the rank of intelligibility.
2 It is noticeable that for these same systems the correlation between the densities of houses and integration will be much lower (R=.555  p=.0499) and the distribution of points more dispersed. This can be observed in the set of more integrated points in Fig 6.06 F.
3 The match of densities of productive activities (in aggregate) against global intelligibility values is presented in Fig 5.06 (p. 270).
Correlation analysis for intelligibility and residential densities

A. $R = 0.475$
   $p = 0.0422$

B. $R = 0.507$
   $p = 0.0052$

C. $R = 0.539$
   $p = 0.0044$

D. $R = 0.396$
   $p = 0.0452$

E. $R = -0.640$
   $p = 0.0206$

F. $R = -0.608$
   $p = 0.0242$

G. $R = -0.24$
   $p = 0.4304$
noticed for the more intelligible set inside the sample of densities of houses) can hardly be identified here. The correlation for local intelligibility is .475 (p=.0122) and indicates that densities of blocks of flats tend to increase consistently in so far as intelligibility increases (Fig 6.09 A). The correlation goes even higher for global intelligibility so pointing out clearly the role of the global scale in the performance of blocks of flats or, more specifically, in the way blocks of flats tend to distribute themselves throughout the street grid (Fig 6.09 B). The distribution of points also shows that the particular group of more integrated systems where it has been identified a strong relationship between segregation and the densities of blocks of flats can hardly be noticed here. In effect for the sample as a whole the measurement of global intelligibility performs as a steady parameter showing that the densities of blocks of flats will increase consistently in the more intelligible parts of the grid. This includes the systems where blocks of flats tend to segregate themselves so showing that the distinct character of that particular set of more integrated systems in relation to the variations in the density of blocks of flats is not captured by measurements of intelligibility, but just from the standpoint of integration.

For the sample of mixed residential densities the association with intelligibility becomes still more clear cut. The increase of intelligibility is consistently followed by an increase in the density of mixed residences (Fig 6.09 C and D). This result is very much in tune with was observed in respect of the relationship between intelligibility and the density of productive activities. Here same as there the strongest correlation is given by local intelligibility; $R = .534$ (p=.0041) (Fig 6.09 C). For global intelligibility the correlation drops to .396 (p=.0452) (Fig 6.09 D). This output was already expected for the

---

1 For the set of systems referred to here - the eight most integrated systems - it has been identified a strong relationship between the density of blocks of flats and segregation. This result is presented in Fig 6.07 B and C.

2 The correlation between the density of productive activities and local intelligibility is .592, while for global intelligibility the coefficient drops to .356. These results are presented in Fig 5.06 B and G (p. 270).
sample of mixed buildings is ultimately a part of the sample of productive activities - the part of the sample where productive activities are mixed with the residential use inside the same building. At any rate this result comes to reassert the conjecture that the intelligibility of each system on its own - independently of its relationship with the surrounding areas - is more effective than global intelligibility in the performance of the densities of productive activities, as given in the current case by the densities of mixed residences.

This output seems to contradict what intuition suggests, i.e. that both mixed residences and productive activities as a whole should be more correlated with the global intelligibility of the street grid than with local intelligibility. Nevertheless it must not be forgotten that the density values utilized for the current tests are mean density values where all axial lines inside each system are computed. As a consequence the possible effects coming from productive activities that are located along globally integrated routes - which would favour global intelligibility values - will eventually be minimized inside the more general tendency observed, that is precisely the tendency given by mean density values. And what the general tendency observed suggests is the predominant role of the local scale both in the performance of the density values observed for mixed residences and for the densities of productive activities as well.

Another aspect of the output discussed above that seems to contradict intuition is that while the densities of mixed residences (and productive activities as a whole) are more strongly correlated with local intelligibility, the more 'pure' residential categories - both houses and blocks of flats - are more strongly correlated with intelligibility measurements taken at the global scale. Nevertheless this same set of results can be taken from another standpoint so allowing for a conjecture on the combined performance of residential uses and productive activities. It is conjectured here, based upon the global
character assumed by residential densities coupled with the local character assumed by the densities of productive activities, that the residential pattern - either given by densities of houses or by densities of blocks of flats - tend to perform as a globally oriented background, in relation to which the pattern of productive activities (and mixed residences) will be more locally distributed, according to 'areas of syntactic reference' which are precisely 'demarcated' throughout the street grid. The distinct performances of local and global intelligibility for productive activities and residential uses seem to provide at least reasonable grounds for the conjecture above.

Finally, as a last step in the analysis of the relationships between intelligibility and residential densities, the sample of housing estates is matched with local and global intelligibility values. In this case, despite the similarity in the coefficients observed for local and global intelligibility values the distribution of points in both scattergrams suggests that global intelligibility is more consistently associated with the variations in the density of housing estates. While for local intelligibility the plot is more dispersed, for global intelligibility values the distribution is consistently more homogeneous (Fig 6.09 E and F). Both tests suggest that the density of housing estates will increase in so far as the intelligibility observed for the different systems decreases. In other words the less intelligible systems will concentrate the highest densities of housing estates.

It is noteworthy that the performance of the densities of housing estates was rather ambiguously described in relation to the patterns of integration (Fig 6.07 F and G). In that case a significant part of the sample - the systems carrying the highest densities of housing estates - have shown that the increase of integration is paralleled by the increase in the density of housing estates, despite the fact that for the sample as a whole the opposite is observed.¹ In respect of intelligibility the

¹ Yet in this case both the coefficient and the probability of the correlation are rather low (R = .225 p = .4383) (Fig 6.07 G).
performance of the densities of housing estates seems to be more clear cut. Most systems are rather close and homogeneously distributed indicating that for the sample as a whole the increase in intelligibility is consistently followed by a decrease in the density of housing estates.1 Nevertheless it is worth to mention that two particular systems that carry two amongst the three highest densities of housing estates of all sample - SA184 and SB45 - are strong outliers in the correlation (Fig 6.09 F). These systems couple high intelligibility values with high densities of housing estates.2 These results show - through the performance of the densities of housing estates - the distinct character of the measurements of intelligibility and integration. The increase in the density of housing estates follows simultaneously the decrease of intelligibility and the increase of integration. This output is to some extent in tune with the combined performance of intelligibility and integration for this particular part of the sample that is restricted to the systems that carry housing estates. For this particular set of systems the correlation between intelligibility and integration will decrease sharply in comparison with the 'all systems' measurement presented in chapter four.3 The coefficient between intelligibility and integration (both globally measured) for the current set of systems decreases to -.24 (p=.4306) (Fig 6.09 G).

In the subsequent step the sample of residential densities is matched with the measurements of axial fragmentation and tension. It is conjectured that the performance of the residential densities in relation to these configurational parameters should follow what has been observed for the relationship between the distinct residential categories

---

1 This result becomes more significant if it is taken into account that only the systems that carry housing estates are computed for the test. That is to say the fact that the most intelligible systems in the sample do not carry housing estates at all is not taken into account.

2 The outlying of SB96 is less significant for the rather low density of housing estates in that system.

3 For 'all systems' the correlation between integration and intelligibility (both measurements for the systems as embedded) is -.416 (p=.0608). This result is presented in Fig 4.12 B (p. 228).
Correlation analysis for axial fragmentation, tension and residential densities

(A) $R = 0.592$  
($p = 0.0041$)

(B) $R = -0.426$  
($p = 0.0258$)

(C) $R = 0.465$  
($p = 0.0096$)

(D) $R = -0.228$  
($p = 0.2526$)

(E) $R = -0.004$  
($p = 0.9894$)

(F) $R = -0.422$  
($p = 0.5942$)

(G) $R = 0.663$  
($p = 0.0045$)

(H) $R = -0.742$  
($p = 0.0089$)
and the measurements of integration and intelligibility. Nevertheless it is precisely in the performance of systems that contradict this more general tendency that the particular character of each of the proposed syntactic measurements is highlighted, i.e. systems that are strongly fragmented yet integrated at the same time, systems that despite the low average length of the axial lines are relatively high in the rank of intelligibility and so on. The performance of these ‘irregularities’ has provided interesting descriptions in the context of the current discussion.

The comparison of the aggregate of residences and the observed measurements of axial fragmentation shows a positive correlation between the two measurements. The coefficient is .592 (p=.0011) (Fig 6.10 A). This correlation is strongly affected by the performance of SA184. This system is represented by the black dot that ‘outlies’ below in the right side of the scattergram. SA184 has a low residential density, despite its high degree of axial fragmentation. If this system is not computed the correlation goes higher to .722 (p=.0001) so stressing that in so far as axial fragmentation increases residential densities will increase as well. As expected, the opposite happens in respect of the measurement of tension as given by the average length of the axial lines inside each system. The coefficient in this case will be lower (R= -.428 p=.0258) yet it confirms, the other way around, what has been observed in respect of axial fragmentation (Fig 6.10 B). That is to say the increase of tension is consistently followed by a decrease in the residential densities.2

---

1 This is consequent to the, already discussed, consistent relationship observed between the measurements of integration and intelligibility with both axial fragmentation and tension. These four measurements are strongly related. While the increase of axial fragmentation tends to bring about a consistent decrease in intelligibility and integration as well, the increase of tension will affect positively both these measurements. These results are presented in Figs 4.15 to 4.17 (p. 235, 237 and 240).

2 If SA184 is deleted from the plot of residential densities against tension the coefficient will increase to -.54 (p=.0044)).
The results observed above are confirmed when the residential densities are relativised to the number of axial lines of each system \((d_{RES}/Ln)\) \((\text{Fig 6.10 C and D})\). The correlations are apparently much lower in this case, although here again the performance of particular systems, which contradict the more general tendency observed in the scattergram is responsible for the lower correlations. The distribution of points shows that the most fragmented systems (measurements beyond 2.1) will perform quite distinctively as compared with the bulk of the sample \((\text{scat C})\). Here again SA184 and SA128 are the outliers. If these strongly fragmented systems are not computed the coefficient will increase to \(0.594 (p=0.0047)\). The same happens in respect of tension. In this case if the systems with the lowest average length are not computed the correlation will increase to \(-0.436 (p=0.026)\). At any rate the distribution of points in this set of scattergrams \((\text{scats C and D})\) confirms what the measurements of residential densities per area have suggested.

The correlations observed above are, as a whole, lower and in opposite direction in relation to the ones observed when both axial fragmentation and tension are matched against the densities of productive activities and its different categories as disaggregated.\(^1\) These opposed performances allow for the conjecture that the effects of fragmentation are more strongly felt in the performance of productive activities than in the residential use. Besides if on the one hand fragmentation brings about a decrease in the densities of productive activities on the other hand it will be consistently associated with the increase of residential densities. The results observed above have also shown that the measurements of axial fragmentation and tension have provided the most effective descriptions (the highest coefficients) for the performance of the densities of productive activities, while in the case of residential densities the descriptions given by the measurements of integration and intelligibility will provide the strongest associations.

\(^1\) In that case, as an example, the coefficient between the mean densities of productive activities per line \((d_{PA}/Ln)\) and axial fragmentation is \(-0.794 (p=0.001)\), while for tension it has increased to \(0.908 (p=0.0001)\).
When the sample of residential densities is disaggregated the performance of the densities of houses seems to be virtually uncorrelated with both axial fragmentation and tension (Fig 6.10 E and F). Nevertheless the distribution of points in the scat E (axial fragmentation plotted against houses) allows for the conjecture that the most fragmented systems tend to perform in a rather distinct way, and in opposite direction, in relation to the less fragmented part of the sample. If the less fragmented systems are plotted as a separate sample the correlation against the densities of houses will increase remarkably assuming a positive direction. The correlation goes as high as .663 (p=.0015) showing that inside the part of sample that contain the less fragmented systems the densities of houses will increase consistently in so far as axial fragmentation increases (Fig 6.10 G). In other words, inside those so called more griddy systems the highest residential densities will happen where the orthogonal pattern becomes more fragmented. Some examples can illustrate this point. SB30 is more fragmented than SB62 (both these systems are second order decompositions of SB89) and the density of houses is higher there as well (Fig 6.04 A).1 SA59 is more fragmented than SA21, and the density of houses will also be significantly higher in the latter (both systems are second order decompositions of SA77).

If the more fragmented systems, inside the sample of densities of houses, are plotted as a separated sample - the set of systems at left in Fig 6.10 E - the direction of the correlation is explicitly inverted and the coefficient will go even higher to -.742 (p=.0089)(Fig 6.10 H).2 This indicates that as soon as the configuration of the system goes beyond a certain degree of axial fragmentation the density of houses will consistently drop towards the more fragmented part of the sample. The explanation for that seems to be straightforward. The predominant

1 The rank of axial fragmentation is presented in Fig 4.14 A (p.233).
2 The four systems right at the middle in the rank of axial fragmentation (Fig 6.10 E), i.e. systems that are neither amongst the most fragmented nor amongst the less fragmented, are included in both scattergrams (Fig 6.10 G and H).
residential pattern inside the most fragmented systems - such as SA184, SA128 and SA71 - in given by housing estates and insofar as the density of housing estates increases the density of houses will decrease. This explains the outlying of SA106 in Fig 6.10 H. This system is an exception to the model conjectured above. Despite its high degree of axial fragmentation - SA106 is the third most fragmented system in all sample - this system is basically composed either by detached or terraced houses.

It is noteworthy that this distinct performance, as noticed when the sample of densities of houses is matched against axial fragmentation measurements, is not described when these same densities are matched against either integration or intelligibility values. The measurement of tension is not effective in detecting this distinct performance observed for the sample of densities of houses either. As matched against the measurements of tension, as given by the average length of the axial lines inside each system, the sample of densities of houses will show a rather even performance which indicates consistently that the higher the average length of the axial lines the lower will be the densities of houses. In this case the coefficient as measured for all systems is low (R=-.122 p=.5442) (Fig 6.10 F). Nevertheless systems such as SA128 and SA184 where the density of houses, as already explained, drops strongly work very much against the correlation. If these two systems are not computed the coefficient will go as high as -.58 (p=.0024).¹

For the remaining residential categories - blocks of flats, mixed residences and housing estates - the performance in relation to the measurements of axial fragmentation and tension will be very much in tune with the results observed for integration and intelligibility. For the sample of blocks of flats the coefficients, more than confirming the results observed when this same sample is matched against integration and intelligibility, will be consistently higher. For axial fragmentation

¹ These two systems are represented in the black dots below at left in Fig 6.10 F.
Correlation analysis for axial fragmentation, tension and residential densities
the coefficient is -.648 (p=.0003), while for tension it drops marginally to .618 (p=.0006) (Fig 6.11 A and B). In other words blocks of flats tend to occupy the less fragmented parts of the grid which are, at the same time, the ones where tension increases consistently.

The distinct performance observed for a part of the sample of blocks of flats - the set of eight most integrated systems - in the plot against integration is less noticed when this same set of systems is plotted against axial fragmentation and tension. Nevertheless both these tests will show a more scattered distribution of points both when axial fragmentation approaches its lower limit and when tension approaches its upper limit (Fig 6.11 A and B). For this particular set of more dispersed points the measurements of integration and axial fragmentation are strongly correlated so suggesting that the distinctive performance described above can also be identified from the standpoint of the axial fragmentation observed for this particular set of systems.

These combined results seem to provide a further evidence, this time from the standpoint of axial fragmentation, in support of the hypothesis previously raised on the distinctive performance of the densities of blocks of flats in the more griddy part of the sample.

For mixed residences the performance of axial fragmentation and tension will strictly follow what the plotting against integration and intelligibility have already suggested. The density of mixed residences will decrease consistently in so far as axial fragmentation increases (R= -.663 p=.0002) and will increase still more consistently (R=.798 p=.0001) following the increase of tension (Fig 6.11 C and D). Here again the coefficients are consistently higher than the ones observed for integration and intelligibility, when these two measurements were plotted against the sample of mixed residences. In effect the standard

1 The distinct performance referred to here has allowed for the hypothesis that the density of blocks of flats tend to increase in a sort of adjacency in relation to the more integrated parts of the grid and yet blocks of flats are hardly concentrated in the most segregated systems, a certain degree of segregation seems to be a requirement for their location.

2 The coefficients are R= .691 (p=.0047) for RRA and R= .789 (p=.0023) for RRAemb.
of the correlations observed here is very much in tune with the ones observed when the measurements of axial fragmentation and tension were matched with the sample of productive activities in the previous chapter.¹

Finally, the measurements of axial fragmentation and tension were compared with the sample of densities of housing estates. Here the results follow what has been observed when the sample of housing estates was matched with measurements of intelligibility. The distribution of points in the scattergram is rather homogeneous and that distinct performance of part of the sample - as noticed in the plotting of the densities of housing estates against integration values (Fig 6.07 G) can hardly be noticed here. **Fig 6.11 E and F** shows that for the current case just two systems will perform as outliers. These are SB96, which has a rather low density of housing estates despite its relatively high degree of axial fragmentation, and SB45 that outlies for the opposite reason.

Despite these outliers the coefficients are rather high both for axial fragmentation (R=.806 p=.0005) and for tension (R=-.746 p=.0022) (**Fig 6.11 E and F**). These figures indicate that the density of housing estates tends to increase consistently in so far as the degree of axial fragmentation increases. This result seems to confirm the conjecture raised previously on the performance of the sample of houses against these same measurements of axial fragmentation, when it was noticed that for the most fragmented systems the density of houses tends to decrease. It was then conjectured that the decrease in the density of houses was associated with a strong increase in the density of housing estates inside the part of the sample where axial fragmentation is stronger. This is precisely what **Fig 6.11 E** indicates. Yet the coefficient observed for tension is marginally lower it also confirms the hypothesis raised above.

---

¹ These results are given in **Fig 5.07** (p.272).
Correlation analysis for ringyness and residential densities

(A) $R = -0.262 \ (p = 0.187)$

(B) $R = -0.264 \ (p = 0.164)$

(C) $R = 0.377 \ (p = 0.053)$

(D) $R = 0.716 \ (p = 0.000)$

(E) $R = -0.392 \ (p = 0.234)$
In the next step the sample of residential densities is matched with the measurements of ringyness observed for the different systems. The set of scattergrams showed in Fig 6.12 shows that the performance of the different residential categories in relation to the pattern ringyness is quite similar to what has been observed above when the range of residential categories were plotted against the measurements of tension. Although the set of syntactic measurements proposed for this part of the analysis is to a large extent interrelated, as the analysis carried out during chapter five has shown, it is precisely from the specific description provided by each measurement that the identification of the peculiarities of the different urban systems has emerged. In other words, despite the fact that ringyness is well correlated with integration, intelligibility (to a lesser extent) and also with axial fragmentation, it is particularly well correlated with the measurement of tension - as given by the average length of the axial lines. As a consequence the similarity between the results observed for ringyness and tension, in terms of the relationships with the different residential categories was already expected.

Nevertheless despite their similar performance the correlations for ringyness will be consistently lower than the coefficients observed for tension so indicating that the effects of ringyness upon the variations of residential density are felt to a lesser extent than the effects coming from the different degrees of tension observed throughout the grid. At any rate the coefficients confirm that the increase of ringyness will be associated with the decrease of residential densities in their aggregate form (Fig 6.12 A). When the residential data is disaggregated the results show that the increase of ringyness will be associated with a

---

1 The correlation between ringyness and tension is .786 (p = .0001) despite the outlying of SA106 and SA128. This result is presented in Fig 4.19 E (p.246). The outlying of SA106 and SA128, in this specific case, provides a fair example on the 'peculiarities' of each system referred to above. Despite the strong relationship between tension and ringyness observed for the sample as a whole, in the case of these two systems the two measurements will disagree entirely. Despite the low average length of the axial lines inside both these systems, they are both rather high in the rank of ringyness.
decrease in the densities of houses and housing estates and, on the other hand, with an increase in the densities of blocks of flats and mixed residences (Fig 6.12).

The plot of ringyness against the densities of blocks of flats shows a distinct performance for a particular set of systems - the most ringy systems.¹ The density of blocks of flats in this part of the sample is lower than expected from the high degree of ringyness observed in this particular set of systems (Fig 6.12 C). The distinct performance of this same part of the sample, in terms of the observed densities of blocks of flats, has already been noticed in the plotting against integration values as embedded (Fig 6.07 C) and to some extent in the plot against axial fragmentation (Fig 6.11 A). The outlying of this same set of systems in the plot of blocks of flats against the measurements of ringyness provides another version for the same phenomenon. For the systems at the top in the rank of ringyness the density of blocks of flats will drop in the same way as it dropped for the most integrated systems. As it has been already explained, in the case of integration the direction of the correlation is literally inverted for this particular set of systems. For the plot of the densities of blocks of flats against ringyness the direction of the correlation is still preserved for these more ringy systems, yet the density of blocks of flats will be much lower as compared with the tendency observed for the bulk of the sample.

Finally it is noticed here again, same as for the previous syntactic measurements, that the correlations observed for ringyness against any of the residential categories are consistently lower than the coefficients observed between these same measurements of ringyness and the densities of productive activities as a whole.² This seems to indicate that the character of ringyness of the different systems is more

¹ This distinct performance is not described in the plotting of the same densities of blocks of flats against the measurements of tension.
² The high correlation observed between the densities of mixed residences and the measurements of ringyness is, as expected, the only exception. An exception that embodies the strong correlations observed between syntactic measurements and the densities of productive activities.
Fig. 6.13 Correlation analysis for connectivity and density of intersections against residential densities

(A) \( R = -0.266 \)  
\( p = 0.04798 \)

(B) \( R = 0.632 \)  
\( p = 0.0004 \)

(C) \( R = -0.318 \)  
\( p = 0.0057 \)

(D) \( R = 0.073 \)  
\( p = 0.7234 \)

(E) \( R = -0.279 \)  
\( p = 0.4589 \)

(F) \( R = -0.47 \)  
\( p = 0.3974 \)

(G) \( R = 0.46 \)  
\( p = 0.0456 \)

(H) \( R = -0.589 \)  
\( p = 0.0042 \)

(I) \( R = -0.510 \)  
\( p = 0.0163 \)
influential on the performance of the densities of productive activities than it counts in the performance of the residential use.

In the next step the sample of residential densities will be matched with measurements of connectivity. This procedure will allow for another comparison - this time from the standpoint of residential densities - between the two ways of describing connectivity proposed for the current research, the first by means of mean connectivity observed for the different systems (relativised to the number of axial lines) and the second by means of the density of connections or intersections (relativised to the area of the different systems).

When the aggregate of residential densities per unit of area is plotted against the measurements of connectivity the output indicates that the increases in connectivity observed for the different systems tend to be followed by a decrease in residential density (Fig 6.13 A). This output despite the lower correlation follows, to a large extent, what has been observed for the previous syntactic measurements. Different from that, when the sample of residential densities is plotted against measurements of density of intersections per unit of area the direction of the correlation is inverted and the coefficient goes as high as .632 (p=.0004) (Fig 6.13 B). As opposed to what was observed for connectivity this correlation says that the increase of residential densities will follow the increase in the density of intersections observed for the different systems. Nevertheless despite the high coefficient and the high probability of the correlation, the scattergram shows that the relatively strong skewness noticed for the distribution of densities of intersections, still remains after the logtransformation of the sample. Most points will still remain close to the origin in the scattergram. If the systems at the top of the distribution are not computed the coefficient will just drop to .527 but the probability of the correlation will be strongly affected (p=.0142) so suggesting that, in
view of the distribution constraints noticed for the sample as a whole, the output presented above must be at least taken with precaution.

When the measurement of connectivity is plotted against the sample of residential densities per number of axial lines - instead of per unit of area - the correlation will improve marginally to -.318 (p=.1057) (Fig 6.13 C). For density of intersections the pattern observed for measurements per line also confirms the measurements per area. In this case the lower correlation given by Fig 6.13 D is brought about by two strong outliers that are SA128 and SA184, whose performance is literally disconnected from what is observed for the bulk of the sample. If these two systems are not computed the correlation between dRES/Ln and density of intersections will increase to .473 (p=.0197) so supporting to a large extent the results observed for the areal measurement.1

When the sample of residential densities is disaggregated, the correlations between both measurements of connectivity and the sample of houses will confirm what has been observed for the sample of residential densities as a whole, in its aggregate form. This result is expected since the largest part of the sample of residential densities is precisely the sample of houses. For connectivity the coefficient observed against the densities of houses will be levelled with the one observed for the aggregate of residences, yet in this case the points that represent the bulk of the sample will be more evenly distributed along the regression line (Fig 6.13 C). The coefficient observed (R= -.279 p=.1589) is here again affected by the performance of SA128 and SA184.2 If these two systems are not computed the coefficient will increase to -.536 (p=.0047) so not only confirming the strong relationship between connectivity and the previous syntactic measurements but also

---
1 Yet the distribution constraints will remain.
2 As it has been said, the residential density inside these two systems is mostly constituted by housing estates and, for both cases, the density of houses is rather low. These two systems are represented by the two black dots low at left in Fig 6.13 E.
indicating that the density of houses will be lower in the more connected parts of the grid.

Nevertheless if the measurement of connectivity is relativised to the area of the system (density of intersections per area) the outcome will point out the other way around. Fig 6.13 F shows that for all systems the correlation is low and negative. Nevertheless both the coefficient and also the direction of the correlation are strongly biased by the performances of SA128 and SA184 (the two black dots below at right in the diagram). If these two systems are not computed the correlation will assume a positive direction - so confirming the results obtained for the sample of residences as measured in aggregate - and the coefficient will go as high as .516 (p=.0099). This output suggests that the parts of the grid where the density of intersections increases tend to be the ones where the density of houses will increase as well.1 The performance of the densities of houses in relation to the density of intersections per area will be right the opposite of what was observed in relation to mean connectivity. The output observed for the densities of houses in relation to the densities of intersections per unit of area seems to be in tune with the observations carried out by Borchert in his already referred study of residential densities.2 This author has detected a strong association between population density, as measured by the number of single family dwellings and 'network density' as measured by intersections.3 This follows the fact that the current sample of houses is mostly constituted of single family dwellings.

For the sample of densities of blocks of flats the correlation against connectivity (mean connectivity of the axial lines inside each system) shows the opposite of what has been observed for the sample of houses. The increase in connectivity is followed by a consistent increase in the density of blocks of flats (Fig 6.13 G). The scattergram shows -

1 The skewness observed for the distribution does not allow for a higher probability.
3 ibid. p.32.
confirming what was observed when the sample of blocks of flats was matched with the measurements of RRAemb and ringyness — that three out of the four most connected systems (black dots at left in the scattergram) are outliers. Their density of blocks of flats is rather low in comparison with the tendency observed for the bulk of the sample.¹

The correlations for density of intersections per unit of area will perform the other way around. The density of blocks of flats will increase insofar as the density of intersections decreases (Fig 6.13). Two distinct sets of points can be identified in the scattergram. The larger, which carries the bulk of the sample, is more scattered and its configuration suggests that the observed correlation would be to some extent biased by the smaller set of points at right which includes the systems at the top in the rank for densities of intersections.² Nevertheless this is not confirmed when these more connected systems are not computed. The correlation will remain high at -.510 (p=.0183) confirming that the increase in the density of intersections is in effect to a reasonable extent followed by a decrease in the density of blocks of flats, yet the low probability of the correlation reflects in this case the high degree of dispersion observed for the distribution of points along the regression line (Fig 6.13 Ⅰ).

The sample of mixed residences following what was observed in the performance of the densities of productive activities as a whole is strongly correlated with the pattern of connectivities. The correlation is

¹ These outlying systems all belong to the most griddy part of SA – SA60 and its two third other decompositions. These systems are not only the most connected systems of all sample, but also the most ringy and the most integrated at the global scale (RRAem).

² As it has been explained during chapter five the systems that have the highest densities of intersections per unit of area within the current sample are, to a large extent, the most fragmented systems. These systems are SA128, SA106, SA184, SA72, SA71 and SB96 virtually in the same order (the ranks for densities of intersection and axial fragmentation are presented in Fig 4.14 (p.233). Despite the fact that for the current sample as a whole the measurements of axial fragmentation and density of intersections are strongly correlated (R= .874 p=.0001) the six systems at the top of both ranks — the set of systems mentioned above — are very much responsible for the high coefficient. If these systems are not computed the correlation between axial fragmentation and density of intersections will drop to .488 (p=.0248). The plot of axial fragmentation against densities of intersections is presented in Fig 4.22 (p.253).
Fig. 6.14 Correlation analysis for connectivity and density of intersections against residential densities

(A) $R = 0.763$  
($p = 0.0001$)

(B) $R = 0.394$  
($p = 0.0449$)

(C) $R = 0.064$  
($p = 0.7820$)

(D) $R = 0.533$  
($p = 0.0495$)

(E) $R = 0.725$  
($p = 0.0033$)
.763 (p=.0001) and shows that the density of mixed residences will increase consistently with the increase of connectivity (Fig 6.14 A).

When this same sample of mixed residences is plotted against the measurements for densities of intersections the outcome points out the other way around. The correlation becomes negative and indicates that the density of mixed residences decreases insofar as the density of intersections increases (Fig 6.14 B). Nevertheless in this case, unlike what happens when the sample of blocks of flats is matched with the densities of intersections, the systems with the highest densities of intersections (which are the most fragmented systems as well) will perform in contradiction with the more general tendency observed for the bulk of the sample. In this case, as opposed to what was observed for blocks of flats, if these systems are not computed the coefficient will collapse to .064 (p=.7828) indicating that mixed residences and density of intersections are in effect hardly related (Fig 6.14 C).

In general the results observed for the matching of mixed residences with the two proposed measurements of connectivity seem to confirm to a large extent what was observed when these same measurements were plotted against the densities of productive activities. Here, same as for that case, while the measurement of connectivity based upon the mean connectivity of the different systems (relativised to the number of axial lines) provides an effective description for the way both productive activities and mixed residences perform, the measurements for densities of intersections per unit of area are hardly correlated with both these categories (mixed residences and productive activities as a whole).

The comparison of connectivity measurements and the densities of housing estates shows that the increase of mean connectivity is consistently paralleled by a decrease in the density of estates (Fig 6.14 D). For densities of intersections the correlation works the other way around (Fig 6.14 E). This outcome is in effect expected. The systems that carry the highest densities of housing estates are precisely those
Fig. 6.15 Correlation analysis for figure-ground ratios and residential densities

(A) $R = 0.453 \ (p = 0.02)$

(B) $R = -0.061 \ (p = 0.7726)$

(C) $R = -0.491 \ (p = 0.349)$

(D) $R = -0.499 \ (p = 0.3287)$

(E) $R = 0.036 \ (p = 0.8596)$

(F) $R = 0.745 \ (p = 0.0034)$
most fragmented systems - which carry the highest densities of housing estates - where the density of intersections per unit of area, as it was noticed during chapter five, will be the highest as well. Although the relationship between axial fragmentation and density of intersections is not consistent throughout the sample, it is particularly strong for this particular set of most fragmented systems.¹

As the last step of this section the sample of residential densities will be matched with the proposed measurements of figure-ground ratios - or densities of public space - as given by the aggregate of axial lengths within each different system relativised to the area of the system. When the aggregate of residential densities per area is plotted against the measurements of figure-ground ratio, the two measurements will be −0.453 (p=0.02) correlated (Fig 6.15 A). The correlation suggests that the systems where the density of public space per unit of area is higher tend to carry higher residential densities. This result is to a certain extent unexpected. What intuition suggest in this respect is that the increase in the density of public space would naturally bring about an increase in the total amount of residences in an urban area yet not necessarily an increase in residential density. Nevertheless this result has to be taken cautiously since the coefficient seems to be biased by the two systems at the top of the rank of figure-ground ratios. These systems are SA128 and SA106, two strongly fragmented systems (black dots in the scattergram).² If these systems are not computed the coefficient will drop to 0.185 (p=0.3866) showing that the sample of residential densities is hardly related to the density of public space of the different systems.

¹ The correlation between axial fragmentation and density of intersections when the systems that carry housing estates are measured as a separate sample is almost perfect (R=0.959 p=0.0001).

² It is worth to remind that the measurements of axial fragmentation and figure-ground ratio are hardly correlated. As an example, the third highest system in the rank of figure-ground ratios is SA30, one of the less fragmented systems of all sample. In fact the correlation between these two measurements (R=0.502 p=0.0077) is strongly biased by systems at the top of both ranks. These results have been discussed in chapter five and are presented in Fig 4.23 C (p.254).
The comparison of mean residential densities per line and the figure-ground ratios observed for the different systems will confirm to a large extent what was observed for the measurements per area. The two measurements are virtually uncorrelated (Fig 6.15 B). When the sample of residential densities is decomposed, the matching of two amongst the four proposed categories - houses and blocks of flats - against the measurements of figure-ground ratio does not change significantly what was observed for the aggregate of residences. In fact some hints of correlation will emerge for houses and blocks of flats, yet in both cases the probability of the correlations are very low and moreover the distribution of points in both scattergrams is very much dispersed (Fig 6.15 C and D).

For the density of mixed residences the pattern changes and the correlations will follow to a large extent what was observed when the measurements of figure-ground ratio were plotted against the densities of productive activities. In effect the coefficient, as measured for all systems, shows that the two measurements are virtually uncorrelated (Fig 6.15 E). Nevertheless this is not confirmed by the way the performance of the different systems is depicted in the scattergram. Two systems are strong outliers which contradict the distribution given by the bulk of the sample. These are SA128 and SA184, two areas where the density of mixed residences is rather low. The outlying of these two systems, in the particular case of mixed residential densities, was already expected since both these systems are mostly constituted of housing estates and in the areas (inside the current sample) where housing estates are predominant, either commercial activities or services tend to be placed apart from the dwelling areas so largely preventing the interaction of the residential use with any other activity inside the same building. This seems to explain the rather low density of mixed residences in both systems. If these two systems are not computed the correlation between mixed residential densities and figure-ground ratios will increase to .486 (p=.0007). This seems to
follow what the plotting of figure-ground ratios against the sample of productive activities, as proceeded during chapter five, has already suggested.\(^1\) The increase in the density of public spaces - as given by the proposed figure-ground ratios - is fairly associated with the increase in the densities of mixed residences, in a rather similar way as they are associated with the increase of productive activities as a whole.

The match of figure-ground ratios and the densities of housing estates follows a completely distinct path in comparison with what was observed for the other residential categories. The two measurements will be strongly correlated. The increase in the density of public space is strongly associated with the increase in the density of housing estates. The correlation is \(R = .745\) (\(p = .0034\)) (Fig 6.15 F). This result could in fact be conjectured from the visual inspection of the axial maps that represent the systems where housing estates predominate.\(^2\) Visual observation suggests that the increase of axial fragmentation in this particular set of systems is strongly associated with the increase in the density of public space. The pattern given by slabs or towers distributed throughout the open space seems to be, at least to some extent, responsible for that. The measurements point out clearly that the visually observable increase in the number of pathways (axial lines) within this particular set of systems is consistently followed by the increase in the density of public space, when these axialities are relativised to the area of the different systems.

In general the analytical procedure developed during this section has shown that each one of the four residential categories has a rather distinct performance when their density values are plotted against the

\(^1\) In that case the correlation between the measurement of figure-ground ratio and the sample of densities of shops is \(R = .748\) (\(p = .0004\)), as measured for the bulk of the sample. This result is presented in Fig 5.10 (p.277). For offices and industries the coefficients will drop to \(.613\) and \(.361\) respectively.

\(^2\) See reference map.
syntactic measurements of grid configuration. The performance of houses has shown that the systems that are more segregated in the street grid tend to be the ones that carry the highest densities. This does not mean that this tendency towards segregation would necessarily be followed by a loss of intelligibility. In effect the correlation between the density of houses and intelligibility is high and positive when the more intelligible systems are plotted as a separate sample.\(^1\) Another interesting aspect is that the densities of houses tend to increase consistently with axial fragmentation, but in this case, just up to a certain degree of fragmentation. From then on - for the most fragmented systems - the density of houses tends to decrease being then replaced by a consistent increase in the density of housing estates.\(^2\)

On the other hand, variations in ringyness have shown a weaker relationship with the densities of houses. The results presented contradict, to some extent, what would be expected in this respect, especially in view of the strong relationship verified between ringyness and integration. Nevertheless the results have suggested that although the densities of houses tend to increase in the more segregated parts of the grid, this search for segregation is not necessarily followed by a loss in ringyness.\(^3\) On the contrary, the analysis has shown that some systems that are high in the rank of ringyness are also strongly residential.\(^4\) The same cannot be said about connectivity and density of intersections which are, especially the first, strongly associated with the densities of houses.

The densities of blocks of flats have in general performed in the opposite direction as compared with the densities of houses. The densities of

\(^1\) This result is presented in Fig 6.08 F. The number of observations is restricted to the twelve most intelligible systems, which correspond to 50% of the whole sample. For the remaining part of the sample the density of houses will be virtually uncorrelated with intelligibility values.

\(^2\) The performance of the densities of houses against axial fragmentation is shown in Fig 6.10 E.

\(^3\) The correlation between densities of houses and ringyness is presented in Fig 6.12 B.

\(^4\) SA106 is probably the typical case in this respect.
blocks of flats tend to increase with integration. It is also noteworthy that amongst the most integrated systems a subtle irregularity was noticed in the pattern described above. When the most integrated systems were plotted as a separated sample the increase in the density of blocks of flats will follow the pattern of segregation.\(^1\) In other words yet the density of blocks of flats as a whole tend to increase for the most integrated patterns, once inside these more integrated systems the highest densities will be observed for their most segregated bits. The conjecture emerged from this result is that blocks of flats would seek to segregate themselves within the pattern of integration.

The irregularity noticed above is not observed when blocks of flats are plotted against intelligibility. In this case the sample tends to perform as a whole and the output clearly suggests that the increase in the density of blocks of flats follows to a large extent the increase of the intelligibility values observed for the different systems.\(^2\) The results for axial fragmentation and tension have followed the search for integration observed for the densities of blocks of flats in general. The increase of axial fragmentation and consequent decrease of tension will be consistently followed by a decrease in the densities of blocks of flats. For these measurements - axial fragmentation and tension - the sample performs as a whole and the 'irregularity' noticed in the plot of blocks of flats against integration can hardly be noticed here.

On the other hand - same as for houses - the character of ringyness has shown itself less important for the performance of the densities of blocks of flats than other syntactic features, including connectivity and density of intersections. As a whole the outstanding feature of the results presented above is the consistent divergent performance of houses and blocks of flats - houses looking for integration and blocks of flats

---

\(^{1}\) This result is given in Fig 6.07 B and C.

\(^{2}\) The role of global intelligibility has also emerged in these experiments so pointing out the effects coming from the surrounding areas in the performance of the densities of blocks of flats.
flats on the other hand looking for integration. This result seems to provide another contribution in support of the 'natural zoning' hypothesis - as raised at the outset of this study - based upon the configuration of the street grid.

Another aspect of the analysis proceeded above that calls for attention is the consistently lower coefficients observed for the correlations between residential densities and syntactic measurements as compared with the much higher coefficients observed when the densities of productive activities are matched against the same set of configurational parameters. This seems to indicate that the syntactic dimension of the street grid is more effective, or more directly associated with the performance of productive activities than with the residential use. This has become evident in the plots of the sample of mixed residences against any of the syntactic measurements. The coefficients observed for mixed residences are consistently higher than the ones observed for any of the other residential categories. As it has been explained, the sample of mixed residences is in effect a part of the sample of productive activities and the high correlations observed for this particular category (mixed residences) have for most cases matched the coefficients observed for productive activities (especially the ones observed for shops and offices).

Finally, the results observed for the sample of housing estates offered some interesting and, to some extent, unexpected results. For start the relationship between densities of housing estates and segregation is not at all clear. The correlation for all systems computed is positive. It in fact indicates a certain degree of association between segregation and the increase in the density of housing estates. Nevertheless for a significant part of the sample the direction of the correlation is explicitly inverted as affected by systems such as SA184, SA128 or SA45 which despite the high density of housing estates are relatively well integrated systems.¹ It is also noteworthy that the 'contradictory

¹ This can be observed in Fig 6.07 G.
The performance noticed above is not observed in the plot against intelligibility. In this case the distribution of points is less dispersed and the performance of the sample has clearly suggested that the less intelligible systems tend to carry the highest densities of housing estates.¹ The same can be said about the relationship between the densities of housing estates and the measurements of axial fragmentation and tension. Housing estates tend to be concentrated in the more fragmented parts of the grid, or to bring about the axial fragmentation of the grid if the argument is put the other way around. The character of ringyness is here again – following its performance against the other residential categories – a less important factor for the performance of the housing estates, than other syntactic measurements.

Another interesting result is the performance of housing estates against the measurements of density of intersections per unit of area. For the three other residential categories – houses, blocks of flats and mixed residences – the measurements of connectivity, as given by the mean connectivity of the different systems, have provided the strongest correlations. Different from what happens for the other categories, for housing estates the measurement based upon densities of intersections per unit of area has proven itself a useful descriptive tool. As it has been explained the sample of densities of housing estates is mostly given by strongly fragmented systems and the measurement of densities of intersections has shown a strong degree of association with axial fragmentation within this specific part of the sample. Finally, the observed association between densities of housing estates and figure-ground ratios has been the most significant performance noticed for this measurement when matched against any of the residential categories, especially for the description it provides for the slabs on the green archetype from the standpoint of the syntactic configuration of the street grid.

¹ This result is presented in Fig 6.09 E and F.
In what follows the analysis is brought back to the level of the syntactic characteristics of each axial line inside each system and more precisely to the investigation of the relationships between the set of proposed configurational parameters and the distribution of residential uses, as given by the four proposed residential categories.\(^1\) The analysis that follows aims on the one hand to provide a comparative assessment of the performance of each residential category from the standpoint of the proposed configurational parameters and on the other hand to test out once again the concept of area of syntactic reference, this time from the standpoint of the residential use.\(^2\)

**The syntactic description for the distribution of houses**

The results observed during the previous section have consistently suggested that the mean density of houses observed for the different systems tends to increase consistently for the more segregated or more fragmented parts of the street grid.\(^3\) In what follows the matching of the distribution of houses against syntactic parameters - at the level of each axial line inside each system - will provide a further opportunity to test out the conjecture above. In effect the question that remains after the analysis of the mean densities, is whether the effects of grid configuration as noticed in terms of variations in concentration of houses at the level of different parts of the grid (from one system to another) can be extended, or specified, to the level of each axial line within each particular system.

---

\(^1\) The ones already dealt with during the previous section from the point of view of the mean density observed for each system.

\(^2\) The configurational (or syntactic) parameters to be utilized in the analysis that follows are the same utilized in order to describe the performance of the distribution of productive activities during chapter five. These parameters are integration and its variations according to the reference for measurement (RRA and RRAe mb), choice, connectivity and axial length.

\(^3\) Yet the measurements of axial fragmentation have shown clearly that for the most fragmented part of the sample the concentration of houses is replaced by a consistent increase in the density of housing estates.
Table 6.04
Distribution of houses and syntactic measurements in SA west: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SR41</th>
<th>SR45</th>
<th>SR60</th>
<th>SR6B</th>
<th>SR30</th>
<th>SR34</th>
<th>SR77</th>
<th>SR59</th>
<th>SR21</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 dHOU x RRA</td>
<td>.113</td>
<td></td>
<td>.101</td>
<td>.124</td>
<td>.287</td>
<td>.047</td>
<td>.019</td>
<td>.096</td>
<td>.021</td>
</tr>
<tr>
<td>2 dHOU x SR45</td>
<td></td>
<td>.058</td>
<td>.367</td>
<td>.825</td>
<td>.053</td>
<td>.170</td>
<td>.014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 dHOU x CRC</td>
<td>-.066</td>
<td></td>
<td>.058</td>
<td>.367</td>
<td>.042</td>
<td>-.121</td>
<td>-.252</td>
<td>.086</td>
<td></td>
</tr>
<tr>
<td>4 dHOU x CRN</td>
<td>-.319</td>
<td></td>
<td>.082</td>
<td>-.874</td>
<td>-.263</td>
<td>-.257</td>
<td>-.313</td>
<td>.092</td>
<td></td>
</tr>
<tr>
<td>5 dHOU x LEN</td>
<td>-.194</td>
<td></td>
<td>-.187</td>
<td>-.409</td>
<td>.016</td>
<td>.112</td>
<td>-.126</td>
<td>.036</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 6.16 Distribution of houses in SA west

A. SA41 dHOU x RRA  
R = .113 (p = .2427)

B. SA41 dHOU x CRN  
R = .319 (p = .0004)

C. SA30 dHOU x CRN  
R = -.674 (p = .000)

D. SA30 dHOU x RRA  
R = .367 (p = .2255)
If the distribution of houses in the west part of SA (SA143) is taken as a starting point, the conjecture above can hardly be accepted, at least from the point of view of integration. The distribution of houses is hardly correlated to RRA inside SA143 (Fig 6.16 A). Nevertheless despite the low correlation a tendency can be noticed, especially at the upper tail of the distribution, that suggests an increase in the density of houses insofar as RRA values increase (increase of segregation).1 Such a segregationist tendency becomes more explicit, if connectivity values are plotted against the distribution of houses, instead of integration values. The coefficient for connectivity goes higher to .319 (p=.0004) and indicates that for the less connected lines there will be a more consistent decrease in the density of houses than the one observed when RRA values were plotted (Fig 6.16 B).

If a decrease in connectivity is accepted as an indication of increase in segregation, the correlation observed for the plot of houses against connectivity can be taken as supportive of the conjecture raised at the outset, that the density of houses tends to increase in the more segregated parts of the grid.2 It is noteworthy that the relationship between RRA and connectivity (syntactic intelligibility) inside SA143 is rather high; $R = -0.800$ (p=.0001), yet when it comes to describe the distribution of houses, connectivity comes to be a more effective parameter.3 This can be, at least to a certain extent explained. If the lines that carry the highest densities of houses (50% highest) are considered as a separated sample the correlation between integration

---

1 The measurement of density of houses is taken in this case at the level of each axial line, that is to say 'house constitutions' relativised to the length of the line. As it has already been explained, this is different from the measurement of density of houses utilized during the previous section when the concept of 'density' was applied in order to describe the mean density within each particular system.

2 Both mean RRA values and mean connectivity values have performed well against the mean densities of houses. These results were presented and discussed in this same chapter (Fig 6.08 and 6.13) and show that the mean density of houses tend to increase with the decrease of connectivity and with the increase of RRA (decrease of integration). Apart from that the correlations between mean RRA values and the mean connectivity values observed for the different systems are rather high. $R = -0.905$ (p=.0001) for each system as detached (RRA) and $-0.833$ (p=.0001) for systems as embedded (RRA emb). This result is presented in Fig 4.21 A and B (p.250).

3 The measurement of intelligibility (RRA : CON) for SA143 is given in Fig 3.47 (p.183).
and connectivity in SA143 will drop to -.402 (p=.0048) showing that for this particular part of the sample - which seems to be the one that counts more effectively for the distinct performances of RRA and connectivity in relation to houses - these two syntactic parameters tend to perform more independently.

For the proposed decompositions of SA143 the picture does not change much. The coefficients observed for connectivity are consistently higher than the ones observed for the other syntactic parameters (Table 6.04). Besides, the coefficients observed for the local areas are consistently lower than the ones observed for the large SA143. The only exception is SA30. For this system besides the increase in the coefficient for connectivity (Fig 6.16 C) the coefficient observed for RRAemb is also relatively high (for the current standards) and indicate that the density of houses inside that particular system tends to decrease insofar as global integration increases. It is noteworthy that in this case the coefficient for local integration (RRA) is much lower so indicating that the distribution of houses in SA30 is very much referred to the global scale of the grid (Table 6.04).

This result seems to contradict the conjecture raised during the previous section on the local character of the densities of houses. Nevertheless, this output is given by just one out of the six local areas observed (table 6.04). For the other systems the distribution of houses is virtually uncorrelated with integration showing clearly that the relationships and conjectures drawn from observations carried out at the level of mean densities of houses per system cannot be extended in equal terms to the variations in the density of houses observed at the level of

---

1 The coefficients observed for choice and length tend to increase occasionally yet the lack of consistency does not allow for the acknowledgement of more significant regularities in respect of the performance of 'houses' against these two measurements.
2 This conjecture has been based upon the observation that the mean densities of houses tend to correlate higher with local integration (RRA) than with global (RRAemb). The coefficients are .392 and .358 respectively - these results are presented in Fig 6.06 E and F. Nevertheless this output is to some extent controversial since in a significant part of the sample - the ten more segregated systems which correspond to 50% of the current cases - the coefficient against global integration increases to .856 (p=.0003).
Table 6.05
Distribution of houses and syntactic measurements in SA east: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA118</th>
<th>411 core</th>
<th>SA299</th>
<th>299 core</th>
<th>SA184</th>
<th>SA06</th>
<th>SA106</th>
<th>SA71</th>
<th>SA72</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 dhou x mRA</td>
<td>.289</td>
<td>-.815</td>
<td>.207</td>
<td>.869</td>
<td>.180</td>
<td>.117</td>
<td>.120</td>
<td>.027</td>
<td>.000</td>
</tr>
<tr>
<td>2 dhou x mh3msh</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>.013</td>
<td>.069</td>
<td>.455</td>
<td>.143</td>
<td>.252</td>
</tr>
<tr>
<td>3 dhou x CMC</td>
<td>-.145</td>
<td>*</td>
<td>-.995</td>
<td>*</td>
<td>-.175</td>
<td>.821</td>
<td>-.330</td>
<td>-.100</td>
<td>-.025</td>
</tr>
<tr>
<td>4 dhou x LLN</td>
<td>-.135</td>
<td>*</td>
<td>-.996</td>
<td>*</td>
<td>-.336</td>
<td>-.186</td>
<td>-.454</td>
<td>-.187</td>
<td></td>
</tr>
<tr>
<td>5 dhou x LEN</td>
<td>-.200</td>
<td>*</td>
<td>-.298</td>
<td>*</td>
<td>.013</td>
<td>.015</td>
<td>-.668</td>
<td>-.861</td>
<td>-.044</td>
</tr>
</tbody>
</table>

Fig. 6.17 Distribution of houses in SA east
each axial line. That is to say, the performances noticed at the level of the aggregate (mean densities) cannot be taken for granted as valid for the more micro scale of densities per axial line; the so called 'distributions' inside the current study. At any rate the performance of connectivity seems to be consistent enough to suggest that in the less connected parts of the grid the density of houses tends to increase. Since the correlations for integration for the different local areas are rather low the current test does not contribute much for a further clarification on the performance of the proposed areas of syntactic reference.\footnote{Since connectivity is a local measurement its value will not be affected by 'embeddings' or changes in the configuration of the areas of syntactic reference.}

For the east part of SA (SA418) the picture changes and for this case the pattern of integration will become more strongly associated to the performance of the distribution of houses than connectivity (Tab 6.05). The correlation between the distribution of houses and integration increases to .289 (p=.0001) in this part of the grid (Fig 6.17 A). Different from what happens in the west part of SA (SA143), this result seems to confirm, to a large extent, what was observed for the analysis of mean densities. In SA418 the increase in segregation tends to be followed by a consistent increase in the density of houses. The coefficient observed for connectivity - yet it confirms the conjectured 'segregationist tendency' - will be much lower (Fig 6.17 B). If the proposed measurements are plotted without computing the short axial lines given by the housing estates all coefficients will decrease so suggesting that although the set of deleted lines is predominantly occupied by housing estates, these axial segments play an effective role in the way the distribution of houses takes place.

When SA418 is further decomposed, for each local area the distribution of houses will perform in a quite distinctive way in relation to the set of proposed syntactic measurements, yet all the results tend to support at least to some extent the segregationist tendency conjectured above. For SA184 the distribution of houses will be more strongly correlated with
connectivity (Fig 6.17 C) increasing in the less connected lines (same as in SA143). In this case the correlations with both local and global integration virtually collapse. For SA69 - that is the same SA184 having the housing estates axial lines deleted - all coefficients will decrease, so confirming the effects coming from the short axial segments, as conjectured for SA299 (that is the same SA418 having the housing estates axial lines deleted).

In SA106 the coefficient for connectivity decreases yet for global RRA and axial length both correlations will be rather significant (Fig 6.17 D and E). The high coefficient for global RRA shows again the effects of the global scale in the distribution of houses, that is to say the segregationist tendency noticed for the increase in the density of houses is referred to the larger area, the whole SA east, and not to the pattern of RRA locally observed - for the system as detached. This result is very much in tune with other characteristics of that part of the grid previously detected. SA106 carries the second highest density of houses inside the current sample (Fig 6.04 A) and, as interacting with the surrounding areas, this system is just the third most segregated system of all sample as well (RRAembr=.89).\(^1\) Hence it is not unexpected that the high coefficient observed between the distribution of houses and integration is explicitly referred to the global scale, and not to the pattern of local segregation.\(^2\) Similar performance can be observed, yet to a lesser extent, for SA72 (Fig 6.17 G). For SA71 the correlation with integration collapses, yet the coefficient for connectivity increases to -.454 (p=.0002) so confirming the conjectured association between the increase in the density of houses and a decrease either in the integration value of the axial lines or in their connectivity (Fig 6.17 F). These results do not point out one - and just one - measurement that provides the highest coefficients and as such the more effective syntactic description for the distribution of houses - as the consistent higher correlations observed for connectivity against houses in the west.

\(^{1}\) This measurement is given in Table 4.01 (p.205).

\(^{2}\) The correlation for local integration drops dramatically to .120 (p=.1237) (table 6.05).
### Table 6.06
Distribution of houses and syntactic measurements in sector B: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>$SB551$</th>
<th>$SB551$ cora</th>
<th>$SB295$</th>
<th>$SB295$ cora</th>
<th>$SB34$</th>
<th>$SB44$</th>
<th>$SB127$</th>
<th>$SB96$</th>
<th>$SB45$</th>
<th>$SB83$</th>
<th>$SB89$</th>
<th>$SB89$ cor99</th>
<th>$SB89$ cor351</th>
<th>$SB62$</th>
<th>$SB50$</th>
<th>$SB69$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 $d_{RNA}$</td>
<td>$^{+}0.258$</td>
<td>$-0.211$</td>
<td>$^{+}0.179$</td>
<td>$-0.246$</td>
<td>$-0.157$</td>
<td>$-0.142$</td>
<td>$-0.559$</td>
<td>$-0.161$</td>
<td>$-0.868$</td>
<td>$-0.809$</td>
<td>$^{+}0.223$</td>
<td>$^{+}0.592$</td>
<td>$^{+}0.093$</td>
<td>$^{+}0.253$</td>
<td>$^{+}0.288$</td>
<td>$^{+}0.423$</td>
</tr>
<tr>
<td>2 $d_{RNA} \times d_{Milen}^{+}$</td>
<td>$^{+}0.067$</td>
<td>$-0.185$</td>
<td>$^{+}0.153$</td>
<td>$^{+}0.083$</td>
<td>$-0.088$</td>
<td>$-0.055$</td>
<td>$^{+}0.071$</td>
<td>$^{+}0.111$</td>
<td>$^{+}0.476$</td>
<td>$^{+}0.371$</td>
<td>$^{+}0.341$</td>
<td>$^{+}0.301$</td>
<td>$^{+}0.269$</td>
<td>$^{+}0.277$</td>
<td>$^{+}0.351$</td>
<td>$^{+}0.415$</td>
</tr>
<tr>
<td>3 $d_{RNA} \times d_{Milen}^{-}$</td>
<td>$^{+}0.258$</td>
<td>$-0.205$</td>
<td>$^{+}0.202$</td>
<td>$^{+}0.178$</td>
<td>$-0.456$</td>
<td>$-0.453$</td>
<td>$^{+}0.871$</td>
<td>$^{+}0.656$</td>
<td>$^{+}0.351$</td>
<td>$^{+}0.311$</td>
<td>$^{+}0.296$</td>
<td>$^{+}0.282$</td>
<td>$^{+}0.277$</td>
<td>$^{+}0.277$</td>
<td>$^{+}0.277$</td>
<td>$^{+}0.277$</td>
</tr>
<tr>
<td>4 $d_{RNA} \times CN$</td>
<td>$-0.147$</td>
<td>$-0.377$</td>
<td>$-0.206$</td>
<td>$-0.859$</td>
<td>$-0.087$</td>
<td>$-0.262$</td>
<td>$-0.519$</td>
<td>$-0.158$</td>
<td>$-0.565$</td>
<td>$-0.010$</td>
<td>$-0.634$</td>
<td>$-0.476$</td>
<td>$-0.351$</td>
<td>$-0.243$</td>
<td>$-0.250$</td>
<td>$-0.210$</td>
</tr>
<tr>
<td>5 $d_{RNA} \times CN$</td>
<td>$-0.326$</td>
<td>$-0.382$</td>
<td>$-0.350$</td>
<td>$-0.450$</td>
<td>$-0.131$</td>
<td>$-0.065$</td>
<td>$-0.519$</td>
<td>$-0.471$</td>
<td>$-0.161$</td>
<td>$-0.432$</td>
<td>$-0.351$</td>
<td>$-0.699$</td>
<td>$-0.489$</td>
<td>$-0.256$</td>
<td>$-0.262$</td>
<td>$-0.262$</td>
</tr>
<tr>
<td>6 $d_{RNA} \times LUN$</td>
<td>$-0.227$</td>
<td>$-0.187$</td>
<td>$-0.218$</td>
<td>$-0.283$</td>
<td>$0.858$</td>
<td>$0.058$</td>
<td>$-0.811$</td>
<td>$-0.116$</td>
<td>$-0.224$</td>
<td>$-0.259$</td>
<td>$-0.210$</td>
<td>$-0.827$</td>
<td>$-0.515$</td>
<td>$-0.262$</td>
<td>$-0.262$</td>
<td>$-0.262$</td>
</tr>
</tbody>
</table>

**Fig. 6.18** Distribution of houses in sector B.
part of SA has done. Nevertheless they all seem to point out towards one same direction. That is to say the concentration of houses tends to increase either in the more segregated or in less connected parts of the grid.¹

The distribution of houses in the SB whole comes to confirm to a large extent what was observed above in respect of the SA systems. In the whole SB351 connectivity is again the syntactic characteristic most closely associated with the distribution of houses, yet in this case the coefficients observed for integration will follow connectivity more closely (Fig 6.18 A and B) than in the case of SA west. For the two large areas emerged out of the decomposition of the SB351 whole - that are SB295 and SB89 - the coefficients drop but the correlations will keep the tendency observed for the whole SB - the increase in the density of houses for the more segregated or less connected parts of the grid (Tab 6.06). For SB295 - that is the east part of SB - the coefficient for connectivity remains relatively high in -.282 (p=.0001)(Fig 6.18 C). While for integration the coefficient will drop to .179 (Tab 6.06).

The decomposition of SB295 shows that connectivity and the integration values observed for the different systems as embedded will provide the two most effective descriptions for the distribution of houses. This applies for SB54 (and its reduction to SB44), SB127 (and one of its third order decompositions, that is SB45) and also to SB83. Some peculiarities are worth mentioning. The performance of integration in the current case shows that the coefficients observed at the level of each local area are consistently higher than the correlations measured either for SB295 or SB351 as a whole. The proposed local areas seem to work quite effectively as the actual areas of syntactic reference for the

¹ These results were also matched against the intelligibility values of the different systems in order to verify whether or not the variations in the coefficients for integration and connectivity could somehow be associated with variations in intelligibility (RRA:CON) as it has been noticed for the distributions of the productive activities (variations in intelligibility for the core level associated, for instance, with the distribution of shops and offices). Nevertheless, for the current case (distributions of houses) no regularity could be detected as associating the two parameters.
Fig. 6.19 Distribution of houses in sector B

A. S845 dHou x RRA
   $R = 0.456 \ (p = 0.0326)$

B. S869 dHou x RRA
   $R = 0.223 \ (p = 0.0633)$

C. S845 dHou x CON
   $R = -0.519 \ (p = 0.0434)$

D. S869 core 869
   dHou x RRA
   $R = 0.592 \ (p = 0.032)$

E. S883 dHou x RRA
   $R = 0.453 \ (p = 0.004)$

F. S862 dHou x CON
   $R = -0.354 \ (p = 0.0107)$

G. S883 dHou x RRA
   $R = 0.471 \ (p = 0.0006)$

H. S830 dHou x CON
   $R = -0.696 \ (p = 0.0008)$

I. S869 dHou x CON
   $R = -0.469 \ (p = 0.003)$
distribution of houses. This is the opposite of what has been noticed for the SA cases where the larger areas (both SA143 and SA418) have consistently provided the highest coefficients and as such a more globally oriented pattern was conjectured. The results presented in table 6.06 indicate that for the systems in SB east - SB295 and its decompositions - the distribution of houses is more referred to the local areas than to the syntactic configuration of the larger SB295 or SB351.

The variations in the correlation between integration and the distribution of houses have also shown that SB44 tends to work more effectively as the area of syntactic reference for houses than the initially proposed SB54.1 This is the opposite of what happens in respect of the distribution of shops where SB54 has proved itself as the most effective area of syntactic reference.2 In SB96 the distribution of houses is virtually uncorrelated with any of the syntactic measurements, however for SB45 - that is together with SB96 the other system emerged out of the decomposition of SB127 - the pattern of correlations will confirm what has been observed for most local areas, i.e. a higher coefficient for connectivity and an also significant correlation for RRAemb (Fig 6.19 A and B). The same applies for SB83 (Fig 6.19 C and D). It is also noteworthy that the global integration values that are better correlated with the distribution of houses are the ones referred to the whole SB351 (RRAemb2) and not those referred to the SB295 (RRAemb1). In effect if all coefficients observed for the distribution of houses against RRA are compared it will be noticed a consistent pattern of higher coefficients for embedded values, so confirming the previously conjectured role of the global scale for the distribution of houses.3

These observations are also valid for SB89, the west part of SB. In this case the measurements plotted for the area as a whole show that the coefficients observed for the distribution of houses against integration

1 The coefficient between the distribution of houses and RRAemb increases from .258 in SB54 (Table 6.06) to .495 in SB44 (Fig 6.18 D).
2 This result is given in Fig. 5.16 (p.289).
3 These results are given in tables 6.04, 6.05 and 6.06.
are higher than the ones observed for connectivity (table 6.06). Nevertheless, when the system is decomposed the pattern of higher coefficients for connectivity is reinstated. This is valid both for SB62 and SB30 (Fig 6.19 G and H). One distinct aspect in the performance of this west part of SB in comparison with the east part (SB295) is worth to mention. The highest coefficients between the distribution of houses and integration are observed for the RRA values of the two local areas - SB62 and SB30 - as interacting inside SB89 (RRAemb1), and not as a part of the whole SB351, as it has happened for the local areas produced out of the decomposition of SB295 (table 6.06). In effect the correlations between the distribution of houses and RRA values relativised to SB351 (RRAemb2) are rather low. The coefficients are -.052 (p=6832) and .011 (p=.8551) for SB62 and SB30 respectively (table 6.06).

This result seems to provide a further evidence - this time from the standpoint of the distribution of houses - on the conjectured autonomy of the west part of SB (SB89) in relation to the east part (SB295). That is to say, the distribution of houses in the west part of SB takes place according to syntactic rules coming from SB89 itself, and are hardly affected by rules coming from the global scale (SB351). This is also shown in the coefficients observed at the core level. In this case the distribution of houses is well associated with the integration values taken at the level of the SB89 core lines (Fig 6.17 F). The density of houses decreases insofar integration increases at the core level.¹ On the other hand if the distribution of houses is matched with the integration values given by SB351 core lines that penetrate in SB89, the correlation will collapse to .093 (Tab 6.06) so showing that SB east and SB west tend to perform quite autonomously at least in respect of the distribution of houses. This result is virtually the opposite of what has been observed for the distribution of shops in this same system. In that case the syntactic effects coming from the global scale are consistently

¹ Yet the distribution of points in the scattergram is rather dispersed.
felt. The direction of the correlations is the opposite as well. While the
density of shops increases at the core level, the density of houses will
decrease.

As a whole the comparative analysis of all sample as given by tables
6.04, 6.05 and 6.06 has shown that connectivity is the syntactic
parameter more consistently associated with the distribution of houses.
The results observed for most cases have shown clearly that the
decrease in connectivity is the syntactic characteristic more effectively
associated with the increase in the density of houses. From the
standpoint of integration the results have shown that the RRA values
observed for each system as embedded have provided the highest
coefficients so indicating that the distribution of houses in general
tends to be strongly affected by effects coming from the global scale.
This is different from what was observed in respect of the distribution
of productive activities - shops, offices and industries - where different
parts of the grid tend to perform in a rather distinctive way, some more
locally oriented some more globally.2

A syntactic description for
the distribution of blocks of flats

For the distribution of blocks of flats the measurements of integration
and connectivity will provide the highest coefficients - same as for the
distribution of houses - yet the variations observed for the direction of
the coefficients will make it clear that some local areas will perform in
a rather distinctive way. For a large part of the sample - in terms of
number of systems - the concentration of blocks of flats tends to
increase in so far as the integration value of the axial lines decreases,

1 These results are given in Fig 5.18 B and C (p.295). The correlation between the
distribution of shops and the core lines of SB89 is -.097(p=.7114), while for the core lines
given by SB351 that penetrate SB89 the coefficient will increase to -.769 (p=.0013).
2 These results have been discussed in detail during chapter five.
Table 6.07

Distribution of blocks of flats and syntactic measurements in SA west: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>S81-45</th>
<th>S81-45 core</th>
<th>S868</th>
<th>S830</th>
<th>S854</th>
<th>S777</th>
<th>S859</th>
<th>S821</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 dBFL vs RRA</td>
<td>.454</td>
<td>.483</td>
<td>.558</td>
<td>.431</td>
<td>.296</td>
<td>.084</td>
<td>.110</td>
<td>-.341</td>
</tr>
<tr>
<td>2 dBFL vs RRAemb</td>
<td>.052</td>
<td>-.087</td>
<td>.159</td>
<td>-.068</td>
<td>.017</td>
<td>.435</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 dBFL vs CFC</td>
<td>-.111</td>
<td>-.176</td>
<td>.367</td>
<td>.007</td>
<td>-.049</td>
<td>.599</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 dBFL vs CON</td>
<td>-.301</td>
<td>-.525</td>
<td>-.399</td>
<td>-.460</td>
<td>-.054</td>
<td>-.001</td>
<td>.448</td>
<td></td>
</tr>
<tr>
<td>5 dBFL vs LEN</td>
<td>-.252</td>
<td>-.408</td>
<td>.004</td>
<td>-.021</td>
<td>-.018</td>
<td>-.003</td>
<td>.507</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 6.20 Distribution of blocks of flats in SA west

A) SA443 dBFL x CON
R² = -.304 (p = .0042)

B) SA443 core dBFL x RRA
R² = .483 (p = .0197)

C) SA460 dBFL x RRA
R² = .53 (p = .0004)

D) SA460 dBFL x CON
R² = -.525 (p = .0009)
that is to say the density of blocks of flats increases in the more segregated parts of the grid. Nevertheless the performance of the parts of the sample where the concentrations of blocks of flats reach their peak will be distinctive (Fig 6.04 B). Inside these systems the density of blocks of flats tends to increase consistently with the increase of integration, all axial lines within each system compared.

This output seems to contradict the results observed when the mean densities of blocks of flats were matched with mean integration values of each system during the previous section. It has then been noticed that in general the mean densities of blocks of flats tend to increase with integration, but within the set of most integrated systems the same densities tend to increase for the most segregated (Fig 6.07 B). In effect there is no contradiction between the two results. The systems where the mean density of blocks of flats reach its peak, as referred above in relation of the current results, are not the most integrated in terms of the sample as a whole but just the systems, within each one of the four larger areas of embedding, where the density of blocks of flats is the highest. The analysis that follows will provide a further clarification on this issue.

The results given by the distribution of blocks of flats in SA west (SA143) embody the opposite performances referred to at the outset. For half of that system - that is SA60 and its two third order decompositions - the density of blocks of flats will increase with segregation (Fig 6.20 C). The coefficients observed for SA60 will be consistently higher than the ones observed for the system as a whole (SA143) so suggesting that in this case the proposed areas of syntactic reference are quite effective.¹ The syntactic distribution of blocks of flats tends to refer to the proposed local areas instead of to the larger SA west. Apart from that the highest coefficients observed for RRA, as compared with the ones observed for RRA emb, point out that the effects

¹ It is noteworthy that the coefficient for connectivity when SA143 is measured as a whole will be much higher than the one observed for integration, although after the decomposition of the system integration (local RRA) will be the most effective parameter (Tab 6.07).
Fig. 6.21 Distribution of blocks of flats in SA west

(1) SA30 $\text{dBFL} \times \text{RRA}$
$R = .434 \ (p = .0195)$

(2) SA30 $\text{dBFL} \times \text{CON}$
$R = -.39 \ (p = .0539)$

(3) SA34 $\text{dBFL} \times \text{RRA}$
$R = .296 \ (p = .1685)$

(4) SA34 $\text{dBFL} \times \text{CON}$
$R = -.46 \ (p = .0274)$

(5) SA24 $\text{dBFL} \times \text{RRA}_{\text{H48}}$
$R = -.635 \ (p = .0035)$
coming from the surrounding areas are hardly felt by the distribution of flats within these systems (Tab 6.07).

Nevertheless if we take the other half of SA143 - that is SA77 - the results will indicate an opposite direction. For SA77 as a whole the distribution of blocks of flats will be virtually uncorrelated with all syntactic measurements. The same applies for SA59 - one of the two systems given by the decomposition of SA77. But for SA21 - the other system emerged out of the decomposition of SA77 - the density of blocks of flats will increase consistently with the increase of integration (Fig 6.21 E).¹ This result is particularly significant for SA21 is the local area that carries the highest mean density of blocks of flats, not only inside SA west but also amongst all systems inside the current sample (Fig 6.04 B). As it has been suggested at the outset, for the part of SA143 where the concentration of blocks of flats is the highest (SA21) the role of integration in affecting the distribution is quite clear.

In the particular case of SA west, the fact that for the most integrated parts of the grid (that are SA60 and its two decompositions) the density of blocks of flats will increase with segregation is very much in tune with what has been noticed during the analysis of the mean densities (the increase in the mean density of blocks of flats for the more segregated parts of the grid). This result in fact comes to be a specification - valid for SA west - of what was observed for the sample as a whole during the analysis for the performance of the mean densities of blocks of flats. Nevertheless this cannot be taken as a rule as the cases to be further presented will show.

The performance of the densities of blocks of flats in the east part of SA leads virtually towards this same direction. Table 6.08 shows that for SA418 measured as a whole the density of blocks of flats will increase

¹ The correlation for connectivity in SA21 (.449) will also perform in opposite direction as compared with the other local areas (Tab 6.07).
Table 6.08
Distribution of blocks of flats and syntactic measurements in SA east: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA410</th>
<th>410 core</th>
<th>SA299</th>
<th>299 core</th>
<th>SA104</th>
<th>SA069</th>
<th>SA106</th>
<th>SA271</th>
<th>SA772</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 dBFL x RRA</td>
<td>-.203</td>
<td>-.137</td>
<td>-.112</td>
<td>-.694</td>
<td>.570</td>
<td>.534</td>
<td>.591</td>
<td>-.193</td>
<td>.251</td>
</tr>
<tr>
<td>2 dBFL x RRAamb</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>.284</td>
<td>.158</td>
<td>-.050</td>
<td>-.554</td>
<td>-.221</td>
</tr>
<tr>
<td>3 dBFL x CRC</td>
<td>-.190</td>
<td>*</td>
<td>-.180</td>
<td>*</td>
<td>*</td>
<td>-.411</td>
<td>-.236</td>
<td>-.198</td>
<td>.818</td>
</tr>
<tr>
<td>4 dBFL x CIN</td>
<td>-.209</td>
<td>*</td>
<td>-.202</td>
<td>*</td>
<td>*</td>
<td>-.461</td>
<td>-.530</td>
<td>-.537</td>
<td>.254</td>
</tr>
<tr>
<td>5 dBFL x LEN</td>
<td>-.140</td>
<td>*</td>
<td>-.117</td>
<td>*</td>
<td>-.626</td>
<td>-.426</td>
<td>-.216</td>
<td>.878</td>
<td>-.157</td>
</tr>
</tbody>
</table>

Fig. 6.22 Distribution of blocks of flats in SA east

A. SA410 dBFL x RRA
R² = -.203 (p = .0097)

B. SA410 dBFL x CON
R² = -.208 (p = .0013)

C. SA104 dBFL x RRA
R² = .57 (p = .0004)

D. SA104 dBFL x CON
R² = .545 (p = .0009)
consistently with integration. The coefficient is \( \text{-.203 (p=.0097)} \) (Fig 6.22 A). It is interesting that in this case the coefficient for connectivity will point out towards the same direction so suggesting that despite the fact that the density of blocks of flats tend to increase together with the increase of integration, it also increases with the decrease of connectivity. This reflects to all extent the low intelligibility value (RRA:CON) observed for SA418, an area where RRA and connectivity are rather poorly correlated.

The output observed for SA418 - association between the increase in the density of blocks of flats and the increase of integration - is not consistent after the decomposition of this system. On the contrary, the results observed for three out of the four local areas given by the decomposition of SA418 will suggest that inside these systems the density of blocks of flats will increase following the increase of segregation, yet the most significant coefficients are given for local RRA values. Nevertheless the performance of SA71 will be distinct from the performance observed for the three other local areas and will confirm the tendency observed for the whole SA418. The coefficient observed for SA71 is \( \text{R.= -.534 (p=.0002)} \) (Fig 6.23 C). For the three other local areas (SA184, SA106 and SA72) the coefficients will point out the other way around and suggest that the density of blocks of flats increases with segregation inside these systems (Tab 6.08).

These results show a significant similarity between the performance of blocks of flats in SA west and east. The performance of SA71, as a part of SA east, provides an equivalent to the case of SA west where just for SA21 the density of blocks of flats will increase with integration. In that case SA21 is the system that carries the highest mean density of blocks of flats amongst all SA143 local areas, in the same way as SA71.

---

1 For the former SA143, measured as a whole, these two parameters are virtually uncorrelated (Tab 6.07).
2 This result is presented in table 3.09 (p. 194). The correlation is \( -0.336 (p=.0001) \), that is the lowest intelligibility value amongst the four large areas of embedding.
3 These results are presented in Fig 6.22 C (SA184) and Fig 6.23 A (SA106).
Fig. 6.23 Distribution of blocks of flats in SA east

(A) SA106 dBFL x RRA
R² = 0.384 (p = 0.045)

(B) SA106 dBFL x CON
R² = 0.337 (p = 0.073)

(C) SA74 dBFL x RRA emb
R² = 0.534 (p = 0.002)

(D) SA74 dBFL x CON
R² = 0.234 (p = 0.126)
carries the highest mean density of blocks of flats amongst all the SA east systems (Fig 6.04 B). Both cases seem to support the model conjectured at the outset. Both in SA west and in SA east the densities of blocks of flats tend to increase consistently with the increase of integration for the parts of the grid where the concentration of blocks of flats is the highest. Inside the areas where the mean density of blocks of flats is lower the opposite will happen, i.e. the density of blocks of flats will increase with segregation.

Some other aspects are worth to mention in respect of the distribution of blocks of flats in SA east. One is that the increase in the density of blocks of flats in SA71 is related to RRA values as embedded, and not local RRA, so indicating that the interaction with the surrounding areas is quite effective for the distribution of this particular part of the sample of flats. Different from that, for the other three local areas - SA184, SA106 and SA72 - the highest coefficients are obtained for local RRA values so indicating a more local oriented distribution. Other aspect that is worth to mention is that the coefficients observed for the local areas are consistently higher than the ones observed for the SA east before decomposition (Tab 6.08). This is true for both the configurations proposed for the large SA east - either SA418 or SA299 - and the output indicates that the proposed areas of syntactic reference tend to perform rather more effectively than the large area of embedding in the description of the syntactic distribution of blocks of flats. One last aspect that is worth to mention is that in the current case the correlations for integration are consistently higher than the ones observed for connectivity, also following what was observed for the performance of blocks of flats in SA west and setting up a distinct pattern in relation to what is observed for the sample of houses where

---

1 The same is noticed in SA west where the part of the sample of blocks of flats that is inside SA21 is well correlated with global integration, while for the other local areas the distribution is locally oriented in terms of RRA values (Tab 6.07).
**Fig. 6.24** Distribution of blocks of flats in sector B

(A) SB351 dBFL x RRA
\[ R = 0.302 \quad (p < 0.001) \]

(B) SB44 dBFL x RRA
\[ R = -0.400 \quad (p < 0.024) \]

(C) SB427 dBFL x RRA
\[ R = 0.505 \quad (p < 0.0085) \]

(D) SB69 dBFL x RRA
\[ R = 0.398 \quad (p < 0.0005) \]

(E) SB89 dBFL x CON
\[ R = -0.235 \quad (p < 0.0475) \]
connectivity has proved itself the most effective amongst the set of proposed syntactic parameters.¹

The observations made for the performance of blocks of flats in the two SA larger areas are confirmed to a large extent in the output given by the SB systems. The correlations plotted against integration will be consistently higher than the ones observed for connectivity (Tab 6.09). The coefficients observed for the local areas after decomposition are consistently higher than the ones observed for the larger areas of embedding (SB351, SB295 and SB89). And most of all, here again the distribution of blocks of flats inside those parts of the grid that carry the highest mean densities of this category will perform quite distinctively from the other systems where the concentration is lower. In the case of the east part of SB (SB295) the more griddy part of this system — that is SB54/44 — concentrates the highest density of blocks of flats (Fig 6.04 B). The matching of the distributions of blocks of flats against the proposed set of syntactic measurements shows that while in all other local areas (inside SB295) the density of blocks of flats decreases with integration, in this particular part of the grid (SB44) the density of blocks of flats will follow rather consistently the increase of integration (Fig 6.24 B).

Nevertheless one distinction must be made. For the SA cases where the density of flats increases with integration — SA21 and SA71 — such an increase tends to be governed by rules coming from the global scale, i.e. the highest coefficients in both cases are given by global integration values (RRA emb). Different from that, for the current case (SB44) the highest coefficient will be observed for local integration. If global integration values are plotted against the sample of flats given by SB44 the coefficients will collapse.² This output brings back to the discussion

¹ The correlations for choice and axial length are consistently lower yet they tend to confirm the directions suggested by integration and connectivity (Tab 6.08).

² The coefficients will be .023 for global integration values observed for SB44 measured as a part of SB295 and .063 when this same system is measured as a part of SB351.
the syntactic autonomy of this part of the grid as conjectured, during chapter four, on the basis of its pattern of 'definitions' and 'differences'. Such an autonomy was to a large extent contradicted by the results given by the distribution of shops and houses as well, since for both cases the highest coefficients were observed when SB44 is analysed as a part of the whole SB351. The results above have shown that from the standpoint of the distribution of blocks of flats the opposite happens. The performance of this particular category is very much supportive of the conjectured autonomy and moreover shows that, above and beyond the proposed set of 'regularities', the complex syntactic character of each part of the street grid tends to interact in quite distinctive ways with the different categories of land use.

The west part of SB - SB89 and its two parts after decomposition - will follow just to a certain extent the pattern described above. When the whole system is plotted the density of blocks of flats will decrease with integration (Fig 6.24 D), but just if global integration values are plotted (RRAemb), i.e. integration values for SB89 measured as a part of SB351. For local integration the two measurements will be virtually uncorrelated (Tab 6.09). When SB89 is decomposed the results will just in part confirm what was observed for the other areas so far analysed. Within SB62 blocks of flats will be virtually uncorrelated with all syntactic measurements. And this is precisely the system that concentrate the highest density of blocks of flats inside SB west. So the observed pattern of association between the densities of blocks of flats and integration - for the systems where the mean density of this category is the highest within each one of the larger areas - seems to collapse in the case of SB west.

Nevertheless the performance of SB30 seems to come in support of the conjectures previously raised. For this system the mean density of blocks of flats - yet not so high as for SB62 - is just the second highest amongst all SB systems (Fig 6.04 B). The performance of the distribution of blocks of flats against the pattern of integration, inside
Fig. 6.25 Distribution of blocks of flats in sector B

A) $S88g \text{ core} \ 351$
$dBFL \times RRA(351)$
$R = .783 \ (p = .0044)$

B) $S830 \ dBFL \times RRA(351)$
$R = -.626 \ (p = .0054)$
SB30, will be rather similar to what was observed for SA21 (within the SA west), SA71 (within SA east) and SB44 (within SB east) - all these systems are the ones that carry the highest mean densities of blocks of flats within each of the four larger areas of embedding. In SB30, same as for the cases above, the density of blocks of flats will increase consistently with the increase of integration (Fig 6.25 B).\(^1\) It is also noteworthy that this coefficient is observed for global integration values, that is to say SB30 measured as a part of the whole SB351 and not as a part of the immediate surroundings (SB89). At any rate the results above have shown that despite the distinct performances of this set of 'high density of flats' systems - SA21, SA71, SB44 and SB30 - in relation to the more effective larger area of embedding, all of them have presented a remarkably consistent association between the pattern of integration, either local or global, and the distribution of blocks of flats.\(^2\)

Unlike the distribution of houses - whose syntactic performance has revealed a consistent tendency towards segregation - a consistent increase in the density of houses in the more segregated parts of the grid - the matching of the distributions of blocks of flats against the same set of syntactic measurements has shown a more heterogeneous performance. On the one hand when the larger areas are computed as a whole it can be noticed that for three of them (SA143, SB295 and SA89) the distribution of blocks of flats is virtually uncorrelated with integration, while for the two others (SA418 and SB351) the correlation point towards distinct directions. In SA418 the distribution follows the increase of integration while for SB351 (the whole SB) blocks of flats follow segregation. Nevertheless this contradictory performance is just apparent since as soon as the larger areas are decomposed a consistent

\(^1\)In this particular case the coefficient observed for the plot against the measurement of choice is remarkably high (R=-.626)\(^{\{\text{Tab 6.09}\}}\). Nevertheless the lack of consistency in the performance of choice does not allow for the setting up of more clearly identifiable pattern of regularities.

\(^2\)SB44 is the only of these four systems where the highest coefficient is observed for local RRA. For the other three - SA21, SA71 and SB30 - the correlation increases consistently with the global embedding.
relationship with integration has emerged and precisely in the systems where the densities of blocks of flats are the highest.

For the systems where the density of blocks of flats is the highest within each one of the larger areas the distributions will consistently follow the increase of integration. On the other hand, for the systems where the mean density of blocks of flats decreases the distribution tends to follow the pattern of segregation, same as for the sample of houses. This result corresponds very much to what the visual observation of the urban areas under scrutiny has suggested and if a syntactic typology for the distribution of blocks of flats is conjectured at least two main categories must be considered. One includes those parts of the grid where blocks of flats are more heavily concentrated. For these areas the pattern of integration will be consistently accompanied by an increase in the concentration of blocks of flats. The other category carries what seems to be a more dispersed pattern of blocks of flats, which are located in more residential areas and for these cases the density will increase consistently in the more segregated parts of the grid, following a pattern similar to the one observed for the distribution of houses. These results seem to embody at least some of the complex and, to a certain extent, contradictory character of the residential use in large urban areas, where the search for integration on the one hand and segregation on the other seem to coexist and interact mediated by the spatiality of the urban environment and more specifically, as far as this study is concerned, by the syntactic character of the street grid.

A syntactic description for the distribution of mixed buildings (mixed residential)

The complex character of residential distributions becomes still more evident when the results presented above - for houses and blocks of flats - are compared with the performance of mixed residences; that part of the sample where the residential use is mixed with productive activities
Table 6.10 Distribution of mixed residences and syntactic measurements in SA west: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA410</th>
<th>41B core</th>
<th>SA299</th>
<th>299 core</th>
<th>SA104</th>
<th>SA69</th>
<th>SA106</th>
<th>SA71</th>
<th>SA72</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 dMIX x RRA</td>
<td>.001</td>
<td>.051</td>
<td>.807</td>
<td>.211</td>
<td>.986</td>
<td>.089</td>
<td>.020</td>
<td>.271</td>
<td></td>
</tr>
<tr>
<td>2 dMIX x RRAemb</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>3 dMIX x CIC</td>
<td>.039</td>
<td>.137</td>
<td>.294</td>
<td>.224</td>
<td>.318</td>
<td>.136</td>
<td>.126</td>
<td>.033</td>
<td></td>
</tr>
<tr>
<td>4 dMIX x CDH</td>
<td>.007</td>
<td>.060</td>
<td>.922</td>
<td>.171</td>
<td>.216</td>
<td>.206</td>
<td>.173</td>
<td>.032</td>
<td></td>
</tr>
<tr>
<td>5 dMIX x LEN</td>
<td>-.045</td>
<td>.058</td>
<td>.884</td>
<td>.822</td>
<td>.111</td>
<td>-.167</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.11 Distribution of mixed residences and syntactic measurements in SA east: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SA410</th>
<th>41B core</th>
<th>SA299</th>
<th>299 core</th>
<th>SA104</th>
<th>SA69</th>
<th>SA106</th>
<th>SA71</th>
<th>SA72</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 dMIX x RRA</td>
<td>-.104</td>
<td>-.206</td>
<td>-.224</td>
<td>-.341</td>
<td>-.242</td>
<td>.100</td>
<td>-.261</td>
<td>.098</td>
<td>.150</td>
</tr>
<tr>
<td>2 dMIX x RRAemb</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>3 dMIX x CIC</td>
<td>.032</td>
<td>.096</td>
<td>.167</td>
<td>.035</td>
<td>.091</td>
<td>.014</td>
<td>.014</td>
<td>.020</td>
<td></td>
</tr>
<tr>
<td>4 dMIX x CDH</td>
<td>.095</td>
<td>.069</td>
<td>.091</td>
<td>.061</td>
<td>.111</td>
<td>.245</td>
<td>.087</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 dMIX x LEN</td>
<td>.052</td>
<td>.094</td>
<td>.011</td>
<td>.071</td>
<td>.194</td>
<td>.158</td>
<td>.044</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 6.26 Distribution of mixed residences in SA west

A) SA60  dMIX x RRAemb
R = -.272 (p = .0688)

![Graph A](image1)

Fig. 6.27 Distribution of mixed residences in SA east

A) SA299 dMIX x RRA
R = -.224 (p = .0025)

![Graph A](image2)

B) SA299 core dMIX x RRA
R = -.541 (p = .0043)

![Graph A](image3)

C) SA106 dMIX x RRAemb
R = -.247 (p = .0406)

![Graph A](image4)

D) SA106 core dMIX x RRAemb
R = -.461 (p = .0047)

![Graph A](image5)
in the same building. The performance of this particular category will be hardly associated with connectivity - a measurement that has performed quite effectively for describing both the distribution of houses and to some extent the distribution of blocks of flats.\(^1\) On the other hand the coefficients observed for mixed residential distributions against integration - a parameter whose performance in the case of blocks of flats and especially in the case of houses has been to some extent random - will reveal a quite consistent association between the two measurements, especially when global RRA values are plotted (integration measurements taken for each system as interacting with the surrounding areas). It is also noteworthy that for this category (mixed residences) the coefficients observed for the larger areas before decomposition (SA143, SA418, SB295 and SB89) will be consistently lower than the ones observed for measurements given by the proposed local areas of syntactic reference (after decomposition).

In the case of the large SA143 the distribution of mixed residences is virtually uncorrelated with integration, as it is with all other syntactic measurements (Tab 6.10). Although when SA143 is decomposed the results will reveal a significant association between the two measurements (dMIX and RRA). The plot of mixed residences against global integration for SA60 shows that the two measurements are -.272 (p=.1688) correlated (Fig 6.26 A). The density of mixed residences tends to increase insofar as the global integration value of the axial lines increases (decrease of RRA). The same does not happen to the other half of SA143, that is SA77, where the coefficient collapses to -.024 (Tab 6.10). For the third order decompositions the coefficients will be lower yet for most cases the direction of the correlations will support the conjecture above (on the association between mixed residential density and global integration). For SA30 and SA59 this seems to be the case. For the first (SA30) the coefficient will remain stable at -.258 (p=.1759) while for the second (SA59) the coefficient decreases to -.132

\(^1\) The only two coefficients higher than .2 - between mixed residential distributions and connectivity - are observed for SA59 (Tab 6.10) and SA71 (Tab 6.11).
Table 6.12
Distribution of mixed residences and syntactic measurements in sector B: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SB351</th>
<th>SB351 core</th>
<th>SB295</th>
<th>SB295 core</th>
<th>SB54</th>
<th>SB127</th>
<th>SB169</th>
<th>SB45</th>
<th>SB89</th>
<th>SB99</th>
<th>SB99 core</th>
<th>SB89 core</th>
<th>SB551</th>
<th>SB62</th>
<th>SB58</th>
<th>SB69</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 d-HIR x BNB</td>
<td>.005</td>
<td>.059</td>
<td>.022</td>
<td>-.364</td>
<td>.165</td>
<td>.108</td>
<td>.082</td>
<td>-.138</td>
<td>.027</td>
<td>.225</td>
<td>-.062</td>
<td>-.041</td>
<td>-.169</td>
<td>.056</td>
<td>.025</td>
<td>.014</td>
</tr>
<tr>
<td>2 d-HIR x c-BBN</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>3 d-HIR x c-BBNn</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>6 d-HIR x LEN</td>
<td>-.016</td>
<td>-.046</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
<td>-.037</td>
</tr>
</tbody>
</table>

Figures (SB30 d-MIX x CEC, SB22 d-MIX x MRA, SB28 d-MIX x MRA, SB32 d-MIX x MRA, SB36 d-MIX x MRA, SB54 d-MIX x MRA, SB63 d-MIX x MRA, SB69 d-MIX x MRA)}
yet the negative tendency is preserved (Tab 6.10). The exception is SA21 where the direction of the correlation points out the other way around, so indicating a decrease in mixed residential density following the increase of integration. Nevertheless this result is unique amongst all observed between these two measurements (dMIX and RRA) throughout the current sample an as such it must be taken cautiously.

The performance described above for SA143 is to a large extent reproduced in the other half of SA (SA418/299). In this case the coefficient observed for the whole SA299 is already quite significant. The correlation is $R = -0.224$ ($p = 0.0025$) (Fig 6.27 A). But even though, as it has been suggested at the outset, this coefficient will be lower than the ones observed for most local areas after the decomposition of the system (Tab 6.11). The coefficients observed for SA106 and especially for SA71 are particularly significant and clearly suggest that the increase in the density of mixed residences is paralleled by the increase of integration values inside these systems (Fig 6.27 C and D). It is also significant that in this case the coefficients observed both for SA418 and especially for SA299 will increase remarkably at the core level (Fig 6.27 B).

Similar results will be observed for the SB whole. Both for SB351 and also for its east part (SB295) the distribution of mixed residences will be virtually uncorrelated with integration, same as for the other syntactic measurements (Tab 6.12). For SB295 the coefficient goes higher at the core level same as it has happened for the previous SA418/299 (Fig 6.28 A). When SB295 is decomposed the correlations against global integration will increase for two out of the three systems emerged out of the decomposition (second order). This is shown in the performance of both for SB54 and especially for SB83 (Fig 6.28 B and C). SB127 - that is the other system emerged out of the decomposition of SB295 - will be an exception in the conjectured model. Global integration will be virtually uncorrelated with mixed residences within
this system and the same will happen when SB127 is further decomposed (SB45 and SB96).¹

For west part of SB (SB89) the coefficient between mixed residential distribution and integration will increase even before the decomposition of the system, so diverging from the pattern so far observed (Fig 6.28 D).² In effect this is just half true since this higher coefficient is observed when SB89 is measured as a part of SB351. If the plot considers SB89 measured on its own, as a separated system, the two measurements (dMIX and RRA) will be virtually uncorrelated (R=-.062 p=.5422)(Tab 6.12). Nevertheless, for the sake of the argument what actually matters is that for the case of SB89, same as for the previous cases, the coefficients obtained after the decomposition tend to be consistently higher than the ones observed for the larger areas measured as a whole. In this particular case the two systems produced out of the decomposition of SB89 will give significant results. For SB62 the coefficient is -.606 (p=.0001) (Fig 6.28 E). For SB30 the correlation is lower (-.416) but still quite high in comparison with the standard set up by the previous cases. It is interesting to notice that in the particular case of SB30 the correlation against choice will go as high as .806 (p=.0087) (Fig 6.28 F). Nevertheless this is an isolated result. For most of the previous cases choice is hardly associated with the density of mixed residences.³

As a whole the results observed for the relationships between the distribution of mixed residences and the proposed set of syntactic parameters have revealed a distinct pattern in comparison with what

---

¹ In effect a hint of correlation (-.134) will emerge for SB96 yet in this case the coefficient will be observed for local integration (Tab 6.12). This is in fact another isolated case within the current sample, since for all other local areas the highest coefficients between dMIX and RRA are observed for global integration values, i.e. RRA measurements for systems as embedded.

² A pattern of low correlations (or uncorrelations) when the large areas are measured before decomposition.

³ Compare coefficients presented in tables 6.10, 6.11 and 6.12.
was observed previously for the categories of houses and blocks of flats. The association between global integration measurements and the increase in the density of mixed residences has proved itself rather consistent throughout the current sample. The results above have also acknowledged, to a large extent, the reliability and effectiveness of the decomposition strategy adopted. The consistent increase observed in the coefficients taken after the decomposition of the large areas of embedding seems to indicate that most of the proposed local areas tend to perform as effective areas of syntactic reference for the distribution of mixed residential uses.

This output is particularly evident in the cases of SA60, SA106, SA71, SA83 and most of all in one of the local areas emerged out of the decomposition of SB89 - that is SB62 - where both the coefficient and the probability of the correlation are quite high. The results have also shown that such a distribution - inside each one of the prescribed local areas - is consistently carried out according to rules coming from the global scale of the street grid. In other words, each one of these local distributions tend to assimilate the syntactic effects given by the interaction of each system with the surrounding areas.

The description above seems to embody at least some of the complexity that is inherent to the interaction and superimposition of local and global rules in the syntactic performance of naturally evolved urban environments and particularly in the pattern of land use distribution throughout the street grid. The results have shown consistently that yet the distribution is local (the higher coefficients will consistently occur for the local configurations) the rules that govern such a distribution are global. The correlations have consistently shown that global integration is - amongst the proposed syntactic parameters - the most effective in describing the current sample of mixed-residential distributions, even in a more consistent way than this same measurement has performed against the distribution of blocks of flats and actually levelling with the
performance observed for connectivity when this measurement is matched with the sample of houses.

A syntactic description for the distribution of housing estates

A fourth pattern of spatial distribution - distinct from the ones observed for the other residential categories so far discussed - will emerge from the matching of the sample of housing estates against the set of proposed syntactic parameters. Such a pattern holds some similarity with the performance observed for the already analysed sample of houses - in terms of an increase in density for the more segregated parts of the grid - yet the 'segregationist tendency' observed for that case (houses) will be very much stressed in the case of the housing estates. Not only the coefficients will get higher - in comparison with the ones observed for the sample of houses - but the probability of the correlations as well.

Apart from that for all syntactic measurements the correlations will get higher, although the measurements of integration and connectivity will share the most consistent results. This output is also distinct from the performance of the sample of houses, since for that case the conjectured 'segregationist' tendency is to a large extent supported by the negative coefficients observed for connectivity (increase in the density of houses coupled with the decrease of connectivity) while for integration the two measurements (dHOU and RRA) are virtually uncorrelated. This is not what happens in the case of the distribution of housing estates. Inside SA418 the matching of the proposed set of syntactic measurements against the distribution of housing estates has shown that the density of housing estates will increase consistently with the increase of RRA (decrease of integration) and also with the decrease of connectivity. Both coefficients are remarkably high for the current standards, yet
### Table 6.14
Distribution of housing estates and syntactic measurements in sector B: correlation analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>SB351</th>
<th>SB351 core</th>
<th>SB295</th>
<th>SB295 core</th>
<th>SB54</th>
<th>SB44</th>
<th>SB127</th>
<th>SB96</th>
<th>SB45</th>
<th>SB85</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 dHES x RRA</td>
<td>-.188</td>
<td>*</td>
<td>.161</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>.112</td>
<td>*</td>
<td>.245</td>
</tr>
<tr>
<td>2 dHES x RRemb1</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>.871</td>
<td>.857</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>3 dHES x RRemb2</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>.878</td>
<td>.858</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>4 dHES x CM</td>
<td>-.527</td>
<td>*</td>
<td>-.366</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>.427</td>
<td>-.237</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>5 dHES x LEN</td>
<td>-.689</td>
<td>*</td>
<td>-.523</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>6 dHES x LEM</td>
<td>-.644</td>
<td>*</td>
<td>.422</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

**Fig. 6.30** Distribution of housing estates in sector B

- **A** SB351 dHES x RRA  
  \[ R = .4 \ (p = .026) \]

- **B** SB351 dHES x LEN  
  \[ R = -.689 \ (p = .0001) \]
integration still presents the most effective performance (Fig 6.29 A).1

When SA418 is decomposed the concentration of housing estates left for three out of the four local areas emerged out of the decomposition of that system will not be large enough for providing statistical significance for the tests. Nevertheless in the system that carries the highest density of housing estates - that is SA184 - the number of observations will suffice this requirement. In this case the output confirms what was observed for the whole SA418. The correlation observed for global RRA presents the highest coefficient; \( R = 0.622 \) \((p=0.0001)\) (Fig 6.29 C). The correlation indicates that the density of housing estates will increase with RRA, i.e. with the decrease of integration. This result indicates that despite the high mean integration value of SA184 - very much enhanced by the straight connections between the lumps of short housing estates axial lines and the global integration core - the distribution of housing estates inside this system will consistently follow a pattern of segregation.2 In other words, the system as a whole is well integrated to the global scale, yet the highest densities of housing estates - at the level of each axial line inside the system - will be given by the most segregated parts of the grid.

The correlation was also measured for SA69, that is the same SA184 having the lumps of short axial lines deleted. In this case the number of observations decreases strongly since only the housing estates' constitutions that are attached to axial segments given by the pre-existing grid - the original grid before the development of the housing estates - have been computed. At any rate the results observed are also supportive of the conjectured segregationist tendency - the increase in the density of housing estates insofar as integration decreases (Tab

---

1 The sample of housing estates is entirely concentrated inside SA east (SA418) and SB east (SB295). The west parts of both sectors (SA143 and SB89) do not carry housing estates.

2 SA184 has the lowest RRA value (.76) amongst all SA east local areas. This output is presented in chapter five (table 1) and is referred to global integration values (measured for each system as interacting with the surrounding areas).
In this case the highest coefficient is given by connectivity but the coefficient observed for global integration is just marginally lower.

The results observed for the performance of the sample of housing estates in SB will confirm just partially what was observed for SA. If the whole SB351 is taken as the area of reference for the measurement the coefficient for integration will be $R = .400$ ($p = .0287$) (Fig 6.30 A). The coefficient is high but the performance of three particular axial lines (the three black dots at the lower tail of the distribution) is very much responsible for the correlation. If these three lines are not computed and the correlation is measured for the bulk of the sample the coefficient will collapse to $R = .007$ ($p = .9735$). For this case the performance of connectivity is more significant. The coefficient is higher than the one observed for integration and the distribution of points for the bulk of the sample is less dispersed in relation to the regression line than it is in the case of integration (Fig 6.30 B).

For SB295 the coefficients will decrease so suggesting that the pattern of segregation observed for the distribution of housing estates is more referred to the global scale - the whole SB351 - than to the more local scale given by the east part after decomposition (Tab 6.14). This is even more stressed when the distributions are plotted against syntactic measurements given by the local areas where the housing estates are located - SB127 and SB45 measured as detached from the surrounding systems. The coefficients for integration in this case will be also lower than the ones observed for SB351 (Tab 6.14). At any rate the set of results presented above holds a common tendency. All correlations, from the standpoint of the observed directions, point out towards an increase in the density of housing estates either following the increase of RRA or the decrease of connectivity. In this sense the results observed for the SB systems seem to be rather supportive of the conjectured tendency

---

1 Same as it has happened for the SA systems, the densities of housing estates inside each one of the SB local areas will not be high enough for providing statistical significance for the tests - apart from the cases of SB127 and SB45 whose results are given in table 6.14.
towards segregation as the predominant characteristic observed for the syntactic performance of housing estates so confirming what was observed for the sample of housing estates given by the SA sector.

These results apparently contradict what was noticed in respect of the performance of the mean densities of housing estates during the previous section. In that case the results have shown that for a significant part of the sample the mean density of housing estates increases with the increase of the mean integration value of the different systems. The contradiction, we suggest, is just apparent. The performance of SA184 provides a fair example of how these two performances – one at the level of the mean densities and other at the level of the syntactic character of each one of the axial lines inside the system – can coexist. In this particular case what the combined results suggest is that despite the fact that this system is relatively high in the rank of global integration (and also in the rank for densities of housing estates) if the distribution of estates is analysed inside the system, at the level of each axial line, the concentration of estates will follow the increase of segregation, in spite of the high degree of global integration noticed for that part of the street grid (SA184). Same as it has been noticed for the distribution of blocks of flats inside the more integrated systems, the distribution of housing estates in the east part of SA seems to provide another example of a distribution that searches for segregation, yet within a globally integrated pattern.

Notes on the syntactic distribution of residential uses

As a whole the results presented in this chapter suggest that each one of the four proposed residential categories performs quite distinctively from the standpoint of the syntactic character of the street grid. Both the densities of houses and the densities of housing estates tend to

---

1 The results given by the match of the proposed descriptions of grid configuration and mean residential densities have already been discussed at the end of that analytical procedure (pp. 349–354).
increase consistently in the more segregated parts of the grid. While for houses the distributions tend to be consistently more associated with the local scale of the street grid as given by the proposed areas of syntactic reference, for the sample of housing estates the distributions are consistently referred to the large areas of embedding and the areas of syntactic reference seem to be quite ineffective.

The distributions of blocks of flats have presented a more complex pattern where the search for integration - as observed for the systems where this category is more concentrated - is balanced with a search for segregation in the areas where the density of blocks of flats decreases. In this case the performance of the distributions has also shown a more effective relationship with the proposed areas of syntactic reference than with the proposed systems of interaction. By contrast the sample of mixed residences has performed quite distinctively in comparison with the three other residential modes. Following what was observed for the sample of productive activities the densities of mixed buildings will increase consistently with the increase of integration. In this case the distributions have shown a rather consistent association with global integration and, same as for houses and blocks of flats, all distributions are more associated with the local areas of syntactic reference than with the larger systems of interaction (where most coefficients have collapsed). Finally it is worth to mention the effective role of the measurement of connectivity in all residential distributions. This is distinct from what was observed for the distribution of productive activities where the measurement of integration is by far the most effective in describing the distribution of the different categories.
Chapter 7
Final Discussion

This research is just an initial step in the study of the association between land use and urban morphology. Further work in the field is most likely to extend the range of descriptive techniques applied here. The measurements of land use distribution, for instance might be the object of a comparative scrutiny where the constitution criterion is matched with other forms of land use measurement such as length of street façade, floor area and others to be thought. The same applies to the axiality of the street grid whose description has so far generated different syntactic measures and it is also most likely that many others are to come insofar as research evolves and computing facilities are made available. The land use classification introduced here might also be refined, not necessarily by extending their range but by identifying syntactic peculiarities within each use category. The assessment of the relationships between land use and morphology might also be enlarged by extending the range of statistical tests to be applied.

To summarize the set of results produced out of this investigation in a short report - as the one required for the conclusion of this work - is difficult, not only for the hierarchy of importance that has to be at any rate set up for defining which results are the most significant but also because there are isolated results buried in the bulk of this thesis whose significance may have not been fully realized and whose importance therefore not completely acknowledged. It is likely that further research on these topic might clarify the significance of these results. Nevertheless some results emerged from this study have presented clearly identifiable patterns and it is precisely these most recurrent patterns that are summarized in what follows.

The investigation of the relationships between land use distribution and syntactic descriptions of the urban space carried out during the last two chapters of this thesis has delivered interesting results. The measurement of  

---

1 An example of that is given by the investigation of the association between intelligibility, scale and size as proposed during chapter four (pp. 215–228).
To summarize the set of results produced out of this investigation in a short report - as is required for the conclusion of this work - is difficult, not only for the hierarchy of importance that has to be set up for defining which results are the most significant, but also because there are isolated results buried in the bulk of this thesis whose significance may have not been fully realized and whose importance therefore not completely acknowledged. It is likely that further research on this topic might clarify the significance of these results.¹ Nevertheless some results which have emerged from this study have presented clearly identifiable patterns and it is precisely these recurrent patterns that are summarized in what follows.

The investigation of the relationships between land use distribution and syntactic descriptions of the urban space carried out during the last two chapters of this thesis has delivered interesting results. The measurement of integration, it is worth mentioning at the outset, has performed as the most effective parameter not only in the description of the syntactic distribution of productive activities but also of residential uses.² This does not mean that the other proposed syntactic measurements - choice, connectivity and axial length - are uncorrelated with land use distribution. This is not the case. In practice the measurement of connectivity for instance has shown a consistent high performance in the description of residential distributions especially for

---

¹ An example of that is given by the investigation of the association between intelligibility, scale and size as proposed during chapter four (pp. 211–226).

² This applies for measurements taken at the level of each axial line inside each system yet not for the mean integration values observed. In this case - in terms of mean values - other syntactic measurements have performed more effectively than integration in describing how land use densities are distributed throughout the street grid. These measurements are axial fragmentation, tension and mean connectivity. These results are presented in chapters five (section grid configuration and density of productive activities, p.262) and six (section 'grid configuration and residential densities, p.315).
houses. Nevertheless despite the effective performance of other measurements for specific parts of the sample (or for isolated cases) the measurement of integration is, throughout the range of proposed tests, by far the most consistent parameter in describing the idiosyncrasies of each proposed land use category. It is also worth mentioning the effective role played by the measurement of integration in the proposed method of decomposition of the urban grid.

The syntactic performance of some land use categories might be regarded as predictable. It cannot be said that the strong association observed between patterns of integration and the distribution of shops is unexpected. Shops are adapted spaces that shelter activities which are by their intrinsic nature tied to the public dimension of the street grid (public oriented activities it might be said). If the number of shops a street carries is accepted as an indication of its public character it might then be said that such a public character has been consistently depicted by the axial lines at the top of the integration ranks throughout this investigation. Nevertheless the extent of such an association and especially the consistent way in which it is captured by the syntactic measure of integration throughout the current sample is far beyond the expected.

Moreover integration has also performed as a strong 'post-dictor' of the performance of the residential use, despite the strong correlations observed for connectivity when compared with all residential

---

1 Throughout the current sample the density of houses has decreased consistently with the increase of connectivity. These results are given in Fig. 6.16 for SA west (p.355), Fig. 6.17 for SA east (p.357) and Fig. 6.18 for sector B (p.359).
2 The measurement of integration is fully explained and discussed in chapter two of this thesis, section 'Measuring the configuration of the street grid' (pp. 76-86).
3 In this case the measurement of integration has evolved into the proposed patterns of 'overlap', 'definition' and 'difference'.
4 It is implicit here that the 'public character' of the street grid weakens in so far as the integration value of the axial lines decreases (increase in RRAs). From this point of view a residential cul-de-sac would be at the other end of the scale as a rather private space whose syntactic description will most probably correspond to lines at the bottom of the rank of integration (more segregated lines). Insofar as integration decreases the conjectured 'public character' is replaced by privacy (or segregation). This point is fully discussed in chapter two (pp. 76-86).
categories. Residential densities have consistently increased in the more secluded parts of the grid, following the decrease of integration. This might also be regarded as not totally unexpected especially if one believes that people tend to look for the more secluded environments for sheltering themselves.

Nevertheless the association between the increase of residential density and segregation has shown itself rather superficial, since it is mostly observed when residential uses are measured in their aggregate form. In fact the results observed after the disaggregation of the sample of residential uses have consistently shown that the association between patterns of integration and residential distributions takes place in a more complex way particularly when compared with the way in which integration and productive activities are related. This is what the distinct performances observed for each different residential category have indicated. The increase in the density of 'houses' and 'housing estates' in the more secluded parts of the grid is an expected result. The same cannot be said in respect of blocks of flats whose densities - despite an overall decrease with the increase of integration - have performed quite distinctively for a particular part of the sample where the densities of blocks of flats have increased consistently for the most integrating lines. These results coupled with the strong (and positive) association observed between the densities of mixed residences and the pattern of integration have shown that each one of the proposed residential categories has performed in a distinctive way so making it clear that the initially observed association between residential densities and segregation was misleading.

1 This expression is coined in Hillier et al., Natural Movement, op.cit.
2 It is worth to remind that a contrasting result is observed when the mean densities of housing estates are matched with mean integration values. This result is given in Fig. 6.07 G (p. 324) and indicates that for a significant part of the sample - which seems to be the most representative since it includes the systems that are strongly 'loaded' with housing estates - the density of estates has increased in so far as the mean integration values observed for the different systems increases (decrease in RRA).
3 These results are given in Fig. 6.24 B for SB44 (p. 367s), Fig. 6.22 A for SA418 (p. 365) and Fig. 6.21 E for SA21 (p. 364).
The 'predictable' strong association between shops and integration does not mean that the demand for integration is shared by productive activities as a whole. Pointing towards an opposite tendency the performance observed for offices and industries has delivered equally interesting results. The match of the distribution of offices and patterns of integration has shown a consistent increase in the density of offices following the increase of integration at the core level. For this specific part of the sample the syntactic performance of offices is rather similar to the performance of shops. For both categories density values increase consistently with the increase in integration. On the other hand a rather consistent association with segregation was observed for the remainder of the sample.

It has been explained earlier in this thesis that high rents and outmoded buildings are accelerating the exodus of businesses (offices) to the greener and, in the case of Porto Alegre, cheaper suburbs which from the syntactic standpoint seem to correspond to the more fragmented systems inside the current sample or even the more segregated lines inside rather integrated areas (urban systems with low mean RRA value). For the majority of cases these offices tend to locate in adapted residential spaces (houses), whose densities have consistently increased in those more 'secluded' or 'less integrated' axial lines.

By contrast the output given by the performance of industries points explicitly towards an opposite direction as compared with what was observed for shops. The density of industries has decreased consistently with the increase of integration so making it clear the tendency of industries in keeping themselves apart from the most integrating lines.

---

1 A significant part of the sample of offices is located at main routes or at one axial step from a main route. For this part of the sample (offices located at the core level) the increase in the density of offices follows the increase of integration. These results are given in Fig. 5.20 C for SA299 (p.300) and Fig. 5.21 E for SB295 (p.305).

2 This specific topic has been discussed in chapter two, section 'On land use classification' (p. 97–105).

3 These results are given in Fig. 5.23 for SA west (p.309), Fig. 5.24 for SA east (p.310) and Fig. 5.25 for the whole sector B (p.311).
Here again the description given by the pattern of integration seems to match to a large extent what intuition has suggested.

Another interesting result was the 'intelligible' performance of the specific part of the sample of shops located at the core level. The correlations between the distribution of shops and the pattern of integration have presented a consistent increase for the most 'intelligible cores'. That is to say for the most 'intelligible cores' the association between density of shops and integration is consistently stronger. For the less intelligible cores the association between the distribution of shops and integration tends to collapse. The 'intelligible distribution of shops' at the core level seems to be much tune with the intuitively grasped demand of 'publicization' which is intrinsic to the shop activity, and eventually the stronger association between the density of shops and the pattern of integration observed for the more intelligible cores seems to provide a fairly elaborated syntactic counterpart.

The role of the measurement of integration in the description of land use distribution is made less effective when syntactic and land use parameters are matched in terms of the mean values observed for the different systems (system effects). When mean values are compared the performances of both productive activities and residential categories are more effectively associated to other syntactic measurements - especially axial fragmentation, tension and mean connectivity - than to mean RRA values (either for systems as detached or as embedded). A consistent increase in the mean density of productive activities was detected insofar as tension (as given by the average length of the axial lines inside each system) and mean connectivity increase and, as a consequence, insofar as axial fragmentation (as given by the density of

---

1 The cores where RRA and connectivity are more strongly related.
2 For the sample as a whole the increase in the density of shops has consistently followed the increase of the integration value of the axial lines (decrease of RRA). Nevertheless the coefficients get consistently stronger for the cores where RRA and connectivity are well correlated, the most intelligible cores from the syntactic point of view.
3 These results are discussed in chapter five (p. 286 and 290).
axial lines per area) decreases. The less fragmented systems are the ones that carry the highest densities of productive activities.\(^1\)

It is also noteworthy that the distinct performance observed for the distribution of shops, offices and industries, as referred to above, is to a large extent reflected in the performance of these three categories when their mean densities observed for the different systems are matched with the mean values observed for different syntactic measurements, i.e. the proposed 'descriptions of grid configuration'. The association between the mean density of shops and axial fragmentation for instance is outstanding. Nevertheless for offices and industries the coefficients have consistently dropped so indicating the lesser extent to which these activities are related to the syntactic character of the street grid (as given by its degree of axial fragmentation).\(^2\)

This result has confirmed to a large extent the conjecture raised at the outset with respect of the distinct 'spatial requirements' demanded for these three land use categories - shops, offices and industries. Densities of shops are consistently well correlated with most syntactic measurements so reflecting the conjectured strong association between locational requirements for commercial activities and the syntactic character of the street grid. For offices the conjectured syntactic 'locational requirements' have also held yet the 'office purpose' does not seem to be so dependent on 'locational facilities' as shops are. By contrast industries have shown a consistently greater degree of 'independence' in relation to the syntactic character of the urban grid.\(^3\)

The syntactic performance of the observed mean residential densities has also delivered interesting results. The performance of houses has shown that for the parts of the street grid where integration - as given

---

1 These results are given in Fig. 5.07 (p.272).
2 These results are also given in Fig. 5.07 (p.272).
3 This applies for the mean values observed for syntactic and land use data. When values observed at the level of each axial line are compared the sample of industries has shown a clear tendency towards segregation.
by the mean RRA value of the system - decreases tend to be the ones that carry the highest residential densities. ¹ It has also been observed that this tendency towards segregation is not necessarily followed by a loss of syntactic intelligibility. In effect the correlation between the density of houses and intelligibility is high and positive when the more intelligible systems are plotted as a separate sample.² It has also been observed that the mean densities of houses have consistently increased following the increase of axial fragmentation yet this applies just up to a certain degree of fragmentation. From then on - for the most fragmented systems - the density of houses decreases being then replaced by a consistent increase in the density of housing estates.³

The mean densities of blocks of flats have in general performed in the opposite direction when compared with the densities of houses. The densities of blocks of flats have increased consistently for the less fragmented (and more integrated) systems. Nevertheless when the most integrated systems were plotted as a separate sample the increase in the density of blocks of flats has changed its direction so following the pattern of segregation.⁴ That is to say although the density of blocks of flats as a whole tend to increase for the most integrated configurations, once inside these most integrated systems the highest densities will be observed for their most segregated bits locally. This result has produced the conjecture that the part of the sample of blocks of flats that is located inside the most integrated systems (systems with the lowest mean RRA values) tend to segregate themselves within the pattern of integration.

¹ So following what was observed when syntactic and land use measurements observed at the level of each axial line were matched.
² This result is presented in Fig 6.08 F (p.328). The number of observations is restricted to the twelve most intelligible systems which correspond to 50% of the sample. For the remainder of the sample the density of houses will be virtually uncorrelated with intelligibility values.
³ The performance of the densities of houses against axial fragmentation is shown in Fig. 6.10 E (p.334).
⁴ This result is given in Fig 6.07 B and C (p.324).
Throughout the experiments referred to above the degree of association between residential densities and syntactic measurements is consistently lower when compared with the much stronger coefficients observed when the densities of productive activities are matched against the same set of configurational parameters. This has allowed for the conjecture that the syntactic dimension of the street grid is more effective, or more directly associated with the performance of productive activities than it is with the residential use. This conjecture finds support when the sample of mixed residences is compared with any of the syntactic measurements. The coefficients observed for mixed residences are consistently higher than the ones observed for any other residential category. As it has been explained, the sample of mixed residences is in effect a part of the sample of productive activities and the high correlations observed for this particular category (mixed residences) have for most cases matched the coefficients observed for productive activities (especially the ones observed for shops).

The sample of mean densities of housing estates has also delivered interesting and somewhat unexpected results. The relationship between housing estate and segregation which is so often taken for granted - as the review of literature has shown - is not at all clear for the sample investigated in this study. When all systems that carry housing estates were compared the density of housing estates has indeed decreased with the increase of integration. In other words for the sample of mean densities as a whole the increase of segregation has brought about an increase in the mean density of housing estates. Nevertheless for a significant part of the sample the direction of the correlation is explicitly inverted as, for example, in the case of systems such as SA184, SA128 or SA45 which despite the high density of housing estates are relatively well integrated systems.

---

1 An example of that is given in Fig. 6.06 and 6.07 (pp. 321-324) where mean integration values are matched with the mean densities of the different residential categories. The coefficients observed for 'mixed residential buildings' are consistently higher than for the other categories.

2 For this part of the sample - which seems to be the most representative since it includes the systems that are more strongly 'loaded' with housing estates - the density of estates will
The contrasting performance referred to above is not observed when these same densities of housing estates are matched with intelligibility values. In this case the performance of the sample has clearly suggested that the less intelligible systems tend to carry the highest densities of housing estates.\(^1\) The same might be said in respect of the relationship between the densities of housing estates and the measurements of axial fragmentation and tension. Housing estates tend to be concentrated in the more fragmented parts of the grid or to bring about the axial fragmentation of the grid if, as it has already been suggested, the argument is put the other way around.\(^2\)

As a whole it might be said that the most conspicuous feature observed in the set of results produced out of this study is the markedly distinct 'syntactic demands' observed for the distribution of the different land use categories. These demands are represented in the enclosed set of diagrams, which provide a comprehensive view of the areas of syntactic reference observed for the different land use categories. Different land uses seem to coexist inside the same urban areas yet governed by rather distinct syntactic rules. In this sense it might be said that the results observed in this study have provided some clarification on the syntactic dimension of the 'natural zoning hypothesis' based upon the configuration of the urban grid.\(^3\)

In this respect the work of Jacobs (1962), as reviewed in chapter one of this thesis, has provided precise insights which are parallel if not coincident with the most general hypothesis raised at the outset of this study. Jacobs has suggested that mixtures of uses and frequency of streets are the most effective factors in generating diversity in urban areas only because of the way they perform.\(^4\)

---

\(^1\) This result is presented in Fig 6.09 E and F (p.330).

\(^2\) These results are in Fig. 6.11 E and F (p.338).

\(^3\) This is discussed in chapter one (pp. 32-39).

The contrasting performance referred to above is not observed when these same densities of housing estates are matched with intelligibility values. In this case the performance of the sample has clearly suggested that the less intelligible systems tend to carry the highest densities of housing estates.1 The same might be said in respect of the relationship between the densities of housing estates and the measurements of axial fragmentation and tension. Housing estates tend to be concentrated in the more fragmented parts of the grid or rather to bring about the axial fragmentation of the grid if, as it has already been suggested, the argument is put the other way around.2

As a whole it might be said that the most conspicuous feature observed in the set of results produced out of this study is the markedly distinct 'syntactic demands' observed for the distribution of the different land use categories. Different land uses seem to coexist inside the same urban areas and yet be governed by distinct syntactic rules. In this sense it might be said that the results observed in this study have provided some clarification on the syntactic dimension of the natural zoning hypothesis based upon the configuration of the urban grid.3

In this respect it is worth to bring back into this discussion the work of Jacobs (1962), already reviewed in chapter one of this thesis, which has provided precise insights which are parallel to if not coincident with the general hypothesis raised at the outset of this study - the association between the distribution of uses and spatial morphology. Jacobs has suggested that mixtures of uses and frequency of streets are the most effective factors in generating diversity in urban areas only because of the way they perform.4 Jacobs proposition is relevant in the context of the current study for the association it implies between functional

---

1 This result is presented in Fig 6.09 E and F(p.330).  
2 These results are in Fig. 6.11 E and F(p.338).  
3 This is discussed in chapter one (pp. 32-39).  
Areas of syntactic reference for the distribution of shops

The diagram shows in red the areas of syntactic reference according to which the distribution of shops in sectors A and B takes place. The increase in the density of shops is consistently associated with the increase of the integration value of the axial lines (embedded values). Shops are for most cases distributed according to syntactic rules given by the second order decomposition of the grid. The distribution of shops is low correlated with integration when its distribution is measured in relation to the whole SA east. Although when the system is decomposed, for the four systems given by second order decomposition the correlations will increase (tab 5.04).

The same applies for SA west where the association between the distribution of shops and integration also emerges only after the second order decomposition. In this case the part of the sample of shops within SA30 remains strongly associated with integration after the third order decomposition (tab 5.03). In SB east the pattern is again reproduced. The association between the distribution of shops and integration gets stronger only after the second order decomposition. SB45 is in this case the exception to the rule. The sample of shops located in this part of the grid remains strongly associated with global integration even after the third order decomposition (tab. 5.05).

The west part of sector B performs distinctively if compared with the three previous cases, that is to say, it performs as a whole in relation to the distribution of shops. The coefficients collapse for SB62 although the part of the sample of shops located within SB30 remains strongly correlated with global integration (tab. 5.05). Apart from SB127 in all other cases the highest coefficients are observed for integration values for each system as embedded.
Areas of syntactic reference for the distribution of offices

The diagram represents in green the systems where the distribution of offices takes place following the pattern of segregation and in red the systems where the distribution tends to follow the pattern of integration. For three out of the four systems produced out of first order decomposition - SA418, SA143 and SB89 - the tendency of the distribution is inverted at the core level (axial lines represented in red). That is to say, despite the overall tendency towards segregation, when the core lines are dealt with as a separate sample, the density of offices will increase for the more integrated lines.

The distribution of the sample of offices located within SB east - measured as a whole - is associated with segregation. Although when SA418 is decomposed the correlations get stronger and the distribution of offices becomes associated with the pattern of integration emerged from second order decomposition (red systems). This applies to global integration values (RRAemb). In three out of the four SA east local areas the density of offices increases for the most integrating lines while for one system - SA106 - the density of offices decreases with the increase of integration (tab. 5.07). The same does not apply to SA west. In this case the distribution of offices correlates weekly with segregation when the system is measured as a whole and when SA west is decomposed the distribution will remain attached to the pattern of segregation. For the western part of the grid the syntactic distribution of offices is referred to the systems emerged from third order decomposition (SB30 and SA34). For the remainder of the sample of offices the distribution will be referred to SA77 as its area of syntactic reference (tab. 5.06).

For the whole sector B the distribution of offices is virtually uncorrelated with integration. Nevertheless after the first order decomposition the distribution will become fairly associated with segregation following the performance observed for SA east and west before their decomposition (tab. 3.08). For the SB systems the number of office buildings that is left for each sub-area after second and third order decompositions is not large enough to allow for a statistical significance of the tests.
Areas of syntactic reference for the distribution of industries

The distribution of industries both in sectors A and B is consistently associated with the pattern of global segregation (RRAemb). Industries tend to segregate themselves in the grid and such a pattern of segregation is consistently set up according to global RRA values. In the case of SA east the areas of syntactic reference for the distribution of industries are given by the second order decomposition of sector A - SA71, SA72, SA106 and SA184 (tab. 5.10). The same applies for SA west although in this case for the part of the grid which carries the highest density of industries - SA34 - the coefficient will remain high especially for local RRA values so showing that the particular strong concentration of industries within that part of the grid is laid out according to local syntactic features (tab. 5.09). The association of industries and segregation is confirmed to all extend in sector B (east and west). In this case the number of industries that is left for each sub-area after second order decomposition is not large enough to allow statistical significance for the tests.
Areas of syntactic reference for the distribution of houses

The density of houses is consistently associated with the pattern of segregation throughout the current sample. House densities increase regularly insofar as the integration value of the axial lines decrease. In the case of SA east the most effective area of syntactic reference for the distribution is the whole SA106. The more labyrinthine part of the grid at northeast (SA106) is an exception. The association between density of houses and segregation is improved for SA106, one of the systems emerged out of second order decomposition. In this case - SA106 - the scale of reference that delivers the highest coefficients is given by the embedding of the system in the whole SA east (tab. 6.05). For SA west this picture changes. The distribution of houses is hardly correlated with RRA values given by SA143, although when the system is decomposed the areas of syntactic reference for the distribution of houses might be identified. These areas are given partly by a second order decomposition (SA77), and for the remainder of the system by a third order decomposition (SA30 and SA34). In this case the strongest coefficients are given by connectivity measurements, that is to say, the increase in the density of houses is more associated with the decrease of connectivity than with the pattern of segregation given by RRA values (tab. 6.04).

The distribution of houses in sector B reproduces to a large extent what was observed for the same distribution in SA west. The two cases coincide in respect of their association between house densities and connectivity values instead of RRA values. Also in both cases the correlations will get stronger only after second and third order decompositions. In SB east, SB127 and SB83 will deliver the highest coefficients, and when SB127 is further decomposed the association between houses and connectivity in SB45 gets even stronger. The same applies for SB west where only the second order decomposition of the system provides an association between the distribution of houses and either RRA's or connectivity values (tab. 6.06).
Areas of syntactic reference for the distribution of blocks of flats

The syntactic distribution of blocks of flats in sectors A and B alternates a search for integration observed in some parts of the grid - systems represented in red - with a search for segregation observed in others - systems represented in green. When the part of the sample that is located in SA east is measured as a whole an association with integration emerges. Nevertheless when the system is decomposed, two out of the four areas given by second order decomposition will perform in an opposite direction. For SA106 and SA184 the density of blocks of flats will decrease insofar as global integration values increase (tab. 6.08).

For SA west the opposition between integration and segregation is again reproduced, although in this case throughout the second and third order decompositions of that system. In SA60 the density of blocks of flats increases for the more segregated parts of the grid while for the remainder of SA west the correlation collapses (SA77). Nevertheless for SA21, that is the portion of the grid where the density of blocks of flats is the highest within the current sample, the densities will increase consistently with integration (tab. 6.07).

Similar pattern is reproduced for sector B. In this case there is an overall tendency towards segregation that is observed both for the whole sector B and also for the first order decomposition (SB east and west). Nevertheless when a second order decomposition is introduced the polarity between integration and segregation will emerge again. For SB east while in part of the system the density of blocks of flats will increase with integration (SB4/44) for another sub-area (SB127) the association with segregation remains. For SB east the pattern is repeated. While for SB62 the overall tendency towards segregation is again reproduced, for SB30 the density of blocks of flats will be strongly associated with global integration values (tab. 6.09).

1 In SB83 blocks of flats are virtually uncorrelated with all syntactic measures.
Areas of syntactic reference for the distribution of mixed residences

The syntactic distribution of mixed residences follows to a large extent the pattern observed for the distribution of shops. Mixed residences are consistently distributed according to rules given by second and third order decompositions while the coefficients observed for first order decompositions are consistently lower. This applies for both sectors A and B. In all cases, except for SA21, the increase in the density of mixed residences is consistently followed by an increase in the integration value of the axial lines (systems in red). In SA21 the tendency is inverted and the density of mixed residences for that specific part of the sample will increase for the most segregated lines (tab. 6.10).
Areas of syntactic reference for the distribution of housing estates

The diagram shows the areas of syntactic reference according to which the distribution of housing estates takes place. In all cases the increase in the density of housing estates is associated with a decrease in the integration value of the axial lines. The housing estates that are concentrated within SA184 (red perimeter in the diagram) are distributed according to global syntactic rules given by the whole SA east (the whole in green). For the concentration of housing estates located inside SB45 (the red perimeter in the middle of the whole sector B) the distribution is even more globally oriented and takes place according to syntactic rules given by the whole sector B (in green).
(mixture of uses) and morphological (frequency of streets) factors as far as 'generating diversity' is concerned. It is precisely the 'way they perform', which is acknowledged yet not identified by Jacobs, that has been scrutinized during the current investigation. It might be said that the range of rather peculiar associations observed between syntactic variables and the different land use distributions have to a large extent supported Jacobs' proposition that the 'intricate minglings of different uses in traditional cities are not a form of chaos but instead a complex and highly developed form of order'.

That is to say a syntactic order that is consistently associated with the distribution of land uses in the urban field. In other words the set of results observed during the current investigation might be regarded as a possible description - of syntactic nature - for the functional diversity so often found in unplanned settlements where different uses inside the same urban area perform according to distinct spatial rules.

The more economic-oriented dimension of the 'natural zoning hypothesis' as represented in the work of Siegan (1973) was not a concern for this thesis. Nevertheless it seems reasonable to conjecture that Siegan's 'strategic locations' might be effectively described by syntactic instruments. It is not suggested here that the conspicuous concentration of particular uses in certain 'portions' of the street grid, as so often noticed in this investigation, is brought about by the syntactic factor or grid effects. Nevertheless the evidence presented has shown that the performance of specific spatial variables (of a syntactic nature) is strongly and systematically associated with the socio-economic

1 Ibid. p.177.
2 The work of Siegan has been reviewed in chapter one of this thesis (pp. 35–39). Siegan's central hypothesis is that there is inherent in the market place a 'planning mechanism' that tends to separate and allocate different activities according to economic requirements related to 'strategic locations' in an urban system. Siegan departs from a harsh criticism on zoning procedures and concludes by suggesting that economic forces tend to make for a separation of uses even without any zoning. Siegan's sample has indicated that business uses tend to look for certain locations, residential in others and industrial in still others; these uses will 'mix naturally' according to economic locational demands: 'A nonzoned city is a cosmopolitan collection of property uses. The standard is supply and demand, and if there is economic justification for the use, it is likely to be forthcoming'. This is in Siegan, B. Land Use Without Zoning, op.cit. p. 76.
dimension of the urban phenomenon as given by the proposed measurements of land use distribution. In other words the syntactic factor seems to set up a spatio-morphological background which acts in parallel to the number of factors which affect the spatial distribution of urban activities in towns.¹

Despite the interesting results observed in this study for the association between form and function at the urban scale it might be said that the main contribution of the current work to the field is in its methodological approach. The axial representation of the street grid, as proposed by Hillier and Hanson, and the description of land use distribution by constitutions, as proposed in the current investigation, are both spatio-morphological criteria, i.e. both descriptions are based upon the spatial character of the urban grid. In a field where form and function have been dealt with almost as if they were distinct subjects - as the review of literature proceeded in chapter one of this thesis has shown - such a 'comprehensive approach' becomes in itself significant.

As it has already been observed the description of the urban space based upon axial lines and constitutions seems at a first sight to be just another version of the most general (and already standard) way of decomposing urban systems in terms of 'movement channels' and 'built forms'.² The limits of this type of procedure have been clearly identified by Anderson: 'Many of the bordering accessed spaces are in such dynamic interaction with the channels that neither the channel nor these adapted spaces can be understood if they are analytically sliced apart.'³ It is precisely in this sense - as identified by Anderson - that the analysis of

¹ These socio-economic factors (or at least some of them) have been discussed during the review of literature presented during chapter one of this thesis.

² The review of literature has shown many versions of this sort of decomposition. Doxiadis, for example, terms these same elements as 'networks' and 'shells'. The Centre for Land Use and Built Form studies at the Cambridge University also make 'networks' and 'adapted spaces' its basic distinction. The operational aspects of this type of procedure is described in detail by Cheesman et al., in the 'Data Bank' for the LUBF studies on English New Towns. This is in chapter two of this thesis (pp.91 - 97).

urban systems in terms of 'axial lines' and 'constitutions' differ from the propositions referred to above. Since both axial lines and constitutions are spatial components of the street grid, an account of the configuration of the public open space based upon the identification of these categories seems to be an efficient way of describing urban spaces without 'slicing them apart'. Both the axial dimension of the street grid and the connections between building interiors and public open space are spatial characteristics of the same phenomenon, i.e. the spatial-morphology of the urban space. Apart from that the analytical procedure based upon axialities - how far one can see and how far one can go - and constitutions - degree of permeability between public and private domains, depicts a phenomenon which seems to correspond, as closely as possible, to the way in which the street grid is actually understood and used.

It is also worth to acknowledge that some of the basic methodological propositions put forward by the current investigation have already been suggested, yet not developed, by other authors. The method for describing of the spatial continuity of the urban grid proposed by Anderson is an example. Anderson has proposed the translation of the urban plan into base graphs that may be analysed topologically. This method, he suggests, 'will not only allow the comparison of different graphs, but also the storage of different types of information, such as the designations of types of accessibility, ownership structure, land use distribution...'. In effect the method of analysis applied to the current investigation might to a large extent be regarded as a specification of Anderson's proposition.

Anderson also anticipates that his base graphs may permit systematic and comparative descriptions of the transformational rules that relate

---

1 As the literature reviewed in chapter one in this thesis has shown.
2 These graphs 'by retaining their metric and topographical reference may also be analyzed metrically or statistically. This is in Anderson, S. Ecological model of the urban environment in 'On streets', Cambridge, Mass, Mit Press(1978), p.284.
3 ibid. p. 284.
one pattern of spatial organization to another. Both his proposal of *loading lines* with socio-economic information and also the possibility of proceeding with *comparative descriptions* based upon topological properties of the street grid are methodological procedures that have been systematically utilized during the empirical part of this thesis. Nevertheless it is worth remembering that however Anderson's base graph resembles in its linearity an axial map, it is precisely the translation of the actual street plan into a diagram of axialities, as proposed by Hillier and Hanson, that has made it possible the description and *measurement* of the syntactic character of the urban grid, which has played an essential role in the development of this thesis.

The roots of the methodological development followed by the current investigation might also be found in the work of Lynch (1981).¹ In his *Theory of Good City Form* this author has criticized the standardized planning procedures that have systematically dealt with patterns of land use distribution without taking into account the spatial properties of the urban phenomenon: *'The familiar land use map is a constant subliminal pitch, urging us to consider spatial patterns in this map-pattern mode'*.² Lynch has acknowledged the necessity of linking a network representation of the urban spaces to the representation of land use distribution. His concern is focused on the problem of measurement of accessibility, in topological terms: *'we might map the degree of access, at any point, to the activities at other points of a settlement and so short out a long circuit of street networks'*.³

Lynch seems almost to anticipate the description of patterns of land use distribution from the stand-point of the syntactic character of the urban space as carried out by the current research. For both these authors what actually matters is that form and function must be dealt with from the standpoint of the physical dimension of the urban phenomenon, and more

¹ The work of Lynch, in what it is relevant for the purposes of the current investigation, has been reviewed in chapter one of this thesis (pp. 37–39).
³ ibid. p. 358.
specifically from the standpoint of its spatial configuration. By following this line of investigation the response given by the current study seems to be in tune with the current demands of the urban studies, i.e. demands for a 'comprehensive morphological approach' in order to study the urban phenomenon.

Looking deeper into the specificity of syntactic studies this thesis has contributed to the field by its proposition for an objective method for decomposing the urban grid for analytical purposes. In this respect the performances of 'ruptures in traverse permeability' and 'choice boundaries' has delivered a rather coincident set of spatial boundaries. These boundaries ended up by defining the contour of a diversified sample of grid configurations. Furthermore the description of these grid configurations has not only given rise to informative measurements but also allowed for the comparison of the configurational features observed for each one of these systems with the corresponding land use densities. The procedural string described above shows the essential role played by the decomposition strategy in the subsequent steps of this investigation where different areas of syntactic reference are compared with land use data.

Some light has also been shed on the problem of describing the degree of syntactic autonomy of the different parts of the urban grid. Here again the performance observed for the pattern of integration - as measured by 'overlaps', 'definitions', and 'differences' - has proved itself a rather effective analytical tool. Here again it is likely that further research in this specific topic might provide more effective ways of measuring the extent of the 'syntactic autonomy' of urban areas. At any rate the output given by this investigation has clearly shown that the proper definition of spatial boundaries must be regarded as an essential pre-requisite in

---

1 In these experiments the measurements of 'overlap' and 'definition', as proposed by Peponis, have also proved themselves as quite effective instruments in describing the complex relationships between local cores and global core lines. These measurements are proposed in Peponis, J. The spatial core of the urban culture, op.cit. This part of the analysis is developed in chapter three.
any syntactic study of urban grids, simply because the demarcation of inadequate spatial boundaries might lead to totally ‘distorted’ measurements and certainly to totally misleading inferences.

The descriptions of grid configuration carried out during chapter four of this investigation - by *examining the quantitative dimensions* of the spatial continuum and *exploring the internal logic of relations between syntactic variables* - have provided an advance in relation to other descriptive methods.¹ The proposed analytical instruments have described in a precise way the extent to which a wide range of grid configurations are distinctive from one another.² The syntactic measurements proposed for describing the set of ‘visually observable’ features have also performed as effective instruments for detecting subtle distinctions between visually similar grid configurations.³

It was suggested earlier in this study that the understanding of the performance of these ‘visually observable’ features might provide a useful set of urban design tools within easy reach of the eyes and hand of the urban designer. Since these measurements are obtained from direct observation of the axial map they are in fact available in a more direct way than ‘deep structure’ measurements - patterns of integration, distribution of shortest paths, intelligibility - whose identification through direct visual inspection can easily misguide the observer and whose more accurate measurement will necessarily require computer

---

¹ Other descriptive methods have been discussed in the review of literature carried out in chapter one. As a whole the works reviewed share the common feature of being quite ineffective in the description of actual grid configurations and especially as instruments of comparison between actual cases. This is particularly evident in the more detailed classifications, such as Lynch’s or Krier’s for whom the matching with actual urban grids shows straightforward the narrow limits of such classification efforts. A synthesis of these ‘typologies’ is given in Fig. 4.01 (p. 202).

² Not only from their ‘local’ point of view but also in terms of how these part relate to the global scale.

³ The measurements of axial fragmentation and tension have performed consistently more effectively than mean RRA values in the description of the mean densities observed for different land use categories, especially productive activities.
A syntactic typology of grids based
on axial fragmentation and global
intelligibility

The first type is represented by the systems in
red, where a low degree of axial fragmentation is
followed by a high global intelligibility. These
systems are the west parts of sectors A and B.

Another type is given by the griddy systems
(systems with a low degree of axial
fragmentation) which are low in the rank of
intelligibility. These systems emerge when the
grid is decomposed. This second type - yellow in
the diagram - is represented by SB30 that is one
of the systems given by the decomposition of SB
west and also SA21 and SA34 that are third order
decompositions of SA west. This second type also
includes SB54/44 which is the part of the more
fragmented SB east where the grid becomes more
orthogonal.

In green are the systems where axial
fragmentation increases and such an increase is
followed by a decrease of intelligibility. These
are the systems at east in both sectors A and B.
Their performance is exactly the opposite if
compared with the systems in red where a low
degree of axial fragmentation is coupled with a
high intelligibility.

Amongst the more fragmented systems (or more
labyrinthine) there are some which are high in
the rank of global intelligibility. This fourth type
is represented in blue in the diagram. These
systems are SA184 and SB45.

Griddy and intelligible
Fragmented and intelligible
Griddy and less intelligible
Fragmented and less intelligible

1 This typology is discussed in detail in chapter
four (pp. 238 - 240).
generated ranks. The proposed set of 'visually observable' seems in effect to perform as a sort of 'façade' which to a large extent embodies and anticipates the 'deeper' syntactic identity of each system. The enclosed diagram which presents a 'typology of grids' based on axial fragmentation and intelligibility, is an effort of identifying regularities in the relationship between a visually observable feature of the grid (axial fragmentation) with a deep structure measurement (global intelligibility).

Nevertheless the relevance of the current study to the urban design practice shall not be reduced to the 'descriptions of grid configuration' referred to above. The procedures developed during this thesis, as a whole, have provided a range of results which make it clear the descriptive power of the syntactic approach and its potential as instrument of analysis and thus as an instrument of design.

The same might be said in respect of the matching of configurational properties and land use distribution as carried out during chapters five and six of this thesis. These procedures seem to be much in tune with current demands of the urban design practice, especially in relation to the design of 'urban voids' inside larger urban areas where the lessons to be learnt from the way spatial form and land use relate in 'naturally evolved' towns seem to be essential for a proper assessment of the relationships between the old (the pre-existing urban fabric) and the new (the scheme to be proposed). This is to a large extent a syntactic problem which has much in common with the relationships between local areas and systems of interaction as proposed by the current investigation.

---

1 The measurement of tension for instance is given by the average length of the axial lines and as such can be directly derived from the axial map. The same might be said about axial fragmentation that is given by the ratio between the number of axial segments and the area of the system.

2 Syntactic analysis has already been utilized as instrument of design in the urban development of King's Cross, London (Unit for Architectural Studies, Bartlett School, 1989).
generated ranks. The proposed set of 'visually observable' characteristics have performed as a 'façade' which to a large extent embodies and anticipates the 'deeper' syntactic identity of each system.

The relevance of the current study to the urban design practice shall not be reduced to the 'descriptions of grid configuration' referred to above. The procedures developed during this thesis, as a whole, have provided a range of results which make it clear the descriptive power of the syntactic approach and its potential as instrument of analysis and thus as an instrument of urban design.

The same might be said in respect of the matching of configurational properties and land use distribution as carried out during chapters five and six of this thesis. These procedures seem to be very much in tune with current demands of the urban design practice, especially in relation to the design of 'urban voids' to be redeveloped within larger urban areas where the lessons to be learnt from the way spatial form and land use relate in 'naturally evolved' towns, seem to be essential for a proper assessment of the relationships between the old (the pre-existing urban fabric) and the new (the scheme to be proposed). This is to a large extent a syntactic problem which has much in common with the relationships between local areas and systems of interaction as proposed by the current investigation. The analytical procedures developed during this thesis also apply to the activity of masterplanning where the study of the syntactic dimension of land use distribution might show itself an effective instrument in the description of 'natural zoning tendencies' inherent to the spatial configuration of the urban grid.

The lessons to be learnt from the syntactic performance of land use distributions are likely to be by far greater than the results delivered by

---

1 The measurement of tension for instance is given by the average length of the axial lines and as such can be directly derived from the axial map. The same might be said about axial fragmentation that is given by the ratio between the number of axial segments and the area of the system.

2 Syntactic analysis has already been utilized as instrument of design in the urban development of King's Cross, London (Unit for Architectural Studies, Bartlett School, 1989).
the current investigation. Nevertheless these incipient results have provided a fair demonstration of the potential conveyed by the investigation of land use from the standpoint of the syntactic dimension of the urban phenomenon.
Bibliography

Alexander, C. A city is not a tree, in Architectural Forum N° 122, April/May 1965.
Aymonino, C. El significado de las ciudades, Blume Ed., Barcelona, 1970
Batty, M. Recent Developments in Land Use Modelling, Urban Studies, Vol.9 1972.


Cheesman, R.; Lindsay, W. and Porzecanski, M. *New Towns: the data bank, its construction and organization*, Land Use and Built Form Studies, University of Cambridge, Department of Architecture 1972.


Doubleday, C. *Some characteristics of the built stock in Reading*, Land Use and Built Form Studies, University of Cambridge, Department of Architecture 1974


Hagget P. and Chorley, R *Network Analysis in Geography*, Edward Arnold, London, 1969


Hillier, B. *Axis as Symbol*, Unit for Architectural Studies, Bartlett School, 1983.


Hillier, B. et al *Mansion House Inquiry*, Unit for Architectural Studies, Bartlett School, 1984

Hillier et al. *Natural movement: or, configuration and attraction in urban pedestrian movement*, Unit for Architectural Studies,


Horton, R., *Drainage Basin Characteristics*, in Transactions of the American Geophysical Union, no13, 1932


Huff, D. *Determination of Intra-Urban Retail Trade Areas*, Los Angeles, University of California 1962.


Kruger, M. *An approach to built form connectivity at an urban scale*, Environment and Planning B, 1979, Vol 6


Thorpe, H. The Green Villages of County Durham, Trans. Institute of British Geographers, 1951
Land use distribution in sector A

Activity Group | Adapted Space
---|---
Productive Activities | Shops, Offices, Industries
Residential Activities | Houses, Blocks of Flats, Mixed, Housing Estates
Land use distribution in sector B

<table>
<thead>
<tr>
<th>Activity Group</th>
<th>Adapted Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productive Activities</td>
<td>Shops</td>
</tr>
<tr>
<td></td>
<td>Offices</td>
</tr>
<tr>
<td></td>
<td>Industries</td>
</tr>
<tr>
<td>Residential Activities</td>
<td>Houses</td>
</tr>
<tr>
<td></td>
<td>Blocks of Flats</td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
</tr>
<tr>
<td></td>
<td>Housing Estates</td>
</tr>
</tbody>
</table>

North