The Fragmented Morphology of Spontaneous Settlements: The case study cities of Jeddah (Saudi Arabia) and Zahedan (Iran)

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Abstract

The rapid expansion of spontaneous settlements is an inevitable response to the increasing poor population in the Third World. These urban areas usually exhibit morphologic irregularities that are conventionally associated with enduring poverty. Nonetheless, cases are reported in which simultaneous physical and socio-economic self-improvements gradually transform a degraded settlement to a consolidated area. Accordingly, the thesis aims at revisiting the relation between irregularity and consolidation in spontaneous settlements. The hypothesis is that morphologic irregularity does not impede the consolidation of spontaneous settlements in long-term.

A theoretical framework is developed in which consolidation is associated with the gradual fulfilment of dwellers’ respective economic and territorial preferences. The theoretical framework also suggests that consolidation is reflected in the formation of local centres within spontaneous settlements. The hypothesis is then tested in two cities of Jeddah (Saudi Arabia) and Zahedan (Iran). Geometric accessibility is the key notion that relates irregularity and consolidation. Firstly, it is illustrated that higher accessibility in intermediate level enforces consolidation. The internal spatial structure of a spontaneous settlement is where higher intermediate accessibility facilitates consolidation through organizing the distribution of commercial land use. Also the lower city-wide accessibility of spontaneous settlements is reported.

Irregularity and accessibility are related in the next stage. Irregularity is redefined as fragmentation (or the higher diversity in urban blocks’ orientations) to prove that the case study settlements are more fragmented than their formal urban surroundings. Then it is heuristically illustrated that fragmentation decreases the city-wide accessibility of a settlement without impeding the emergence of its internal spatial structure. The thesis concludes that consolidation of a spontaneous settlement is facilitated when the lowered city-wide accessibility caused by fragmentation fulfils the dwellers’ territorial preference while at the same time the emerged internal spatial structure satisfies their economic preference in an intermediate accessibility level.
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Chapter 1: Introduction

Introduction

Informal settlements are understood to be the primary affordable housing solutions for the increasing population of the urban poor in developing countries (UNCHS, 2003a; 2008) although these places usually suffer from a lack of basic infrastructure, high population density, sub-standard building construction and illegal or unclear legal status that labels them as slums. The rate of urban population growth in developing countries is higher in harsh and inequitable economical circumstances and it is exacerbated by inadequate housing policies, which is claimed to be the main reasons behind the shortage of affordable housing (UNCHS, 2003a). This, in turn, has led to an increase in slums -that encompass spontaneous settlements as one of their categories- to accommodate less advantaged socio-economic citizens or the urban poor.

In 2003, realizing the increasing proportion of the world’s poor urban population by at least 30 percent who live in such slums, international bodies were motivated to improve the living condition of 100 million of those dwellers by 2020 that is known as the Millennium Development Goal, target 11 (UNCHS, 2003a/2003b; Moreno and GUO, 2003). As a result, at an international level, there has been more interest in programs and policies that aim at improving the informal settlements’ condition through provision of basic infrastructure, financial aids and protecting their dwellers from eviction through legal means (for example see Cities Alliance, 2008). These programs are termed ‘upgrading’\(^{1}\) which encompasses both the physical and socio-economic improvement of an informal settlement and is based on the idea that

\(^{1}\) also called ‘settlement upgrading’ (Oliver, 2007), ‘urban upgrading’ (The World Bank Group, 1999), self-help and ‘in situ upgrading’ (UNCHS, 2003a)
such areas have the potential to self-improve or ‘consolidate’ themselves: “ … [Pacione, 1996, Page 528, in defining the consolidation of informal settlement] Many settlements that originated as unserviced agglomerations of huts gradually develop to become recognised suburbs in the Third World city”. According to this view of informal settlements as potential ‘housing solution’, (Turner, 1988) the role of officials is then to facilitate the consolidation process through supporting adequate policies and implementing improvement plans.

A significant but gradual change in the scope of upgrading approaches is the inclusion of spatial and physical aspects of the targeted settlements in order to identify and hence direct the efforts to the areas in more need of intervention (Sliuzas et. al, 2008). Moreover, it has been realized that some upgrading strategies that are appropriate for a certain spatial situation - arisen from the settlement’s location or size - might not be effective for another case (UNCHS, 2003a) while in some cases the morphologic irregularity of a settlement like its narrow roads and dense built fabric might even act as a barrier to its socio-economic development and upgrading (Mukhija, 2001).

Considering the urban morphology is challenging for upgrading schemes because a significant proportion of informal settlements in the Third World are formed on their own and without any planned supervision that results in very irregular urban layout. The formation of such settlements can either happen through occupying others’ land without permission (i.e. ‘squatter settlement’) or through illegal subdivision and selling of the land (named ‘illegal settlement’). The two latter groups (i.e. squatter and illegal settlements) are termed ‘spontaneous settlements’ which will be used in this study henceforth.

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2 This categorization is suggested by UNCHS (2003a) but other sources might put the two groups of ‘illegal’ and ‘squatter’ settlements in one category like Pacione (1996) or use different names like Davis that uses ‘squatter settlements’ and ‘pirate subdivision’ to distinguish the two (Davis, 2006).

3 Davis (2006) quotes from Baross and van der Linden (1990) that suggest illegal settlements are more likely to have orderly layout with equal size plots comparing to squatter settlements. The thesis however is not to distinguish the two categories of spontaneous settlement from each other due to the legal factors as it goes beyond the study scope.
to distinguish those from other categories of informal settlements. Barros (2004) also gives the following definition: “A spontaneous settlement, as a general concept, is understood as any settlement whose development is left entirely to individuals who live on the land, without any kind of plan or control” (Page 25).

The urban morphology of spontaneous settlements, interpreted with terms such as ‘chaotic’ or ‘disordered’ (see a full review in chapter 2) indicates that they are different from the conventional and planned urban forms. Such interpretations also imply the difficulty to spatially model and analyze the spontaneous settlements mentioned by some writers (Sobreira and Gomes, 2001; Sliuzas et. al, 2008). On the other hand, because of the non-compliance of spontaneous settlements with the urban planning conventions, their growth is usually considered something unwanted and hence unrecognized by the authorities and this in turn impedes further studies to be done to understand the resulted irregular morphology (Abbot and Douglas, 2003). Overall, some of the pronounced morphologic attributes of spontaneous settlements are ‘irregular’ and ‘fragmented’ (full review of the terms in chapter 2) that will also be used throughout this thesis which points to the deviation of these areas from the conventional attributes observed in formally planned areas such as geometric order and repetition of uniform built-elements.

The research problem

Although there has been many studies addressing spontaneous settlements, there is a lack of understanding of the way that their irregular morphology interacts with the socio-economic attributes of their dwellers. This problem is dividable into three separate but inter-related issues, where the first issue leads to the second and third problems. The first and the major problem is the lack of
an integrated theoretical framework that includes major physical and non-
physical poverty factors related to spontaneous settlements (as a category of
slums) that can explain their interaction which leads to consolidation or
otherwise degradation. The second issue is the lack of morphologic
interpretations that can reflect the dwellers’ socio-economic circumstances.
The third problem is the lack of understanding of the impact of morphologic
irregularity on the consolidation process. A brief explanation for each problem
is presented.

The first problem: Lack of comprehensive theoretical
framework for the consolidation of slums and spontaneous
settlements

Poverty and slums are closely related and are both multi-dimensional issues,
that is, their status is the result of interaction among several factors. Although
poverty studies address the cause-effect relation between factors (such as
income and education) in reinforcing or easing further deprivation, they do not
pay enough attention to the physical and spatial aspects that are crucial in the
case of slums and spontaneous settlements. On the other hand, the current
approaches to slums, although acknowledge the physical dimension of poverty,
they do not pay due attention to the interactions among a variety of factors and
the potentials for consolidation through these interactions. A key reason for
this shortcoming is lack of attention to the poor’s point of view and the way
they prioritize between the poverty factors in overcoming their limited
resources. When dealing with spontaneous settlements as a category of slums
with morphologic irregularities, the lack of such comprehensive theoretical
framework leads to two other problems.
The second problem: Lack of a socio-economically relevant interpretation of morphologic irregularity

The second problem that results from the lack of knowledge about the interaction of poverty factors (i.e. the first problem), is the difficulty with socio-economic interpretation of the irregular physical fabric of the spontaneous settlements. A hasty conclusion would be that poverty and irregular morphology are directly causing and reinforcing each other agreeing with the same deterministic approach to built-environment and society that lead to the cleansing of spontaneous settlements in the Early Modernist era (Mukhija, Page 215).

Moreover, irregularities such as deviation of urban layout from geometric order, does not necessarily imply social disorganization and economic problems as is demonstrated by organic cities (see Karimi, 1997 in chapter 2). Furthermore, the socio-economic condition in a spontaneous settlement does not always remain at its initial poor status as implied by the definition of consolidation indicating simultaneous self-improvement in physical and socio-economic factors; In this regard, one might find relatively intensive clusters of commercial activities (or internal markets) within some of these areas that emerge with no prior plan and in a seemingly irregular manner. Such clusters while manifesting themselves as local centres –the thesis will argue- can be considered as indicators of ongoing economic improvement and contributors to further consolidation.

In other words, the second problem is the lack of understanding of how the irregularity of urban fabric and land use in spontaneous settlements as a physical factor can reflect the ongoing dynamism of socio-economic poverty factors (i.e. improvement or degradation). This in return requires a deeper understanding of the incremental growth process and its resultant irregularities as a reflection of dwellers’ economic and social preferences. In this regard,
there has not been enough attempts to interpret aspects of irregularity (e.g. the seemingly unplanned land use distribution and the heterogeneous built-up density) in order to infer the underlying socio-economic circumstances in the spontaneous settlements.

The third problem: Lack of explicit theoretical framework to formulate the impact of irregularity on socio-economic circumstances

The third problem is lack of understanding of the impact of the irregular morphology on the course of socio-economic changes and consolidation. Most of the current studies on the irregularity of spontaneous settlements limit their assessment to the socio-economic results of low accessibility in a conventional geographic sense (i.e. difficulty in reaching activities from a certain point of origin). The reasons for low accessibility are mentioned—by these studies—to be the narrow or unpaved roads or the very irregular urban fabric. However, there is no explicit approach to relate the irregularity of the urban fabric and accessibility. Moreover, the notion of geographic accessibility can explain aspects of poverty based on unavailability of services and facilities to the dwellers but it cannot explain why there are internal markets (emerged as dense linear arrangement of commercial land use) within some of spontaneous settlements. This weakness can be attributed to the very foundation of the notion of geographic accessibility which deals with places as points in a large-scale space but less concerned about the geometry of street network in fine-scale, especially its linearity⁴.

⁴ These weaknesses can be overcome—the thesis argues—by application of a finer scale notion of accessibility called ‘geometric’ accessibility that will be introduced in chapter 2.
**The aim and objectives**

Addressing the aforementioned problems, the main aim of the thesis is to develop a theoretical framework that relates the irregular morphology of spontaneous settlements to their consolidation process. The developed theoretical framework will then try to explain the consolidation from the point of view of dwellers’ preferences: if their two main preferred poverty factors – deducible from literature- are overcome in time (i.e. the income poverty and uncertainties regarding affordable shelter) then –despite the prevalence of other poverty factors – they can improve their status gradually that leads to consolidation. Each of the two preferences then is respectively translated into preferences for informal commercial activities (i.e. ‘economic preference’) and increasing territorial control (or briefly the ‘territorial preference’) through less accessibility from the formal city. An evidence for the first preference is the emergence of local centres (or internal markets) within spontaneous settlements. The evidence for the second one is the sense of belonging that the community develops towards its settlement.

This gives rise to the ‘dilemma of local centres’: while low accessibility is preferred by the dwellers to satisfy their territorial preference, the local centres require higher accessibility for connecting to the wider city and fulfilling the ‘economic preference’. Consolidated settlements should provide a clue to this dilemma. As will be seen, irregularity of urban fabric (or ‘fragmentation’) might play a role in solving this dilemma.

As a result the thesis will pursue four main objectives. The first one is to infer the degree of consolidation through examining the formation of local centres. The second objective is to apply an appropriate measure of accessibility (and not the mentioned geographic accessibility as it is too coarse) to find the logic

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5 As will be explained in the second chapter this territorial sense of belonging also solidifies the community of dwellers against threats of eviction.
behind the formation of local centres within spontaneous settlements. In other words, using the measures of geometric accessibility (see definition in chapter 2) can help with quantifying the accessibility of street network in a settlement to find the logic of commercial land use distribution. The third objective is to develop a measure of fragmentation to quantify the irregularity of case study spontaneous settlements. The fourth and final objective is to illustrate the effect of urban block fragmentation on the accessibility of street network through analyzing hypothetic layouts.

**Hypothesis**

The hypothesis of the thesis is that the fragmentation of urban blocks (as a measure of morphologic irregularity) can contribute to the consolidation of spontaneous settlements. In this relation, fragmentation, through its impact on accessibility of the street network has two major impacts on consolidation: First, it makes the internal areas of the settlement less accessible from the city-wide that fulfils the dwellers’ ‘territorial preference’ and in favour of the overwhelmingly residential land use of these areas. Second, the fragmentation contributes to the formation of an internal street structure (see below) in a spontaneous settlement that organizes the commercial land use due to its higher local accessibility. The previous commercial activity would satisfy the dwellers’ ‘economic preference’. The fulfilment of the two preferences then should lead to consolidation.

It should be stressed that the emergence of an internal street structure in cities and settlements in general is predicted by theories of geometric accessibility (known as the field of ‘space syntax’). The ‘structure’ in this regard is a connected set of settlement-wide highly-accessible streets, stretching from the centre of a settlement to its edges with more concentration of commercial and public land use alongside its alignments (see chapter 5). Although the
emergence of this structure is predicted to happen not only in spontaneous settlements but generally in gradually growing urban settlements and cities (see the review of ‘deformed wheel pattern’ by Hillier, 2001 in chapter 5), the thesis argues that fragmentation can also facilitate this emergence by making the internal structure more distinct from its context.

**The research methodology**

The study of different morphologic and socio-economic aspects of spontaneous settlements regarding their consolidation requires techniques for storing, analyzing and interpreting different sorts of spatial data. This can be best done in GIS (Geographic Information Systems) software where different layers of data such as land use, infrastructure, population and buildings can be recorded and analyzed independently or in combination. GIS techniques of density-diversity calculation (Batty et. al, 2003) will be specifically applied to the footprint and land use data to quantify the strength of local centres in spontaneous settlements. The density-diversity measurement of the case study spontaneous settlements will then be compared against a variety of other factors such as the settlement age, residential area per dweller and distance from the city centre using a combination of GIS and statistical techniques. This comparison is to show that the density-diversity measure can sufficiently reflect the consolidation ratio of the case study spontaneous settlements.

Afterwards, the measures of geometric accessibility of street network will be calculated in space syntax software Depthmap (Turner, 2001) and the outcome will be incorporated into GIS environment as a separate data layer. This allows for the assignment of accessibility measures to buildings which already have land use data. The Gini coefficient of inequality calculation can then show how the distribution of commercial buildings with regards to their accessibility rank deviates from a random pattern; the non-random distribution highlights the
existence of an internal street structure within the case study spontaneous settlements. The effect of this local structure on the consolidation ratio of the settlements will be examined as the last step in the empirical accessibility analysis.

Also, to quantify the irregularity of the urban fabric in spontaneous settlements, measures of shape directionality and elongation will be developed and applied to the case study cities. The measures are easy to calculate in GIS environment and the outcomes will then be summarized using a particular kind of radar diagram developed in the field of directional statistics. The radar diagrams will be mainly used to compare the diversity of blocks direction in spontaneous settlements against the formal part of the city. The radar diagrams will show that the spontaneous settlements are more fragmented than the rest of the city (the more diverse the direction of urban blocks, the more fragmented an area is). Finally, to show the impact of observed fragmentation of urban blocks on the accessibility of street network, some hypothetic (or heuristic) layouts would be designed and analyzed with space syntax software.

**The case studies and data limitations**

This study would mainly focus on two case study cities from the Middle East (more specifically Islamic countries). The city of Zahedan has been selected as the case study for its considerable proportion of spontaneous settlements. Zahedan is located in the south-east region of Iran close to the border with Pakistan and Afghanistan. It is a relatively recent city adopted as the official capital of the province by the central government in 1930s and since then the city has been experiencing a quick increase in urban population. The population reached about 550,000 in 2001 according to the official announcements which is slightly 32 times more than the 17,000 in 1950s
(IMH UD/WB, 2003, Piran, 2000). The last source underlines that this growth has been mostly due to migration flows of surrounding rural areas and partly afghan refugees fleeing their country during the political conflicts of 1980s. The result of this population growth, coupled with a highly polarized and inequitable socio-economic structure of the city has given rise to vast areas of spontaneous settlements in it with quite distinct morphological characteristics comparing to the rest.

The second case study of this research, city of Jeddah is also located in the Middle East but has a longer history compared to Zahedan. Moreover, Jeddah is sufficiently larger than Zahedan with about 2.56 million citizens by 2001 (Beeah, 2001) and has a more strategic location in its region due to its function as the gateway for pilgrims that enter Mekkah and Medinah each year. Jeddah shows an exponential rate of population growth in recent years and after the economic boom of 1980s (due to the national oil resources) it has started to absorb more immigrants from within and outside the country (ZFP, 2003). Because of the larger size of the city, the morphological and locational differences amongst its spontaneous settlements are starker than Zahedan. As a result of these differences and in order to perform comparable analyses of the spontaneous settlements from the two cities of Jeddah and Zahedan it is of great importance for the thesis to be clear about the available data for each city and its limitations.

It should be reminded that the datasets for Jeddah and Zahedan are gathered by different institutions and therefore the resulted differences in their formats, geographical spreads and accuracies should be considered before doing any comparison between the two cities. For example, some socio-economic data is gathered by WB/IMHUD (2003) for the whole city of Zahedan. The final results of this survey are available as raster images exported from GIS software that are not finer than urban block level (the aggregation in urban block level was done to keep the households’ privacy). While this data can not be used for
any precise and fine-scale analyses in Zahedan as it is not in vector format, such socio-economic data for Jeddah is not available. Instead there are building-related and infrastructural data available for only the spontaneous settlements of Jeddah in the fine level of individual land plots.

The above circumstances make it necessary for the thesis to conduct its core analyses by using only datasets that has the same format and geographical spread for both of the cities. These basic datasets are mainly (1) the city road maps, (2) land use in the plot level and (3) building footprint maps. These three components are available for each respective city covering all urban areas within their municipal boundaries including the spontaneous settlements. Moreover, the population of each spontaneous settlement is available for Jeddah and Zahedan and the figures can be used in conjunction with the land use dataset to calculate the provision of residential and public built-area per head of the dweller. Other kinds of available data such as Zahedan socio-economic data or Jeddah infrastructural data (just available for the spontaneous settlements) can be used in a complementary manner for qualitative comparison with the main analyses performed on the three basic datasets mentioned above.

The other data-related issue is the lack of fine-scale chronologic data such as time series aerial images of the two studied cities and their spontaneous settlements. For example, the stages of urban growth can be roughly inferred for Zahedan using the available aerial images taken in 1940, 1974 and 1987. However, the long time span between the snapshots does not allow for tracking the gradual development of Zahedan spontaneous settlements. As a result, finding out how the building footprint pattern in the year 2000 – available in vector format for the whole city of Zahedan- is arrived at, cannot be done with sufficient accuracy. This problem is exacerbated for the case study city of
Jeddah because the stages of urban growth were only inferable from the schematic maps presented in various reports⁶.

Overall the thesis makes use of secondary data sources for its empirical analysis. This is mainly because of the time and budget limitations that did not allow for the thesis to perform extensive field studies. As a result of this limitation and particularly in the case of socio-economic factors (e.g. crime and employment) there has not been any direct data collection from the communities using questioner, focus groups or other methods and instead the existing official reports done by others are used whenever necessary. Nonetheless, the author has had trips to Jeddah and Zahedan in order to familiarize himself with the urban environment of the studied spontaneous settlements. These trips were also helpful in understanding the overall atmosphere of the studied areas while it was possible to check the correctness of the base maps meanwhile each site visit.

**Outline of the thesis**

Chapter two will introduce the spontaneous settlements and slums in the context of urbanizing Third World cities. The literature review will cover the major approaches to slums and the closely related notion of urban poverty. The intention of the second chapter is to provide a theoretical framework in which the different physical and non-physical poverty-related factors are categorized along with the mechanisms that their interaction leads to consolidation or degradation of a settlement. This is done based on extracting the poor’s priorities from the literature that suggests fulfilment of their two main preferences (i.e. economic and territorial) would facilitate consolidation. Spontaneous settlements will also be introduced as a category of slums with

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⁶ Even if a sufficient number of aerial photo snapshots were available for both cities, it would still be very laborious to extract the building footprints data in vector format from those.
morphologic irregularities. Including irregularity in the theoretical framework would then bring questions about its impact on consolidation through satisfying or hindering the dwellers’ main preferences. The theoretical framework also underpins the idea that consolidation while is reflected as simultaneous reduction of physical and non-physical poverty, can be measured through its physical manifest that is the higher built-up density and more land use diversity in a settlement (i.e. having stronger local centres). Finally and reviewing the literature on the impacts of irregularity on consolidation, chapter 2 inevitably appraises the notion of geographic accessibility (and its shortcomings) used in conventional studies of spontaneous settlements. This is a pretext for using more appropriate definition of accessibility in chapter 5.

The next two chapters will introduce the two respective groups of case study spontaneous settlements in the Middle Eastern cities of Zahedan in Iran (Chapter 3) and Jeddah in Saudi Arabia (Chapter 4). The beginning of the third chapter will present a brief comparison between Iran and Saudi Arabia in terms of their urban issues especially related to poverty and slums. Both chapters 3 and 4 aim at introducing the case study settlements in their urban contexts with limited referral to the wider national and regional context in which their respective cities are located. As it will be shown many of the circumstances giving rise to slums in the Third World are observable in the two studied Middle Eastern cities. Chapters 3 and 4 will then establish the ratios of consolidation for the case study spontaneous settlements through examining the strength of local centres in those areas. The results of consolidation measurement will also be checked against other socio-economic and physical factors indicating that the age of examined correlates with the consolidation ratio. One raised question at the end is then how areas with similar ages have different consolidation ratios.

Chapter five would begin with a brief review of the notion of accessibility in the context of urban studies particularly in the case of slums and spontaneous
settlements. It will be argued that the general definition of accessibility is relatively too coarse in dealing with the local attributes of spontaneous settlements such as their land use distribution. The solution then would be to use a finer scale definition that is more sensitive towards the street layouts and geometry of spontaneous settlements (called geometric accessibility). This will be accompanied by some theoretical and methodological debates about performing geometric accessibility analysis and the research field that is mostly concerned about these issues i.e. ‘space syntax’. The chapter will then further develop by performing the geometric accessibility analysis for both groups of spontaneous settlements in Zahedan and Jeddah and interpreting the results. In the next stage, the commercial land use distribution in the spontaneous settlements will be analyzed against the accessibility measures to detect the impacts of their internal spatial structure. The hypothesis is that the more accessible the internal structure of a settlement from an intermediate urban level, the higher its impact on the commercial land use distribution and hence the more distinct the local centres formation will be as an indicator of consolidation.

Chapter six would focus at developing a new concept of morphologic irregularity that can be related to geometric accessibility. It will be inferred that such definition of fragmentation should be based on the geometric shape and direction of urban blocks. For this purpose, a brief review of the term fragmentation in urban studies and its closely related fields (e.g. geography) will be presented. The chapter then continues with a brief review of the existing measures of shape directionality and elongation to highlight the necessity for a new approach. The chapter would argue that such new approach should focus on the shape boundary for its calculation to be able to capture accessibility-related properties of urban blocks. Then a new mathematical concept of shape directionality and elongation will be put forward along with the GIS techniques and the statistical procedure to measure the fragmentation of urban blocks in urban areas. The method will then be applied to the case
study spontaneous settlements to illustrate the higher ratio of their fragmentation compared to the formal parts of their surrounding context.

Chapter seven would aim at understanding the impact of urban blocks fragmentation –observed empirically in the previous chapters- on the particular accessibility pattern of the streets (observed in chapter 5). The chapter would take a heuristic approach in which some hypothetic urban layouts will be designed for the purpose of the accessibility analysis. These experimental layouts will be attempts to imitate the effect of urban block fragmentation on breaking (or interrupting) the linearity of the street network. As will be shown, in this way the fragmentation reduces the overall accessibility of settlement while makes it sensitive in a way that a slightly more linear alignment can distinctively emerge as its internal street structure.

Chapter eight will put together the outcomes of different chapters to synthesize a conclusion. To do so there will be return to the theoretical framework set up in the second chapter in order to revisit the role of morphologic irregularity (conceptualized as urban block fragmentation) with regards to the consolidation of spontaneous settlements. Further steps for the development of this line of research will be suggested after highlighting the significance, limitations and contributions of the thesis.
<table>
<thead>
<tr>
<th>Stage</th>
<th>The corresponding chapter(s)</th>
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| Stage 1: Background and theoretical framework | Chapter 1: Introduction  
Chapter 2: Spontaneous settlements in the Third World cities and their consolidation |
| Stage 2: Empirical | Chapter 3: Urbanization in Iran and Saudi Arabia and the spontaneous settlements of Zahedan (Iran)  
Chapter 4: Spontaneous settlements of Jeddah  
Chapter 5: Accessibility analysis of the case study spontaneous settlements  
Chapter 6: Empirical examination of urban block fragmentation |
| Stage 3: Heuristic and synthesizes | Chapter 7: A heuristic approach to fragmentation and accessibility  
Chapter 8: Conclusion |

Table 1.1- Main stages of the thesis and their correspondence with the chapters.
Chapter 2: Spontaneous settlements in the Third World cities and their consolidation

Introduction

In 2008, for the first time in history the urban population on the planet outnumbered the rural population (UNCHS 2008). This rapid process of urbanization has had a significant pace in the developing world; for example in the period between 1995 and 2005 the population of cities in these countries has grown by an average of 1.2 million people per week. The fast pace of urbanization has coincided with major issues of unprecedented urban poverty fuelled by the flux of in-migrants to the cities and the proliferation of slums from which a considerable proportion are in form of unplanned (or spontaneous) settlements. The latest estimations by UN-Habitat (UNCHS, 2008) reveal that during the last decade in spite of decline in the proportion of Third World urban population living in inadequate housing condition in slums, the absolute number has grown from about 650 millions in 1990 to around 825 millions in 2010 (Ibid. Page 32).

With practical questions facing the decision-makers, urban authorities, planners and academicians about the relation between slums and urban poverty there has been a growing appreciation of the multi-dimensionality of both phenomena, including spatiality, as an important aspect of both poverty and slums. The multidimensionality of each phenomenon indicates that the dynamism in their overall condition (i.e. improvement or exacerbation) is the result of interaction among different factors. Some of these factors like employment and secure ownership of shelter are of higher importance for the urban poor and preferred by them as their priorities. Not fulfilling such
preferences would result in both economic poverty and degrading physical condition of a settlement. In the opposite scenario where the poor manage to resist relocating incidents such as eviction or gentrification, they might have more chances for consolidating their settlement through gradual gains from meeting their preferences. This inevitably leads to the spatial concerns regarding the slums or other places where the poor choose to live. What determines the poor in-migrants to decide on their location in the city? Why do they cluster at some areas? What determine the size of a slum and how does it grow with regards to the surrounding urban areas? These spatial questions are important for programs aiming at alleviating poverty or improving slums (i.e. 'upgrade' those) through highlighting the opportunities that could be exploited or the problems that should be dealt with.

Although slums are introduced as a physical manifestation of urban poverty, the relation between the two is not simple. It should be stressed that although slums and urban poverty are closely related, not all the poor live in slums and not all the slum dwellers are poor. Understanding such interaction between poverty as an overwhelmingly non-physical issue and slums and spontaneous settlements as mainly physical urban entities is important in answering some key questions relating the consolidation or self-improvement of slums. For example, how can the officials make sure that their investment to upgrade a slum does not lead to gentrification during which the poor leave the improved area and dwell in another slum? What physical factors attract the poor to come and cluster in a slum? How does poverty and physical deprivation reinforce each other and how can planned interventions break the self-feeding cycle of physical and non-physical poverty in favour of consolidation? One should see the complexity of such questions when dealing with spontaneous settlements as a category of slums with physical characteristics most of which is expressed through the morphologic irregularity: how does irregularity of urban fabric interact with poverty?
In this regard, the current approaches to poverty and its measurement (e.g. reviewed by Haughton and Khandker, 2009) cannot be applied in the case of slums and spontaneous settlements as such approaches generally ignore physical factors such as built-up qualities. However, the spatial nature of poverty is appreciated in some of the current approaches (See ‘The spatial dimension of poverty and its mapping’ in this chapter). On the other hand, the prevalent approaches to study slums (See ‘The operational definition of slums’ below) have started to appreciate the distinct physical features of these areas to identify or map them though these approaches usually do not take into account the socio-economic factors and their interaction with physical ones with potentials for degradation or consolidation.

In the case of spontaneous settlements, this shortcoming can be extended to the way the irregular morphology of the settlements reflects and influences the non-physical poverty factors. The negative effects of irregularity are mostly expressed through lowering accessibility but the question is whether it has any positive impact that is preferred by the poor in overcoming aspects of poverty and moving towards consolidation in long term. Moreover, examining the notion of accessibility in the context of slum studies show it is mainly based on the metric distance to different destinations (or attractors) in a Cartesian coordinate system. This definition known as ‘geographic accessibility’ (Jiang et al, 1999), cannot explain socio-economically relevant issues such as the emergence of linear concentration of commercial land use within the spontaneous settlements and its effect on the consolidation. This is mainly because geographic accessibility in its foundations deals with destinations or ‘places’ as points (Ibid.) hence its measurement methods –as will be discussed in the last section- are generally inappropriate for dealing with urban layouts especially the linearity of the street network.

This argument requires a theoretical framework for the study of slums that first appreciates the multi-dimensional nature of poverty and locates the various
poverty factors in categories according to physicality/non-physicality and spatiality/non-spatiality. The theoretical framework should then highlight those poverty factors that are the most crucial from the poor's point of view as their preferences. This enables us to put forward a hypothetic process through which the interaction between poverty factors in the context of slums can lead to the fulfilment of the poor’s preferences and hence consolidation. An inferred assumption based on the literature is that physical and non-physical poverty factors are more likely to reduce in parallel during consolidation.

In the more particular case of spontaneous settlements this framework would make it possible to consider morphologic irregularity as their most pronounced feature in relation to other poverty factors. The theoretical framework can first suggest how the growth process in these areas can mark consolidation through physical factors such as land use patterns (i.e. the emergence of internal markets) and differences in built-up densities. In the second step, the theoretical framework would illustrate how irregularity –through its impact on accessibility– might help with dwellers’ dual preferences that are territorial and economic.

Outline

Following the aforementioned objectives, I will start this chapter by defining spontaneous settlements as a category of slums or informal settlements that generally reflect the urban poverty in physical dimension. Other sorts of slums different from spontaneous settlements and different terms referring to those will be also discussed. Then the focus will shift to urban poverty as a multifaceted phenomenon and its different components or factors will be discussed in the urban context of developing cities. The argument will be around the lack of physical and morphologic concerns in the existing approaches to poverty. This is of course not to undermine the spatial dimension
of poverty that is appreciated by the current approaches which constitutes the subject for the following section. This leads to a discussion on poverty maps that reflect such approaches with the ability of considering the effect of multiple factors in geographical space but not with proper attention to the morphology. However, the issue of spatial distribution would bring the question of why the poor citizens cluster in certain locations. In this regard, different theories will be reviewed that suggests physical factors such as inherent qualities of land as important as other socio-economic and ownership factors.

For gaining more insight into the physical characteristics of slums especially regarding the practical concerns of upgrading projects, the following section would address the 'operational' approaches to slums. Operational approaches lack due attention to the consolidation potentials caused by mere attention to limited physical factors in slums. In this regards, the concept of poor's preference will be extracted from literature to further assist the theoretical framework that explains the consolidation process and factors influencing this process. Addressing the spatial factors affecting consolidation would lead to the city-wide forces that the poor has to respond to by preferring some advantages over others. A few relevant models of Third World cities will be critically reviewed in order to understand the overall urban structure where slums and spontaneous settlements are located with a brief reference to the classic urban models that underlie those models of Third World cities. These models, despite the general picture that they provide of the cities, can be criticized for their lack of attention to the ‘micro’ or local -level interactions.

The final part will then focus on the local properties of spontaneous settlements as a particular group of slums. A main characteristic of spontaneous settlements will be discussed as their irregularity that arises from the local-level decisions during their piecemeal and incremental growth. The growth process –as will be argued in next relevant section- has implications for the
consolidation while it can also result in morphologic irregularities. The relationship between irregularities, the dwellers' preference and potentials for consolidation will be the next point that will be discussed with particular stress on the notion of accessibility. Finally, it will be revealed that the conventional notion of accessibly (or ‘geographic accessibility’) is not easy to relate to socio-economic poverty factors in the studies of spontaneous settlements.

**Spontaneous settlements as a category of slums**

As was mentioned in the introductory chapter, more than one third of the world population, mostly in the developing countries, are living in inadequate housing referred to as ‘slums’ or ‘informal settlements’. A large proportion of such informal settlements are due to the lack of housing which are formed as spontaneous settlements around the developing cities. In this study, spontaneous settlements refers to the informal areas built and occupied by low-income citizens in the absence of planning interventions, located either in the inner parts of the city or on the periphery. Potter and Lloyds Evans (1998, P. 140-1) deem the term ‘spontaneous settlements’ more appropriate for referring to the irregular morphology of a category of low-income housing areas with an incremental formation process “being based on slow infiltration and individual initiatives” [Ibid.]. This thesis also uses the term ‘spontaneous’ in a morphologic sense and regardless of the ownership or locational issues. 

Based on this definition, one might wonder about the wider category of low-income or informal housing to which spontaneous settlements belong. The poor might also obtain their shelter through other means e.g. renting in mass housing estates or high density tenements with overstretched infrastructure.

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7 This definition of spontaneous settlements is similar to that used by the Expert Group Meeting on slums as ‘incremental and unstructured’ informal areas (Sliuzas and others, 2008). However, this idea of spontaneous settlements as areas with ‘lack of spatial order’ will be relaxed by this thesis suggesting that the morphologic irregularity does not necessarily mean the lack of spatial structure.
Because most of these housing areas either lack basic infrastructure or suffer from multiple deprivation factors, they are referred to as ‘slum’. A general definition of ‘slum’ can be found in dictionaries such as the Oxford advanced learner's dictionary of current English: “an area of a city that is very poor and where the houses are dirty and in bad condition” (Hornby, Ashby and Wehmeier, 2000). Alternatively, because the low-income housing areas usually contravene with formal planning regulations of land occupation/construction they are called ‘informal settlements’. The two terms are used interchangeably in major recent sources especially UNCHS (2003a) and throughout this thesis. This should be added that an informal settlement can be regularly laid out for different reasons: it can be a dilapidated housing estate based on a formal and regular plan or it can be overstretched and highly subdivided residential fabric but originated from initially orderly plots of land, in any case in slum condition. In contrast, spontaneous settlements show signs of layout irregularity as a result of their incremental formation process.

Of the four terms related to ‘spontaneous settlements’ i.e. ‘peripheral settlements’, ‘squatter settlements’, ‘unplanned settlements’ and ‘irregular settlement’ the third and fourth ones are the closest to the meaning of ‘spontaneous settlements’. It is because the first one has locational connotation referring to marginal places while in many cases a spontaneous settlement can grow in inner parts of a city (See Jeddah in chapter 5 or Rio’s favelas by O’Hare and Brake, 2003). The second term, squatter settlement although is used as a proxy for spontaneous settlement, has legal connotations, referring to the cases where the land owner has not given any permission to the dwellers to occupy or build in it. This is despite the fact that in some spontaneous settlements the land owner can subdivide and sell his/her land in an illegal

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8 Some writers like Obiefuna, G. U (1999) uses the spontaneous settlements referring to all categories of informal settlements.

9 UNCHS (2003a, Page 10) uses the term ‘spontaneous squatter settlements’ or Sobreira and Gomes (2001) use both attributes of ‘squatter’ and ‘spontaneous’ for referring to the same settlements.
market so the dwellers are not always ‘squatting’ but are on an ‘illegal settlement’ or ‘pirate subdivision’; the term 'spontaneous settlements' would then include both cases of squatting and illegality. The adjectives ‘irregular’ and ‘unplanned’ are the closest terms to ‘spontaneous’, the former as an outcome of spontaneity and the latter as a condition before and throughout the settlement’s growth. However, due to consistency, the term ‘spontaneous’ will be used in the thesis as a category of slums or informal settlements. Also, there are myriad of local names for spontaneous settlements. Those related to the case studies of this thesis in Iran and Saudi Arabia will be addressed later on.

From a global point of view, most of the spontaneous settlements are currently growing in the cities of the Third World\textsuperscript{10}. The reason for this concentration is claimed to be the increasing urban poverty exacerbated by the weak economy of these countries resulting in degraded housing areas facing with harsh life condition and multiple deprivations. The higher land and property value in this context leaves the poor with no choice but to use unconventional ways to obtain shelter in unattractive or unsupervised vacant land. The illegal or informal status of spontaneous settlements causes their exclusion from the urban services and infrastructure that goes hand in hand with other poverty factors both physical (such as substandard construction) and socio-economic issues (e.g. unemployment or illiteracy) to create a cycle of deprivation, squalor and slum condition.

The slum condition observed in spontaneous settlements and other low-income housings has different dimensions that need to be further explored because it is different from sole socio-economic poverty. Slums are “physical and spatial manifestation of urban poverty and intra-city inequality” (UNCHS, 2003a, P. xxvi). It suggests that slums have distinguished physical features that indicate

\textsuperscript{10} Although there is no accurate statistics on the matter but according to UNCHS (2003a, page 246) the ratios of slum dwellers in ‘developed regions’ and ‘developing regions’ are 6 and 43 percents respectively that shows a considerable difference that can be assumed for spontaneous settlements as well.
the less well-off status of its dwellers in a tangible way such as decaying environments or prevalence of shanty buildings. Moreover, slums are spatial in the sense that their limits, area and location can be marked in the geographical space considering their distinct physical attributes. These attributes of physicality and spatiality will be further defined here. The physical attributes are different in nature though they can be originated from socio-economic poverty or reinforce it. In the context of slums a similarity between physical and non-physical factors is that both groups can be considered in geographical space like in poverty maps (defined later in this chapter). Also, the two groups of physical and non-physical poverty factors as will be shown here do not necessarily coincide perfectly. A rough example is when a spontaneous settlement still remains dilapidated (although not necessarily for a long period) despite socio-economic improvement in its dwellers’ status (Giusti de Pérez and Pérez, 2008).

The previous example also was to remind that despite the initial poor condition slums, these do not remain in the same condition constantly. This is reflected in the categorization of ‘slums of despair’ and ‘slums of hope’ by Stokes (1962) in which the former are deprived areas suffering from interrelated poverty factors manifested in physical and socio-economic degradations while the later self-improving settlements that overcome their deprivation gradually and become recognized parts of the city (in that case the settlements is ‘consolidated’). These processes are regardless of the irregularity of a settlement as a spontaneous settlement on the city fringe might become consolidated while a public housing compound despite its regular layout remains degraded that is called ‘slum estates’ by UNCHS (2003a, P. 81). The conclusion is that the term ‘slum’ on its own does not have any negative connotation because it can self-improve and hence the authorities can see these areas as 'housing solutions' rather than 'deficits' (Turner, 1988).
**Urban poverty in the Third World**

Despite the emphasis on the physical aspects of slums, the main contributor to their formation that might stay with their dwellers is urban poverty. What is poverty then? Britannica (2009f) gives the following definition: “the state of one who lacks a usual or socially acceptable amount of money or material possessions... Poverty has been associated, for example, with poor health, low levels of education or skills, an inability or an unwillingness to work, high rates of disruptive or disorderly behaviour, and improvidence”. Even this brief description suggests that poverty has more than one aspect such as income.

In their manual for analyzing poverty, Haughton and Khandker (2009) points to three main broad approaches to poverty and its measurement. The first approach deals with lack of command over commodities and resources that are usually measured against one’s income using a monetary threshold. The second approach is about the inability to obtain particular sorts of goods for consumption that can be nutritional, educational or health care. The third, as the source claims is the widest approach and maintains that poverty is a multifaceted phenomenon arisen from the lack of multiple key ‘capabilities’ such as education, income, assets and so on. In addition to the fact that the latter view does not reduce poverty to a single variable (such as income). It also suggests that overcoming poverty needs empowering people in different interrelated aspects. For example, poor education and health can result in unemployment that leads to income poverty and consequent social pathologies.

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11 The concept of urban poverty (as opposed to rural poverty) has a clearer relevance for this thesis but their difference needs some clarification. Some argue that rural and urban poverty are interrelated and this is not always easy to separate those into distinguished categories. Some others claim that rural and urban poor are selecting different coping strategies to deal with hardship. Anyways, slums and spontaneous settlements are spatial entities within or on the fringe of cities and are results of increasing poor population and that is why this thesis is more specific on the term ‘urban’ when referring to poverty.

12 This idea has a parallel in practical policies aiming at improving slums for example UNCHS (2003a) points to the in long term the issue of urban poverty should be solved.
The concept of ‘capability’ is an important aspect of poverty definition. It acknowledges that poverty in an aspect such as income does not necessarily imply being poor in other aspects and hence being locked into poverty as far as a household has access to the key assets, skills and social networks. Moreover, the capability approach also implies that other factors beyond income or consumption would play a role in poverty, some of which can be obviously of physical and spatial nature such as easy access to public facilities (e.g. schools) and basic infrastructure. Finally, the capability poverty concept can identify what combination of poverty factors and to what degree of each a household or urban area is suffering from so they can be graded according to poverty severity as in the case of poverty maps. This multi-dimensional approach to poverty also seems to underlie the operational methods to identify slums as areas with deprivation in mostly physical aspects.

Before returning to the concept of poverty in more particular context of urbanizing cities a point should be made about a closely related concept of ‘inequality’. Inequality is different from poverty in that it considers how consumption, income, wealth or other indicators are distributed amongst the whole population. It is usual to observe in Third World cities that the poor get less share of the total wealth in spite of the fact that they comprise a considerable portion of population. While urban-rural inequality enforces migration to cities, uneven distribution of amenities and opportunities within the cities enforce urban poverty that can fuel slums’ expansion (UNCHS, 2003a)

An important question is why Third World cities are the foci of urban poverty? Part of the answer would be provided by looking at the definition of Third World. One definition is given by Pacione: “In a socio-economic sense the Third World refers to countries that generally, although not uniformly,
failed fully to develop economically after independence” (Pacione, 2005, Page 452). The terms 'Third World' and 'developing countries' will be used interchangeably through this thesis. This definition requires further thoughts as it picks on an economic criterion for development regardless of wealth distribution and other matters. However, it makes it possible to compare national economic indicators to see which country is more likely to be developed. But again economic development or wealth accumulation gained from natural or other resources in some Third World countries does not mean alleviation of poverty as this can be unequally distributed. This issue would be addressed in the next two chapters for the cases of Iran and Saudi Arabia. This suggests that poverty has different dimensions or factors that go beyond the sole economic issues.

Aspects of urban poverty and slums

One aim of this chapter is to explain the consolidation process of slums through its theoretical framework. Knowing that such areas are closely related to urban poverty, one solution is to expand the existing poverty frameworks/approaches to include the physical and spatial attributes of these areas. As a result, such a framework would first appreciate different factors underlying urban poverty and then hypothesize the way that factors interaction leads to slum-like condition (i.e. degradation) or consolidation (i.e. self-improvement) especially in the case of spontaneous settlements. Later, by prioritizing the poverty factors, the more critical for the poor will be revealed.

14 As Blake and Lawless (1980) elucidated, the problems of economic underdevelopment gets worse in such countries when the governments emphasize on broad economic solutions to solve the issues of poverty. This is based on the assumption that the benefit of such wide-scale solutions such as industrialization would then be distributed between low-income people but the reality of unequal economic growth and unemployment, indicates that such ‘broad solutions’ are not so efficient. Instead as the above writers indicate these distract the governors from tackling the problem of shelter and employment directly.
Also, those factors that they need to overcome would indicate their ‘preference’.

The first step to build such a framework is to review the existing categorizations of poverty factors. One helpful idea was suggested by Henninger and others (2002) in which he divides the factors into ‘status’ and ‘outcome’. The first group refers to the circumstances in which a household is living and the second is the result or ‘consequence’ of such initial condition. For example, access to water and sanitation as a ‘status’ factor can affect health problems and water-related diseases. This categorization has the strength of explaining cause and effect relation between factors but as Deichmann (1999) reminds in some cases a ‘cause’ of poverty in some aspects can also be the ‘outcome’ of other factors (like low education and poor health in a household that enforce further poverty) so it is not always easy to solely ascribe outcome or cause to a factor. Henninger’s categorization (Henninger et al, 2002) has also three broad sectors of economic, social and environmental dimensions with more specific sub-sectors in each. Due to the focus of this categorization on socio-economic poverty, it has certain shortcoming in dealing with slums as physical entities but it has been used in ‘poverty mapping’ with focus on the spatial distribution of these factors in cities that can be related to slums as well (see below).

As was claimed earlier in this chapter, the distinct physical characters of slums (e.g. run-down and decaying fabric) make it possible to delimit those as spatial entities in the wider city context. Such features are termed by Giusti de Pérez and Pérez (2008) as physical-spatial poverty as different from socio-economic deprivation. They also extend their categorization of spatial poverty to ‘visible’ and ‘invisible’. They further subdivide those to more detailed factors or ‘components’. The factors related to the former are lack of open space with fair quality and precariousness of built environment. The latter category –as they list- is divided into uneasy circulation within the settlement,
inaccessibility of public transport and facilities in the surrounding formal areas and finally unavailability of urban infrastructure.

In brief, Giusti de Pérez and Pérez (2008) advocate the distinction of two categories of physical/spatial and non-physical/non-spatial poverty and in support of such separation they mention the cases where the poor becomes better-off in terms of income but their settlement remains degraded (Ibid. Page 64). Nonetheless, the above categorization of physical/spatial and otherwise has some weaknesses. Firstly, ‘spatial’ and ‘physical’ can be two different attributes of factors or indicators but there is no clear distinction between them in the approaches used in studying them; even non-physical indicators such as level of income can be examined in a spatial sense. This also applies to the case of poverty maps. Interestingly, Giusti de Pérez and Pérez (2008) argue, “We can combine socioeconomic conditions, measured as nonphysical (or nonspatial) components, with urban poverty, measured in physical or spatial components. Furthermore, some nonphysical components such as the network of social and community relationship are spatially dependant” (Ibid, Page 65). This suggests that each one of the attributes (i.e. physical and spatial) needs to be defined independently because spatiality and physicality are different issues.

In a paper about the importance of slums’ morphology on their consolidation, Mukhija (2001) gives a helpful account of what ‘physical’ attributes are. While arguing that during the improvement projects, the physical and morphologic characters of slums have been conventionally ignored in favor of legal and financial issues, Mukhija traces back the foundations of this approach in the conventional literature. According to his review, most of the sources from early 1970s and 1980s in response to the modernist interpretation of slums as chaotic fabrics started to establish the assumptions that these areas are on the contrary orderly laid out and has a kind of underlying structure\(^\text{15}\). In

\(^\text{15}\) As will be shown such structure would emerge in a spatial sense in some settlements and facilitate the consolidation but as Mukhija (2001) reminds in other settlements such as the cases in Mumbai the
summarizing these assumptions about the ‘physical’ attributes of slums he points to the peripheral location, heterogeneous land use mix, layout regularity and orderly street pattern and large lot size. He further argues that these attributes are not always the case (for example, the layout can be irregular) and hence can hinder the self-improvement of a settlement. From Mukhija’s debate, it can be concluded that physical attributes of settlements are separate from but related to socio-economic factors.

The physical factors then can be defined as the ones that relate to the static, non-abstract and non-living matters in an urban area either visible or invisible to the dwellers. As a result, issues related to buildings and plots such as size, construction material and quality or land use, the quality and condition of public spaces and roads such as the lighting, plantation or road paving and also infrastructure such as water-pipe and sewerage networks are in the physical category of factors. In contrast, socio-economic indicators of individuals or households like income or literacy, dynamic matters such as people’s movement either walking or on vehicle or the occurrence of crime, abstract issues related to land and property such as value or ownership and finally time-related issues are non-physical.\(^\text{16}\)

It should be mentioned that according to this definition when talking about slums, for the ‘physical’ and ‘non-physical’ factors one might find divergence in their trends. This is best described below: “\textit{Slums and poverty are closely related and mutually reinforcing, but the relationship is not always direct or simple. On the one hand, slum dwellers are not a homogeneous population, and some people of reasonable incomes choose to live within, or on, the edges}” morphology would impede the improvement and physical intervention in a limited degree would be the preferred solution by the dwellers.

\(^{16}\) Also factors such as population, residential built-up area per person or density of people in unit of areas are non-physical as the last one is resulted from dividing a non-physical indicator (i.e. population) to a physical issue and hence is likely to vary between day and night (see Patel and others, 2007 on density differences in night and day). Built-up density then is obviously a physical factors.
of slum communities. Even though most slum dwellers work in the informal economy, it is not unusual for them to have incomes that exceed the earnings of formal-sector employees. On the other hand, in many cities, there are more poor outside slum areas than within them. Slums are designated areas where it is easiest to see poor people in the highest concentrations and the worst conditions; but even the most exclusive and expensive areas will have some low-income people.” (UNCHS, 2003a, Page 13).

This statement further justifies the necessity of having physical and non-physical indicators relating to poverty in urban contexts. Therefore, the theoretical framework of this thesis proposes that the features indicating ‘slum’ condition in a settlement are physical poverty factors but are very likely to be coincided with non-physical poverty. Another implication is that citizens’ decisions on where to dwell according to their socio-economic status in the city inevitably have a geographical or spatial dimension. In the next section the following general questions will be answered; what aspects of a slum location determine the poor’s preference for dwelling in it? Do such individual decisions aggregate to make certain distribution of socio-economic groups in city-wide scale such as in clusters?

The spatial dimension of poverty and its mapping

Answering the above questions and similar ones requires mapping poverty factors of households especially the non-physical ones in the city-wide scale. The poverty maps address such requirements in which one can record a single or various poverty indicators of households or individuals with their respective geographical locations. Such data can be gathered through housing census and field surveys and then recorded in Geographic Information Systems that are computer applications with the ability to analyze and visualize such data for urban areas as small as neighborhoods or urban blocks. By using this method
it is possible to unmask the variation between smaller areas that otherwise would be evened out in an aggregated statistical summary for a whole region or city. Using this method and through analytical methods the factors related to households or individuals can also be summarized or aggregated for larger areas. Such locational knowledge then can be used to prioritize areas with severe condition and in need of intervention by urban policy makers\(^\text{17}\).

In addition to revealing variations in the socio-economic status of citizens, poverty maps can also include physical condition of housing and availability of infrastructure as components of their aggregated multidimensional indicators (See Deichmann, 1999). In some cases a non-physical poverty factor either one dimensional such as household expenditure or multidimensional like HDI (Human Development Index\(^\text{18}\)) can be compared against physical factors such as distance to public health facilities to find correlations in a cause-effect manner. Also, it is possible to overlay poverty maps with physical attribute such as land instability or environmental hazards to identify settlements with high risk and vulnerability to disasters.

Poverty mapping as mentioned above can provide a proper methodological base for studies of slums and spontaneous settlements as it take into accounts different physical and non-physical factors as well as their relations. However, a few points should be born in mind when using poverty maps. In cases when poverty maps use a single variable as a proxy for the rest of the variables, they can just deal with the ‘outcome’ of a complex multidimensional process and hence have weak explanatory power. Secondly, when correlating physical with non-physical factors, identifying a cause-effect relation is not simple. For example, is it the lack of infrastructure that causes deprivation or is it the clustering of the poor that hinders municipal investment due to factors such as

\(^{17}\) It should be noted that the first attempts to map poverty goes back to Booth (1902) which was done for London.

\(^{18}\) HDI is a combination of three indices with equal weight including life expectancy, education and income. This measure is devised by UNDP (UNCHS, 2003a).
illegality or delayed tax payments? Finally, it seems that the focus of poverty maps is more on describing the socio-economic factors with less focus on physical issues. For example, the settlement where the poor is living at is not of interest as the literature suggests especially the morphologic issues, settlement size and boundary are not addressed in this practice.

Despite these limitations, poverty mapping implies that physical and nonphysical factors when considered in the geographical span of a city have a spatial dimension. ‘Spatial’ in the context of this study means the attributes of entities are geographically recorded with regards to a reference coordination system or alternatively when the object is considered in relation or interaction with other geographical entities. This definition of space is influenced by the writings of Couclelis (1997) in which she reviews two major concepts of space in geography as ‘absolute’ and ‘relative’; the former points to the location of entities (including trajectories, points and objects) in a Cartesian referencing system similar to a neutral container and the latter consists of a set of relations or proximities between objects or spaces with more focus on the interactions between them\(^{19}\). Accordingly, the proposed definition of spatiality for poverty factors is parallel with Couclelis’s two conventional concepts of space.

With this definition, a physical factor like availability of infrastructure and public amenities has an ‘absolute’ spatial dimension. The size, boundary and location of a settlement as are measured through relations between physical attributes in a Cartesian geographical space are also spatial. This is also the case about poverty maps even when the socio-economic data is aggregated in neighborhood level\(^{20}\). Again, with this definition the topologic (or ‘geometric’)

\(^{19}\) Although Couclelis (1997) defines a third concept of ‘proximal’ space to reconcile the two conventional notions of space into a single one as a foundation of Cellular Automata models but that concept is not investigated in this discourse for its limited scope.

\(^{20}\) In such cases the factor is spatial in city-wide level but not within the neighborhood because the variations are evened out for this scale. This brings the issue of the smallest unit in such geographical space that below its level no spatial variation is represented. The smallest unit is dependent on the scale and resolution by which a study is conducted. For example if the smallest unit is a household
accessibility of streets to be discussed in chapter five is a spatial factor as it is calculated based on the relation of each street with the rest of other streets. In this regard, the most important non-spatial category of factors is temporal or time-related ones such as the age of a settlement.

Knowing that poverty and slums have spatial dimensions and following the previous UNCHS (2003a) quotation, now the question is about the reason for spatial overlapping of poverty clusters and areas with physical deprivation. What determines the size of a poverty clustering? Is it affected by or affecting the physical poverty factors and how? Understanding the reasons for clustering can also help with explaining the dwellers’ preferences i.e. why they choose to group in a certain area and how would that decision relate to physical factors such as the initial land condition or built-fabric qualities.

**Poverty clustering**

Before reviewing reasons for poverty clustering a note on methods of explaining cause and effect relation in spatial studies is necessary. If an observed pattern amongst entities in a geographic space (such as occurrence of car accidents) is due to the local variations of an independent factor or set of factors (e.g. sharp road bends) it is of first-order effect. If on the other hand, the observed pattern is due to the interaction of entities amongst themselves, and regardless of independent factors, then the variation is a second-order effect (like when an accident along a highway causes other accidents). Now, the question is whether poverty clustering is a first-order effect due to other factors such as locational, legal and physical factors or second-order that is just like a self-feeding circle of attraction that brings other poor to settle close together.

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then that unit is regarded as a point and matters below that level as are aggregated (like household members’ individual data) are considered as non-spatial.
It should be noted that clustering of the poor is not confined to the Third World cities. Some studies indicate this tendency in the developing world where no spontaneous settlement exists (for example see Orford, 2004). Secondly, although the consequences of poverty clustering - mainly isolation from the better-off and creation of an ‘underclass’ population suffering from social pathologies- is a well-known hypothesis (Greene, 1991), only few hypothesize poverty clustering from the poor’s point of the view or their preferences. Is there any benefit for the poor for clustering that makes them doing it on their own?

Such questions can be answered by understanding the reasons for clustering. A plausible review of theories pointing to reasons for ‘spatial concentration of poverty’ or clustering in the context of Third World cities is presented by UNCHS (2003a). This source tries to answer why people of similar socio-economic classes especially the poor despite the advancements in communication and transportation choose to live close together. The answer seems simpler when talking about ethnic minorities who need to benefit from the social networks and specific local services close to them. However for other social classes the answer is not very straightforward.

Four scenarios are suggested in response to this question by the same source (UNCHS, 2003a). First is the effect of employment areas with the issue of transport cost and time in the hindsight. The poor cannot afford to travel a lot and need to stay close to its job sources. This is like a first-order effect that brings the poor together. The second possible explanation is related to ‘amenity’ as a consequence of intrinsic land qualities. Better locations receive more facilities as a result of their inherent characteristics and poor/risky land accommodates less well-off citizens and will receive fewer amenities as a result. This gap is magnified by more provision of higher-class amenities for

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21 Most of the slum dwellers although are newly arrived in-migrants to the cities and hence it is likely that they cluster according to their places of origin or ethnicity as the case of spontaneous settlements of Zahedan.
the rich areas and social services for poor in the second group of areas. This trend is followed by different maintenance prospects due to the tax collection issues that will decrease the infrastructure quality in poor areas pushing the formal employers out of the location which contributes to less advantage for dwellers. The third answer, is ‘exclusionary zoning’ mechanisms through which the poor is forbidden to construct their kind of dwelling in rich areas and at the same time the middle class can prevent the poor informal economic activities in their areas because of their local political power. The flip side is the lack of political representatives in poor areas that make them defenseless against the decisions to bring hazardous unfavorable land uses in their areas with the consequence of lowering land value. Very strong examples of exclusionary policies are ghettos and apartheid era townships. The forth answer is the post-modern notion of cultural landscape. Slums and poverty in this line of thought are considered as a reproduction of a social construct assigned to a certain group of people who maintain it through living close together (Ibid.)

With this description in mind, the clustering can then be seen from the household point of view. It is plausible to assume that when a poor household dwell in a better-off area, they have to keep-up with the particular standards and norms of that neighbourhood while at the same time they have to pay indirectly for the higher levels of services and amenities that are afforded by the wealthier residences. On the other hand, when the same household decides to live in a poor neighbourhood, it is like an implicit collective agreement to relax the social norms and lower amenity costs in a spatial territory that is the cluster. This scenario can also support the idea that living outside the poverty cluster would put unnecessary pressure on the limited resources of the poor and is an extra poverty factor for them. This functions as a second-order effect that brings the poor together. Overall, deciding to live in a group of socio-economically and culturally similar people and isolated from outside can be related to what Hillier and Hanson (1984) call ‘aspatial solidarity’ (based on
Durkheim’s idea of ‘mechanical’ solidarity)\(^{22}\). In this mode, interaction between community members is limited through the physical layout. What keeps them together is their shared values and norms\(^{23}\).

According to the above review, it can be hypothesized that the clustering of poverty although a non-physical matter is inevitably in interaction with physical factors, some of which (like the intrinsic land quality) promote clustering while some others (like substandard building) are caused by poverty. Other issues such as lack of public amenities and infrastructure are to some degree caused by these initial conditions and its illegality but will cause more deprivation (both physical and non-physical) later on. The clustering of poverty can also reflect the poor’s’ preference (and also the preference of other better-off formal areas) for separation from the rest of the city due to their socio-economic and cultural differences. The location of such clusters can be determined and then further established by physical and spatial factors both outside the site (e.g. regarding the city centre) and on the site (e.g. hazardous or unattractive land). As a result of these physical signs of poverty, it is less likely that investors become interested in that neighborhood which increases the security and territorial stability of the poor against eviction\(^{24}\).

**The operational definition of slums**

The observable physical poverty factors results in a settlement being recognized as slum. UNCHS (2003a) summarizes from definition of such

\(^{22}\) See a new print of Durkheim’s original book (Durkheim, 1997).

\(^{23}\) The idea of ‘spatial solidarity’ is built on Durkheim’s idea (1893) on ‘mechanical solidarity’ observed in traditional societies in which the social cohesion is maintained through similarities (shared values, kinship groups and religious views).

\(^{24}\) The situation remains so unless the location becomes attractive due to city growth after which the high potential land value would trigger decision on total redevelopment of a settlement and relocating its people like in the case of Bangkok (Khan, 1994)
settlements in different countries that a slum generally has a certain (minimum) size, lacks services and infrastructure, has unhealthy living condition and sometimes layout irregularity, has substandard buildings and its dwellers are suffering from poverty and social exclusion. A generic definition according to the above condition is also as follow: “...a contiguous settlement where the inhabitants are characterized as having inadequate housing and basic services. A slum is often not recognized and addressed by the public authorities as an integral or equal part of the city” (Ibid, Page 10)

The word ‘slum’ roots at the English Victorian era and referring to low quality housing that usually were suffering from the lack of air ventilation and natural light, overcrowding and hygienic problems. Merriam-Webster online dictionary gives the following definition for the word: “a densely populated usually urban area marked by crowding, dirty run-down housing, poverty, and social disorganization”. The above definition and similar ones, however, are not suitable for practical and research purposes because of their ambiguity (for example how one would measure social disorganization?) A more comprehensive definition of the term ‘slum’ is given by the MIT website on slum upgrading sponsored by the World Bank Group:

“Slums are neglected parts of cities where housing and living conditions are appallingly lacking. Slums range from high density, squalid central city tenements to spontaneous squatter settlements without legal recognition or rights, sprawling at the edge of cities. Some are more than fifty years old, some are land invasions just underway…” (World Bank, 1999)

This definition is neither operational (i.e. identify and measure slums) nor general but it points to settlements in a range of locations that can end-up in slum condition.

A crucial thing to remind is that slums are relative to their context (i.e. their definition varies) and are found all around the globe mainly in the Third World
To have a reliable understanding of the spread of these areas around the globe and to inform international agencies, local urban planning and decision-making authorities, international agencies and institutes there is a need for an operational definition of slums. A necessary attribute of such a definition is its applicability in different regions considering the difficulty of obtaining reliable data in Third World countries. As a result, an ‘operational definition’ is proposed by relevant experts (Moreno and GUO, 2003) to identify and measure slum areas in cities. A slum is operationally defined as a settlement with one or a combination of the following factors (Ibid., Page 18-19): 1- Nondurable structure that includes both risk-prone locations and substandard construction materials; 2- Overcrowding as insufficient living space per person; 3- Insecure tenure and lack of protection against eviction; 3- Lack of access to improved water and 5- Lack of sanitation.

Although slum is mostly a physical phenomena, the inclusion of non-physical factors can indicate that those are in interaction with other poverty factors. This is however the case for all of the mentioned factors. For example, non-durable house on a dangerous site can increase the health risks due to sudden incidents. Overcrowding can also become unhealthy and cause shortage of amenities. Insecurity of tenure (as a non-physical factor) would impede further investment at housing and participation in the community due to the uncertain future residency that feeds back to further dilapidation. Lack of basic infrastructure including water and sanitation can also pose health risks and also drain household resources. Regarding the spatiality of these operational factors, GIS applications have been used to record the availability of basic infrastructure to dwellings as well as data regarding construction material and building quality which is more for monitoring purpose (for example see: Joshi et al, 2002; Hackenbroch and Gruebner, 2008).

The previous source also points to the fact that the operational definition would exclude some of the aspects of slum dwellers’ life “... their social and
economic conditions such as standards of living among different groups of informal settlers, cultural aspects, employment, income and other individual and household characteristics.” (Moreno and GUO, 2003, Page 18). This simplification is claimed to be in favor of making the measurement and monitoring of slums more practical in a global scale and to focus on the main characteristics of these areas but this can lead to some weaknesses especially in explaining the potentials for consolidation despite a current physical degradation. Such criticisms to the ‘operational’ definition can also be found in other texts especially regarding its so-called ‘crude’ measurement method that simply identifies a settlement as slum if more than half of its households are suffering from at least one of the five indicators (Sliuzas and others, 2008). Therefore, an area in which households are suffering from multiple deprivation factors and another with a single deprivation are both selected as slum with no differentiation (Ibid.). The last source adds that the local condition of the settlements such as its road condition, drainage system, pollutions and its site location regarding natural and manmade hazards are also absent from the operational slum measurements.

Other factors that can be added to the above list are the morphologic characters, location with regards to the wider city, accessibility, public amenities and land use character. Moreover, because the ‘operational’ definition aims at detecting areas with an urgent need of intervention, it ignores the fact that despite all deprivations the poor preferred to live in a settlement so there might be potentials or gradual benefits from their choice that can be reinforced to facilitate consolidation. Also the use of GIS in operational practices is usually for monitoring purposes (like which households have gained access to water over a period of time) and is more of descriptive nature rather than trying to explain factors that can reinforce consolidation. The term ‘consolidation’ was defined in the first chapter but based on the theoretical framework, now it can be redefined. Consolidation happens if the negative impacts of outcome poverty factors -i.e. the ones that are caused by other
factors such as lack of infrastructure and substandard construction- are accommodated and coped with through gradual benefits of overcoming more serious non-physical poverty factors (such as unemployment and insecure tenure). Note that the term ‘gradual’ here refers to the factor of time as an important factor during which both physical and non-physical poverty factors are eased\textsuperscript{25}.

**The notion of ‘preference’**

Here it should be noted that the idea of ‘preference’ in this thesis is to a large extent influenced by the ideas of Turner (1967). In his hypothetic model – Figure 2.1 - he argues that for newcomer migrants with very low income the priority is proximity to job and central areas and not the security of tenure or ownership so they settle in rundown inner city tenements\textsuperscript{26}. As time goes by and those migrants get more established in their jobs and improve their economic status, the proximity to job opportunities lose its importance because the casual nature of their jobs diminishes and on the other hand they can afford to commute. In contrast, they seek social status as well as more secure ownership over their home and hence they are more willing to improve their housing. For this reason the migrants go to more peripheral locations to have larger spaces for living as well as more secure status. The peripheral location, as Turner theorizes, has more tendency for consolidation (as ‘slums of hope’) as the more basic preferences of their dwellers are satisfied. Turner’s model is helpful in relating the location of the poor (and their settlements) and their

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\textsuperscript{25} The opposite scenario occurs when the gradual benefits are insufficient for the poor and they become locked into a vicious circle of poverty in which physical and non-physical factors reinforce each other (that is ‘degradation’) or when the settlements is being evicted and partially or totally redeveloped (that is ‘eviction’).

\textsuperscript{26} As Eckstein (1990) interprets Turner’s model at this stage the newly arrived immigrants are “upwardly-mobile” dwellers who are not wiling to invest in their housing due to their intention to leave for better locations but at the same time they have to share their neighborhood with “downward-mobile” poor who are the main contributors to the culture of poverty an social problems in the inner city slum tenements.
socio-economic priorities. It also points to the economic preference of slum dwellers at their early stages and security of tenure as a major priority for them during the later consolidation phase.

However, Turner’s model has some weaknesses as it contradicts with proposed models for Third World cities in that the socio-economic status of low-income dwellers is more likely to decrease in the peripheries. Eckstein (1990) also argues that the assumed higher consolidation potential of peripheral slums imbedded in Turner’s observations on 1970s Latin American cities was inversed later on and due to harsh macro-economic condition of 1980s. At that time the debt-stricken governments where less willing to invest in infrastructure improvement of the peripheral slums while the remained available lands outside the cities were remote and economically disadvantaged compared to inner-city informal settlements. However, as will be discussed below the relation between consolidation and settlement location should be seen in relation to other important factors.

Figure 2.1- The changing priorities of the poor according to Turner (1967).
Factors affecting consolidation

In the followings section, a group of factors contributing to consolidation or its opposite scenario (i.e. degradation or eviction) are discussed. The main objective is to specify those factors that have the highest impact on physical and non-physical poverty factors. These factors, according to the theoretical framework, should be the ones that are naturally preferred by the poor who want to improve their own condition and consolidate their settlements. As Mukhiija (2001) argues that in most reviews the factors contributing to do not include the local physical and morphological aspects. For example, in a categorization presented by Pacione (2005) he points to ‘security of tenure’, ‘access to credit’, ‘price of construction materials’, ‘infrastructure provision’ and ‘land availability’ (Pages, 528-9). Examining the previous list of factors, one can see that the two last factors have more spatial and physical aspects but are dependent on the authorities’ attitude towards the low-income settlements while issues like the availability of financial credit or construction material price are less physical in nature and can be related back to the dwellers’ level of income and the external issues like the market condition.

Before carrying on with factors influencing consolidation, a point should be made about consolidation process itself. The overall physical improvement and gaining of legal/ownership recognition has already been mentioned, but what are the main components of consolidation process? As Greene (2003) suggests the overall or ‘global’ consolidation of an informal settlement comprises three main indices of physical aspects of the properties or ‘Housing Consolidation Index’ (HCI), the level of public amenities and infrastructure services or ‘Neighborhood Consolidation Index’ (NCI) and the level of social organization amongst the dwellers that is ‘Community Consolidation Index’ (CCI). The study of Greene and others will be reviewed in more detail later on because they focused on the effect of spatial accessibly of streets on consolidation that
is the focus of chapter 5 but a few of their key findings are relevant to this section.

First, they found that HCI and CCI, reflecting the physical and social dimensions, would generally improve in parallel. Also, the provision of public services and infrastructure (reflected in NCI) although not directly controlled by the dwellers, their degree of social organization would influence and facilitate official decisions to do so. Moreover, they found that the higher gain through commercial activities on the outward and well-accessible parts of settlement would facilitate the overall consolidation of a settlement. This is in line with the idea put forwards by the thesis’s theoretical framework in which the fulfillment of economic preferences in long term would facilitate consolidation. It should however, be noted that the settlements studied by Greene are all small size with the same age and orderly laid out that would make their cases very homogenous and hence specific. For this thesis that deals with slums of different sizes in the city-wide level and with different ages (see chapters 3 and 4), using simpler set of factors and proxies for inferring consolidation would be more practical. Factors like the emergence of inner markets and ratio of built-up densities would be as proxies the theoretical basis of which will be addressed towards the end of this chapter.

Going back to Pacione’s above list, one of the major factors claimed to influence consolidation is ‘insecurity of tenure’ which is also part of the slum ‘operational’ definition. Tenure status itself is a non-physical factor but when examined in an aggregated manner for households in a settlement or for a whole settlement in the larger urban context becomes a spatial matter. Tenure insecurity would decrease the dweller’s willingness to invest at their house or neighborhoods as they are not sure how long they would be there (Pacione, 2005, Page 528). Also, UNCHS (2003a, Page 87) indicates that when the

27 Moreover such objective measurement of consolidation by Hillier et al (2000) is comprised of many sub-components or factors that requires extensive data gathering and is very laborious over long term.
chances of eviction are high the poor tend to use more temporary material for building their dwellings. In the worse cases (like the case of squatter settlements), the illegality underlying the tenure insecurity would lead to the forced eviction and demolition of a slum by authorities.

However, a slum can essentially gain more resistance against eviction through its larger size and population. As UNCHS (2003a, Pages 91-2) discusses the large and medium settlements as opposed to smaller and scattered slum islands that can resist forced relocation and demolition. Moreover, for sufficiently large settlements, the supply of labor force can support viable internal markets that provide employment for as much as 40 percent of the dwellers; the internal markets in large slums can rival the formal markets in their city due to competitive prices (Ibid.) The internal markets, the thesis infers, can then indicate an ongoing consolidation process of a settlement as their contribution to the local economy could facilitate socio-economic and physical self-improvements.

These settlements size issues (resistance against eviction and gain from markets) might also justify the poor people’s preference for clustering as they can support each other and have the freedom to operate their informal economic activities in areas where official supervision has been low (otherwise the settlement wouldn’t be built in the first place). Another point to bear in mind is that although the effect of settlements’ large size have been discussed in the literature, the effect of their adjacency is not addressed but logically it can be inferred that a number of contiguous settlements can make the effect of a large settlement.

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28 UNCHS (2003a) indicates slum cases between 400,000 to 140,000 people as large (Ibid. Page 90). The two other size categories suggested by the same source are medium and small settlements but it does not specify any population threshold for them.

29 The more intense the commercial land use within a settlement, the stronger such markets are and hence the more potential for consolidation.

30 The association of informal economic activities and informal settlements and slums have been reported by various sources such as UNCHS (2003a) and Pacione (1996)
Settlement size and location are observed to have a direct relation as more peripheral settlements are usually larger mainly due to land availability (Dwyer, 1975). Dwyer also observed that the availability of job opportunities used to turn the city centers to a major preference for the poor. However, as a study of spontaneous settlements of Bangkok from 1984 to 1988 concludes (Khan, 1994), the smaller central settlements have been more susceptible to eviction. Moreover, as third World cities expand, an initially peripheral spontaneous settlement might become more central and become the subject of eviction. This process of succession and ‘pushing out’ of settlements is well-hypothesized by Barros (2004) through highlighting the effect of time. Her computer simulation model of the growth of Latin American cities (i.e. ‘peripherisation model’) can illustrate how the settlements are pushed outward from the city during its growth. In addition, the settlements that can resist the forces of eviction become consolidated after a while and can stay wherever they are even if they are within the city and surrounded by formal developments.

An indirect implication of Barros’s model (Barros, 2004) is that the older slum settlements are more likely to be central and therefore be the ones that have managed to consolidate. This is in contrast to the conventional understanding that referred to more peripheral settlements as ‘slums of hope’ because of their perceived potential for improvement. Based on Barros’s idea, one can argue that a more recent study on spontaneous settlements in Rio de Janeiro also confirms that the more central areas that are older have a better socio-economic status (O’Hare and Barke, 2003) although the authors claims that their cases do not follow the excepted inverse relation between settlements’ distance from centre and their population size. The positive effect of time on consolidation has also been reported for the more central informal settlements of Santiago.

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31 This can be a reflection of higher competition for land and higher land value in the central area as will be discussed in the schematic models of Third World cities.
compared to the more recent ones on the peripheries (Hillier et al., 2000, Page 69).

Based on such arguments a generalization can be made that the size, location (i.e. distance to centre) and age of a slum are usually related and affects consolidation. Proximity to city centre, however, is not the only attractive locational factor for slums and especially the spontaneous settlements tend to grow along the transport corridors (Sobreira, 2003). This can indicate the importance of city-wide accessibility for the poor either for their own transportation or for benefiting from the movement flows that pass by their settlement.

Based on the through the theoretical framework adopted for the thesis, it can be argued that the very poor prefer the smaller central locations with access to jobs and amenities in adjacent formal areas. The downside of their choice is more susceptibility to eviction due to the smaller settlement size, more attraction for redevelopment due to the potential land value and more visibility to official supervision. If they manage to stay in their place, such central areas might have more chance of consolidation. It can be inferred that the initially peripheral settlements that are absorbed by the city expansion and subsequently found themselves within the expanding city have more chance of consolidation because they are larger than the central areas and have had more time to develop despite the hardship of dealing with an initial lack of infrastructure. It should also be added that the very peripheral settlements although are more immune to eviction and are larger due to availability of cheap or unsupervised land but they usually have more difficulty in receiving basic infrastructure due to their remoteness, uncontrolled expansion and lower density that renders such projects unfeasible.

This discussion can be further taken and one may understand that the distance from the city centre is a decisive factor behind the location of slums and low-
income settlements. The other major factors (such as settlement size, proximity to major developments or transport corridors and the overall land value pattern) discussed above are also concerned at city-wide scale. These assumptions are based on some underlying models of the third World city that indicates the location of a single centre and other major functional zones in relation to it. One might question some of assumptions in such models as a city can grow around several centers.

Moreover, the Third World city also has other zones of affluent housing, industry and commercial activity. Knowing how slums are located in relation to the other zones requires an understanding of the general structure of Third World cities and how and why these zones (such as the city centre, local centers, zones of poverty and affluence, industrial hubs) are situated in relation to each other. Understanding the major urban components or major land use ‘patches’ with their specific densities and knowing if they form certain arrangements in Third World cities can help with understanding further issues that the urban poor should respond to and the mechanisms they adopt to do so in the local level of their settlements (such as overcrowding or setting up their informal commercial activities). The next section then reviews general urban models.

The structural models of Third World cities and spontaneous settlements

The basic models of urban structure

As the main focus of this thesis is on the urban context of the Third World the discussion is limited to city structure and the models generalizing it. The only exceptions are some of the theories and ideas that models of third World cities
are based on. By ‘urban models’ the thesis means the definition by Batty (2006) in the context of urban planning: “The models here are essentially physical representations of cities whose functions determine where activities are located and their visualisation is largely through spatial configurations of land use and buildings as 2D and 3D ‘maps’ and/or through the numerical quantities of activity associated with these.” (Ibid, 2006, Page 8). In a close context and reviewing the foundations of land use - transport models, Torrens reviews some of the basic urban models that have influenced the succeeding ones though - in his view - they have theoretical and empirical weaknesses. Amongst the models he reviews, the concentric zone theory, radial sector theory, and multiple-nuclei theory seems to have influenced the models of Third World cities. These models will be discussed in the next section\textsuperscript{32}.

The concentric zone theory was conceptualized by Burgess (1925) and was based on his observation of the growth of Chicago (Figure 2.2, above). Torrens in suggesting his theory argues that as cities expand outwards on radial directions, different concentric rings with various characters are formed with the central business district (CBD) as the heart of these rings with higher urban activities. The CBD will be surrounded by the next rings that are ‘the zone of transition’ (mostly industrial with limited residences), ‘the zone of factories and working men’s home’ (working class living next to their workplaces in dilapidated housing and with inappropriate public infrastructure), ‘the residential zone’ (better quality middle-class housing) and finally in the outside ring the ‘the outer commuter zone’ that accommodate the better-off with more spacious houses and higher (Ibid.) Although Torrents points to the criticisms of this model especially its assumed mono-centricity but as UNCHS (2003a) indicates, it predicts the emergence of old and dilapidated housing zones or ‘slums’ within many Western cities in its time. This happens in the second and third zones (i.e. ‘zone in transition’ and ‘zone of factories and working men’s

\textsuperscript{32} The other model of Von Thunen that is not mentioned in his core list actually acted as the foundation for bid-rent theory that Torrent examines later in the same paper.
home’) especially when the earlier worker’s dwellings become occupied by the poor and immigrants in the context of many Western cities.

The radial sector model is another case addressed by Torrens in his review of basic urban models. It was developed by Hoyt (1972) in which, similar to the Burgess model, the CBD is the central focus of urban structure but different land use zones are formed such as wedges along the transport corridors that radiates from it (Figure 2.2, middle). An indirect implication of Hoyt’s model, this thesis would add, is the more intensity of the main transport network in the centre as all roads meet there and also the zones or tracts that are created between those are getting narrower (this might be a simplistic interpretation of the narrow side of the wedges but agrees with the actual higher density of activities in the centre)\(^{33}\). Before proceeding to Griffin and Ford model, two classical urban models from Torrens’ review should be addressed namely multiple nuclei theory and bid-rent theory. The former is based on ideas by Harris and Ullmann (1945) in which they appreciated the fact that different factors such as history and topography can cause the urban growth to happen around multiple centres (Figure 2.2, bottom). Each ‘cell’ in this representation of urban structure has its own functional characters such as ‘residential suburbs’ or ‘wholesale and light manufacturing’.

The last basic urban model addressed by Torrens (2000) is the bid-rent curve theory developed by Alonso-Muth-Mills. In this model, they hypothesized that the location of each urban activity can be predicted from the ‘rent-gradient’ of that activity (explained below). Each activity values its accessibility to the centre in a different amount according to a trade-off between the cost (e.g. time or energy for commuting) and the profit that the activity can gain from space. With greater distance from the centre, this value falls at different rates for different land uses that is the ‘gradient’ or slope for that activity. For example,

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\(^{33}\) As Barros (2004) highlights the significance of Hoyt’s model- although it is considered as outmoded now- is that it might have influenced the work of Griffin and Ford (1980) whose suggested models for the spatial structure of Third World cities will be reviewed in the next section.
for the agricultural land use, proximity to the centre might be a slightly more advantageous than its peripheral location while for commercial activities central location means much more profit. This means that commercial activities have a higher rent gradient and hence in the ‘bid’ for central locations, commercial activities would win the place by affording to pay more rent.

Figure 2.2 - Illustration of Burgees concentric model (above), Hoyt sector model (middle) and multiple nuclei model (bottom), Source: Torrens, 2000.
Assuming a rent-gradient for each activity, this model predicts the geographical distribution of land use categories in a concentric arrangement around the CBD like in Burgees model. In the context of Western cities because commuting is the longest from peripheries to centre which might make it just affordable for better-off citizens who wants larger houses and spacious yards to live there. In other words, there is a trade-off between space (i.e. the land and property size) and distance to centre. In the case of Third World cities, as UNCHS (2003a) indicates while the poor cannot afford to commute and prefer to stay close to central job opportunities, the only way to win the bid is to decrease their living space dramatically and pay more rent collectively that is resulted in overcrowded slum condition. As Torrents indicates the bid-rent model has been criticized for its simplistic assumptions such as assumed mono-centrality. This study believes it is helpful in explaining the relation between factors such as distance from urban centres, settlement size and population density.

An implication of all the reviewed models is that the higher diversity or intensity of activities and denser developments are found in the centre (or ‘centres’) due to its higher accessibility and older age. In other words, the oldest and densest zone in concentric ring model, the focal point where all transport corridors and wedges are converging in the Hoyt model and the most accessible location that worth higher land value in bid-rent model is the central zone. This also indirectly implies the less built density and land use diversity should be observed in the periphery as a sign of its less consolidated status. These assumptions on density and diversity will be further discussed in the following section ‘The growth process of spontaneous settlements’. Examination of the reviewed models also suggests that the underlying factor that determines the location of a zone with regards to the centre(s) is the ease of reaching it through either short metric distance (as in the concentric and bid-

34 Moreover, the poor that live in the periphery would be more deprived from central opportunities and gets locked into what UNCHS (2008) calls a ‘poverty trap’ where a vicious circle of deprivation self-enforce itself.
rent models) or being located along the transport corridors (as in the Hoyt model). This can be translated to ‘higher accessibility’ in a general geographical sense. As it will be discussed in the chapter five, it has shortcomings in explaining the socio-economic variations and land use distribution in the finer urban scale.

In the next section, models of Third World cities are discussed. The models discussed above would be used as their foundations. Overall, these models still can help with understanding the overall structure of case study Third World cities and the location of spontaneous settlements in those as will be shown in the next two chapters for the case study cities of Zahedan and Jeddah.

The structure of Third World cities

It should be mentioned that the two case cities in this study are located in two developing countries that are Islamic countries (i.e. Saudi Arabia and Iran, both also known as Middle Eastern countries). Due to the diversity of urban forms of Third World cities, some writers suggest that there is no single model that can generalize these forms (Pacione, 1996; Potter and Lloyds, 1998). Potter and Lloyds also refer to Sjoberg (1960) that cities of the Third World are essentially pre-industrial in having three major land-use characters. First is the predominance of centre over periphery as it accommodates the elite residences and major religious, administrative buildings; this dominance was more socio-culturally related and had less to do with economic performance that is observable in CBDs of the Western cities. The second characteristic of Third World cities is the division to ‘quarters’ according to ethnic, kinship or job status (grouped as guilds) and finally the third attribute is the simultaneous

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35 In this regard the authors state: “A declining social gradient of residence from core relegated the more disadvantaged groups to peripheral settlements, a pattern which is maintained in many developing world cities today” (Ibid. Page 121)
use of buildings or land plots for different means such as living and working due to the lack of modern transportation.

Following this discussion and reviewing the work of other researchers, Potter and Lloyds-Evans (1998) conclude that the pre-industrial characteristics can still be found in developing cities but due to the introduction of modern transportation, industrialization and rapid growth (such as in the Latin American mega-cities), deviations from the pre-industrial mode are more pronounced and hence other models are required. It should be added that such modernizing forces are now inseparable feature of many developing cities especially in the Middle East. This will be discussed in the beginning of the next chapter. Here it suffices to add this quotation from Altenmüller and others (2008, Page 1036) in the context of changing urban context of Islamic cities most of which are in the Middle East: “... The models and image for cities in the Islamic World have indeed changed [from its traditional and pre-industrial status]. The contemporary Islamic city is modelled on the mythic images of the modern American city -New York, Houston, Chicago, etc. - as a symbol of mobility, corporate power, centralization, and “progress”. As Muslim countries follow similar economic and development models, cities in the Arabian Peninsula, Iran, Pakistan, Malaysia, and Indonesia, for example, are being based on those models, and are looking more and more like Western cities”.

It is assumed that the model of Latin American cities proposed by Ford and Griffin combines the element of pre-industrial city (i.e. concentric residential rings with declining status as getting far from the centre) with elements of modern urbanisation (Potter and Lloyds, 1998; Pacione, 1996). In this model, (Figure 2.3), some modern urban elements are superimposed on a background of pre-industrial concentric rings with declining socio-economic status of dwellers as getting far from the centre (opposite to Burgess model of Western
The particular modern elements that are absent from the pre-industrial cities are a CBD and a commercial spine that radiates from the CBD. The CBD is the dominant hub of employment, commerce and entertainment. The inner city next to the CBD which is maintaining its livelihood through small commercial activities and informal markets is different from the declining inner-city of Burgees model for Western cities. The main spine as a major transport corridor is a sort of linear expansion of the CBD that organizes the majority of formal public amenities (e.g. parks, recreational and cultural buildings, hospitals and food places) along with tighter planning control and more governmental investments (Pacione, 1996).

Adjacent to the main spine and within the ‘elite residential zone’-that according to Pacione (1996) has borrowed its wedge formation from the Hoyt sector model- the socio-economic distribution is like the Western cities with outer residences belonging to the better-off and higher-class citizens. The spine ends with a ‘mall’ –as the model suggests- includes luxurious suburban commercial land uses as a newly emerging urban node with high-end residences around it. The two other major elements introduced to the Model are ‘industrial park’ and a peripheral ring-road that connect the ‘mall’ and the ‘industrial park’ together. The peripheral ring-road can be growing edge for the peripheral squatter settlements. These attributes are claimed to be regularly found in the large Latin American cities.

Apart from the above modern elements, the major zones are three concentric zones of generally residential functions similar to Sjoberg’s pre-industrial model. The first ring of these zones in order from central to peripheral is the ‘zone of maturity’ with better-off central housing, well-serviced and upgraded amenities. The zone making the second ring is ‘in situ accretion’ that is of mixed or medium housing stock quality that presents a more dynamic

36 This pre-industrial character of cities was also said to be a feature of Middle Eastern cities when the centre was the dominant ‘public’ zone with higher status citizens living closer to it. This was also the case for old Jeddah as Abu-Ghazzeh (1994) reports that will be reviewed in Chapter 4.
condition indicating being in the process of improvement and consolidation. The third residential ring is the ‘zone of squatter peripheral settlements’ that accommodates newly-arrived migrants to the city and the existing poor citizens. The low housing quality and lack of infrastructure and amenities are the most distinct attributes of this zone. The previous ring is also similar to ‘disamenity’ zones, that are under-serviced and poor areas spread throughout the city represented as Hoytian sectors in the model. Despite their more central locations, these zones would remain in slum condition due to their inherent natural unattractiveness in terms of topography, terrain, earth instability, flood risks or proximity to factories, railroads, power lines and highways.

Figure 2.3 - The revised model of Latin American city by Ford (1996) according to Barros (2004, Page 21).
The scenario above explaining the location of slums including both ‘zones of disamenity’ and ‘peripheral squatter settlements’ in Third World cities seems to be in line with the previous discussions on the causes of poverty clustering and its physical outcomes. The less attractive available lands either in the centre or periphery is selected by the poor for dwelling that become the zones of disamenity, represented as wedges with narrower width in the centre that suggests the settlements should be smaller there\(^{37}\). There are two more points regarding the Griffin and Ford model to bear in mind. First, the centre and the main spine are supposed to have more density of commercial activities and diversity of public land uses due to the higher accessibility and planning policies. Secondly, and similar to the reviewed basic urban models, the higher accessibility in Griffin and Ford model is equal to either metric proximity to the centre or being along the main transport corridors that provide easy access to the centre, both of which are based on a city-wide geographic scale (i.e. ‘geographic accessibility’) and are ignorant of the fine-scale subtleties and the local geometry of the urban fabric.

A few conclusions can be drawn from the above discussion. Considering the morphologic aspects of urban centre(s) in a city, such as higher built-up densities and concentration of diverse non-residential land uses on one hand, and the older and more consolidated status of the zones in the vicinity of these centres on the other, one can infer the degree of an areas’ consolidation from the strength of these centres (i.e. the built-up density and land use diversity). These centres also act as attractors for the formation of inner-city slums with smaller size and higher population density while the peripheral slums are mostly in the form of spontaneous settlements\(^{38}\). This suggests that the

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\(^{37}\) Although the narrowing wedges towards the centre is just a schematic representation in Griffin and Ford model but it imbeds in the reality of higher density of transport network and also higher competition over the more valuable central land due to higher accessibility.

\(^{38}\) These peripheral settlements would be absorbed by the city expansion and if remain totally intact can maintain their overall arrangement as a consolidating continuous ring (like the ring of *in situ accretion* in Griffin and Ford model) or otherwise be totally redeveloped and pushed outside on an extreme scenario. Usually the actual situation is something in between where some of the peripheral
consolidation of a slum can be also examined by the degree to which such morphologic properties pertaining to land use and built-up density can be observed within it and in the form of internal local centres.

Another inferable point from this review was about the locational preference of slum dwellers. Knowing that the inner-city settlements are riskier to dwell (especially in terms of higher relocation possibilities), still such settlements got more chance for consolidation. This is because the economic preferences of the poor can be satisfied more easily in those inner-city areas due to proximity to job opportunities and higher demand for informal economic activities (such as hawking or small shops). To reduce the high cost of land value and the investors’ interest at redeveloping their area (i.e. the inner-city slum), the poor in return use overcrowding and living in an under-serviced and dilapidated condition as defensive mechanisms. In parallel, they prefer less surveillance or access from outside to maintain their internal territoriality, resist against redevelopment and retain their local social networks. Confirming the existence of such territorial sense, Giusti de Pérez and Pérez (2008) report the ‘strong sense of belonging’ that dwellers develop towards their smaller neighbourhoods within the spontaneous settlements. Each smaller sector then is marked by elements such as stairs or walkways that are identifiable by the dwellers and within each sector people know each other and the boundary of their community. Nonetheless, such territorial preference with relative isolation was already addressed through the concept of ‘aspatial solidarity’ in this chapter and will be further explained using the notion of ‘socio-cultural forces’ shaping residential areas in the fifth and seventh chapters.

According to Greene (2003) the physical signs of consolidation and the socioeconomic circumstances are both improving during consolidation. Now, if we consider that the emergence of local centres within the settlements (comprised settlements become consolidated and the rest would be relocated outside as Barros (2004) reflected in her thesis.

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of higher intensity of commercial and public activities) as a sign of ongoing consolidation, how can such centres benefit from demand from the outside the settlement? In an ideal situation, such internal centres should be well accessible to the dwellers to satisfy their local demand for goods and services and also to benefit from the local labour force and their products. The same local centre (in order to get prosperous) should simultaneously connect this local economy to the wider economy of the city but how can that happen in parallel with the overall territorial preference that requires isolation? Such dilemma (or the ‘dilemma of local centres’ as we call it) should have been resolved in already consolidated slums in which probably the overall settlement is isolated from surrounding but local centres play the role of organizing the internal commercial activities and connecting those to the outside in a controlled manner. This inevitably leads to the question of the accessibility of such markets both from the local level of the settlement and also the wider city.

Before dealing with questions of accessibility, it is worth mentioning that the focus of this thesis is on the spontaneous settlements as an irregular category of slums. The spontaneity of the growth process in these areas and the resulted irregularity has implications for this enquiry especially through the resulted variations in built-up density, unplanned land use distribution and particular accessibility pattern of the street network. Knowing how these morphologic issues can influence or reflect the consolidation process requires a better understanding of the nature of irregularity as the most distinct local character of spontaneous settlements in the next section. As will be shown later in chapter 7 the aforementioned ‘dilemma of local centres’ can be partly explained through the impact of morphologic irregularity on accessibility.
Morphologic irregularity in spontaneous settlements

This section studies irregularity of spontaneous settlements as their most distinct local character. Irregularity in the context of this study mainly refers to the deviation of urban layout (including both the built fabric and street network) from the conventional geometrical order and repetition observed in formally planned areas). It should be noted that further elaboration on less conventional aspects of irregularity (e.g. regarding legal issues) will be made. In other sections of this topic, irregularity will be related to other poverty factors as related to the theoretical framework of this thesis. The core question is whether irregularity despite its pronounced negative effects can also indirectly help with consolidation. In theory, such occurrence requires irregularity, despite its direct inverse effects, would indirectly help with the fulfilment of the main preferences of the poor (such as their economic and territorial priorities). For clarification of this hypothesis the nature of irregularity will be reviewed in the literature to find out how it relates to socio-economic circumstances of the people who live in such urban fabrics.

The local physical properties of spontaneous settlements and their growth process are conventionally interpreted as ‘chaotic’ (Dwyer, 1975, Page 36), ‘complex’ (Hublin et al., 1996), ‘uncontrolled’ (Obiefuna and Agbo, 1999), ‘unplanned’ (Karimi and others, 2007) or by using other terms indicating the peculiar condition of these areas compared to the formal urban fabric. Peculiarity in this range of interpretations refers to the differences of spontaneous settlements with the formal urban fabric characterized by regularity. Some authors use ‘irregularity’ to refer to these areas39 as was referred to Mukhija’s argument before (also see Mahmud and Duyar-Kienast, 2001).

39 Because ‘irregularity’ can also mean not agreeing with normal rules and standards it is used by some writers in a totally non-physical meaning and with regards to sole legality and ownership which is not used in this thesis.
The concept of irregularity in the context of slums as Durand-Lasserve (1996) defines in a broad sense refers to deviation from urban, legal and environmental official standards during occupation and (physical) development of settlements. Regarding the general lack of data on tenure and ownership issues (UNCHS, 2003a, Page 241) and limiting Durand-Lasserve’s definition, ‘irregularity’ will be studied more in the context of urban standards/conventions of physical development and less with respect to the legal, occupation or ownership matters. Elsewhere Sobreira and Gomes (2001) argue that in urban history official planning standards and controls in favour of idealized cities described as “highly structured geometrically and formally planned”. They define regularity in terms of shape and size distribution of built-elements. This will be further discussed here. However, they contrast spontaneous settlements with formal fabric of cities as these do not follow the mentioned physical regularities.

On the other hand the irregularity of settlements often coincides -though not perfectly- with socio-economic poverty (for example see Lemma and others, 2006). As a result one might simply relate the coexistence of these physical and non-physical poverty factors together as happened during 1930s. At that time, the irregularity was deemed as a cause of social disorganisation and pathologies in the writings of early modernist architect which justified the demolition and clearances of slums in different countries (Mukhiya, 2001). It should be reminded that morphologic irregularity per se is not considered as a cause for social disorganisation such as in the case of organic urban fabrics. In a paper about the organic cities in Iran and UK, Karimi refers to Papageorgiou (1971) to explain ‘irregularity’ as an underlying character of organic urban form:

“Perhaps the primary concept which distinguishes organic cities from the other types is the notion of ‘irregularity’. Unlike regular patterns, organic forms do not follow geometrical orders. They cannot be easily measured, since
they lack basic properties such as repetition, symmetry, parallel elements, alignment and so on. However, the notion of irregularity has not been conceived equal to ‘disorder’, ‘chaos’ or ‘disorganisation’ by recent urban theorists; on the contrary, the freedom from a predetermined urban grid, many urbanist believe, can create a highly flexible system of urban growth which intermingles the demands for various functions with the customary social conventions, and cannot be obtained in regular patterns…” (Karimi, 1997, Page 2).

Although some writers have pointed to the similarity between spontaneous settlements and organic urban forms (see Erickson and Lloyd-Jones, 1997; Hublin, 1996) due to shared aspects of irregularity and the incremental growth process, there is an underlying difference between the two. As Karimi (1997) acknowledges organic urban forms grows out of individual small-scale decisions at local level but he also points to the long time period that is required for the evolution of such fabric. Although he does not mention the time span of such a period, considering the historic periods behind the growth of organic cities, one can almost make sure that the informal spontaneous settlements of Third World are a more recent phenomenon and do not have such longevity. It can then be discerned that spontaneous settlements are not organic but share aspects of irregularity with organic urban forms mainly due to their unplanned and incremental growth process. Another result of this discussion is that the irregularity of spontaneous settlements does not necessarily imply social disorder and at least as time goes by, (similar to organic cities but in a shorter time span) these might present higher degrees of social and economic order as is evident in consolidated spontaneous settlements.

Having said that irregular urban forms can consolidate in time to accommodate organized social and economic activities, the question is under what condition such consolidation process can be facilitated, especially in the
case of spontaneous settlements. Impoverishing impacts of irregularity are more established in the literature (and will be discussed further below) but is there any positive impact from it? This might sound counterintuitive but the first clue to follow this idea is that spontaneity, at first place, is an attribute of the growth process that helps the poor to find cheap land and property and also keep the land cheap due to the lack of accessibility and services. Therefore, the resulted irregularity from the spontaneous growth is not only an outcome of dwellers’ initial poverty but it also indicates the existence of their common socio-economic preference. This is like saying that irregularity marks the physical territory in a settlement that is built by a like-minded group of dwellers.

As far as the dwellers can safeguard their territory from formal interventions, their preferences will continue to be satisfied. In this way time is of more importance and even if they suffer from other poverty factors such as lack of amenities, it is still preferable for them to stay there as their main priorities in economic terms (e.g. affordable shelter on cheap land, informal economy, proximity to job opportunities and etc.) and socio-cultural aspects are being satisfied. The more time they keep their position, the more gain and hence more chance for consolidation\textsuperscript{40}. As presumably irregularity can help with further loss of land value through less accessibility at the same time it means less supervision from the authorities at city-wide level. So it can buy more time for the dwellers by deterring the investment interests and at the same time supply the formal city with competitively cheap labor because of their lower living costs.

How does irregularity have such impacts in separating a settlement from its surrounding urban context? What are the local impacts of irregularity on the dwellers’ circumstances? Doesn’t irregularity result in a kind of social and

\textsuperscript{40} This is not to undermine the effect of the wider city developments on the condition of spontaneous settlements but to say that even these issues such as the city expansion \textendash with its impact on the overall location of the settlement\textendash is happening in time.
economic problems within the spontaneous settlement? Does the irregular growth and the built-up density resulted from it indicated anything about consolidation potentials? Answering these questions needs an understanding of the growth process of spontaneous settlements.

The growth process of spontaneous settlements

In a categorization by Sliuzas (2008) spontaneous settlement is termed slum with ‘incremental and unstructured’ growth process as opposed to ‘sudden and structured’ slums that are the result of invading land. This definition points to the gradual formation process of spontaneous settlements that is done according to the individual decisions and in the absence of a formal plan. One implication is that the resulted development pattern should become different from the geometric properties and repetitive order that is observable in the planned cities. An opposite process to the piecemeal and gradual addition is sudden invasion of land that results in a more orderly urban fabric similar to the formal areas\(^{41}\). The spontaneous settlements studied by this thesis are however different to the latter cases in that there is no prepared plan for them in advance and moreover land occupation and construction of structure would happens in a piecemeal manner.

In other words, each intervention is decided according to the already happened ones in its neighborhood (like an addition to the existing plots) and other physical constrains like topography. Also, social and functional requirements that usually define the interface between public and private domains are

\(^{41}\) For example, De Soto (1989) describes how a group of people collaborate and organize themselves to minimize the chances of eviction through careful evaluation of invasion time and location. He adds: “A plan is then drawn with the help of engineers or engineering students. Individual lots in the settlements are distributed. The area which in future will be occupied by public buildings (schools, health centers, or municipal authorities) and recreation areas (parks or sport grounds) are marked off.” (Ibid. Page 21)
followed during this local process. A well-known attempt to simulate a similar process – observed in French villages– was the ‘Basic Generative Process’ presented by Hillier and Hanson (1984). It included simple local rules in aggregating built-elements but because the focus is on spontaneous settlements, their models will be addressed in the 7th chapter.

Based on the existence of local rules governing the gradual formation, Erickson and Lloyds-Jones (1997) argue that it is not unusual to find in contemporary spontaneous settlements “... a clear consistency of form and urban structure which varies from place to place. Such consistencies derive at the local level from the relationship between urban form and social processes. Local spatial customs and unwritten social codes determine the layout, spacing and growth of houses and the development of plots and settlement form. Housing and settlement typologies reflect both socio-economic and cultural constraints on who lives where and how they live.” (Ibid. Page 4). The theoretical base for their argument was that urban systems (such as spontaneous settlements) are complex entities in that their global structure is the result of occurring movement flows and decisions at local scale. This idea will be further explained below.

**Complexity, simulation and the growth process**

The idea of city as a complex system has been propagated by many researchers (see Allen, 1997; Portugali, 2000; Batty, 2005). Reviewing theoretical foundations of complexity theory in urban studies would definitely go beyond the capacity of this thesis. In this section, the focus will be on its application to spontaneous settlements. A key assumption in studying complex systems is that the interaction of their components in the micro-level would give rise to emergent order in the macro-level. The global behavior of complex systems then could not be reproduced through abstract formulae. This is because the
basic requirement for such mathematical models is to reduce or simplify the diverse micro-interactions responsible for the global order (Cilliers, 1998). However, such a system (or its pattern) might exhibit properties that are consistent in various scales as an evidence of the complex process that has given rise to it. These ‘robust’ properties can be measured through statistical techniques. The practical implication of complexity theory for modeling a complex system such as a spontaneous settlement is then to first formulate the statistical properties in a structure and then to reproduce the same properties through simulating the interaction of large number of agents (representing actual decision-making individuals) in computer environment.

In this regard and following the first step, Sobreira and Gomes (2001) observed that spontaneous settlements when bounded by growth obstacles show particular diversity in the size of building islands (i.e. contiguous buildings clusters) that could be captured through power-law formula. The power-law property as a sign of a complex process indicates that there is a continuum of size occurrences starting from a very large number of small elements and a small number of very large elements\(^42\). They call this property of bounded spontaneous settlements ‘fragmentation’ referring to a statistically explainable diversity of built-elements’ size.

In another step, Barros and Sobreira (2002) used a complex simulation to reproduce the same scaling properties formulated by Sobreira and Gomes. The agents in their simulation represent the low-income households that try to build their dwellings on vacant pieces of land following local rules and in favor of attractive factors in their immediate surrounding (such as the edge of a passing road). Although their simulation of spontaneous settlements growth has reproduced the same scaling properties and morphologic patterns, there are some empirical and theoretical concerns about it.

\(^{42}\) This was reflected in a robust exponent \((t)\) relating each size of element \((s)\) to the frequency of occurrence of that size \(f(s)\) through following equation: \(f(s) \sim [s^{(-t)}]\)
Firstly -as Batty and Torrens (2001) argue- these methods are in their infancy and are of heuristic nature so there are limitations in their application for predictive purposes. The lack of predictive power is also an inherent aspect of complexity theory which suggests that the exact prediction of a complex system behavior is not possible but instead the simulation can help with understanding the variety of scenarios or trajectories that the system would follow. This constitutes the main advantage of these models as they can provide the decision-makers and planners with more insight into the effect of various initial conditions on the overall possible patterns as the initial condition can be changed relatively easily regarding different study contexts.

This method and other methods aiming at quantifying the morphologic and physical characteristics of settlements to distinguish those from their urban context are called ‘mapping’ approaches in this thesis. These include other attempts to reproduce those properties through simulation. Overall, an advantage of these approaches is in their concrete definition of irregularity in quantitative terms. Such measurements can use aerial image analysis techniques to highlight certain materials radiation on dwelling roofs, plantation, and diversity in the buildings directions through their shades and so on. The weakness of these approaches is mostly in their implicit or unclear relation to socio-economic poverty and consolidation process due to their descriptive nature.

Moreover, this thesis would also argue that complex simulating models of irregular urban fabric should take into account the existence and effect of the

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43 For example the assumption of time reflected in a sequence of iterations or the definition of agents as households that can move in every direction are although abstraction to enable modeling but are empirically difficult to establish.

44 Another criticism to complex simulation models as Batty and Torrens (2001) accepts from others is that the similarity between a simulation outcome and real-world phenomenon does not necessarily means the processes that have given rise to those is the same. To alleviate this problem Crooks and others (2007) draw an outline for a methodological procedure according to which the complex modeling process (in the case of agent-base simulation but applicable to other classes) should go through phases of verification, calibration and validation to ensure the process is generating plausible outcomes at each phase.
road network, public open spaces and their major impact on the settlements’ physical growth and the socio-economic issues. Considering the road network in the growth process would also provide an explicit theoretical and empirical base to relate the physical and socio-economic aspects of the built environment together. This will be illustrated in the fifth chapter.

Regarding the importance of roads in the growth process of spontaneous settlements, Erickson and Lloyds-Jones (1997, Pages 11-12) summarize three major patterns. The first scenario is the case of simultaneous development of both buildings and streets that starts with a low density of buildings that gradually form urban blocks by filling the land surface. Second case is the street-led development pattern in which the construction of buildings follows road edges followed by plot development. The third scenario is when the construction of buildings precedes the street development while the initial foot pathways (or tracks) connect those buildings to locally important nodes such as shops, communal water sources or public transport. Regarding the third scenario they add: “As the settlement consolidates, the more dominant of these paths develop into streets. Plots expand to fill the available space” (Ibid.) later on in the same paper they demonstrate how they use these three actual scenarios as a base for three simulation models of spontaneous settlements in computer environment.

Thinking through the three different scenarios, it can be inferred that the built density should be gradually increasing during the formation process either along the attractive roads or local attractive seeds (in the third scenario) and then when there is not enough space around these spots the development should expand outward again. This is roughly like a small model of Burgees concentric ring in a settlement-wide scale where the urban development always

Also based on a similar observation on actual settlements, Sobreira (2003) defines density thresholds for his simulation model after which the agents change their search behavior and development sizes. This is to replicate the real world development of these areas in which the density goes up along the attractive edges in the same way depicted in the ‘road-led’ growth scenario.
has higher built-density and more public or commercial uses in its older central part(s) while on the peripheries it is expanding with lower density of homogenously residential land use. They add, “We can identify two phases of urban development. In the first, the street pattern and the functional distribution of buildings are laid down together, the distribution of each influencing the development of the other. The second, mature phase is characterized by a more stable structure and a dynamic process whereby the distribution of uses continues to shift with only minor modifications to the physical structure. As cities expand, a ring characterized by the initial phase surrounds a core characterized by the latter. These two zones tend to have a different urban structure…” (Ibid., Page 7).

An inference from the previous paragraph is to expect higher built-up density, more concentration of amenities and commercial buildings and more intense land occupation around the older and initially more strategic nodes of a spontaneous settlement. This description of intense cores matches with the local centers with their higher levels of social and commercial activities within spontaneous settlements the intensity of which can then reflect how consolidated a spontaneous settlement is. The quantitative method to capture consolidation ratio of spontaneous settlements through measuring morphologic density and diversity of their local centers will be explained in the next chapter. However, the above discussion was based on a growing settlement that expands outwards; what does happen when the settlement becomes surrounded by the formal city or steep hillsides and cannot expand any further?

When the settlement faces obstacles to its growth on every direction and when all the vacant land is occupied then another phase of densification starts that seeks to maximize the use of land through subdivision and increasing built-up density (Sobreria and Gomes, 2001). The mentioned notion of ‘fragmentation’ as Sobreria and Gomes explain is indicative of such ‘packing’ process that leads to an optimum use of land because the diverse size of islands would
eliminate the problems arisen from all built elements being the same size (either all small or all large). However, this claim seems a bit difficult to prove as there are unlimited combinations of built element sizes that can optimize the use of land. Nevertheless, one can assume that this internal densification of a bounded settlement is more likely to increase the density and diversity of land uses as a sign of further consolidation.

It should be stressed that the above approach to fragmentation based on the size of built-elements does not have an empirically and theoretically explicit way of relating socio-economic factors to the physical and spatial issues. One question is then about the socio-economic significance of power-law distribution of built-elements. Can the overall packing of a settlement (i.e. optimized coverage of land) reflect its consolidation? Such claim can hardly be related to any signs of the economic performance or social organization similar to what was discussed for ‘local centers’ because important clues such as land use and variations of built-up density are not addressed by it. Moreover, although Sobreira and Gomes (Ibid.) argue that power law can also be found in the size of public open spaces of bounded spontaneous settlements, the other concern would be if the network of open spaces would create any socio-economic impact through its influence on the accessibility.

There are also concerns about the simulation models based on reproducing the defined fragmentation pattern in the local level of the settlement. In these models (Sobreira, 2003), the generated fabric is the result of settling of agents when they find the local condition appropriate (i.e. the agents turns to fixed cells or dwellings) evaluating attractive factors such as the edge of a main road as more accessible areas form the city-wide level. Again, as Sobreira shows the formation stages are visually similar to those of the real settlements and the size distribution of built-elements follow statistical properties of fragmented systems, but he fails to relate his discussion to any explicit socio-economic matter regarding consolidation. Moreover, in his simulation of spontaneous
settlements in local level, he ignores the importance of the road network and its accessibility on the growth, socio-economic issues and consolidation.

Although Erikson and Lloyds-Jones (1997) consider the role of road network in their simulation models of spontaneous settlements, again they do not offer a clear definition of what constitutes the spatial structure of streets and confine their aims at reproducing the patterns of connected rings of streets around the buildings or observed patterns of built element and streets together. As will be explained further in chapter 5, the key concept that is missing from their model is the notion of ‘deformed wheel pattern’ that is a structure of road network that organizes the internal socio-economic activities in a settlements and at some cases connect it to the wider urban context.

The literature suggests that the strength of local centers (or centers within the settlement) reflected in higher built-up density and more diversity of land use can be indicative of an ongoing consolidation process in spontaneous settlement. This idea will be used in chapters three and four to measure the consolidation of the case study settlements. This review of the spontaneous growth process also suggests that the irregularities in both road network and built elements are the result of the piecemeal formation process while the road network plays an important role during the settlement formation and afterwards. Before dealing with the irregular properties of the road network, their impact on the accessibility and consolidation, the nature of irregularity in spontaneous settlements needs to be clarified.

**Different aspects of irregularity in spontaneous settlements**

Concerning the initial discussion of irregularity and with regard to the growth process of spontaneous settlements, their morphologic irregularity can be defined as deviation from orderly geometric patterns, repetition of built-

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elements and formal standards of planning and construction. Many physical characteristics of spontaneous settlements then can be regarded under the term irregularity. The smaller size of buildings (Lemma and others, 2006; Lemma, 2005; Kemper and others, 2008), diversity in the size and orientation of buildings (Kemper and others, 2008) and diversity in the size of islands of contiguous buildings or ‘fragmentation’ (Sobreira and Gomes, 2001), and the use of substandard material detectable on the roofs, (Kemper and others, 2008) can be regarded as aspects of built-structure irregularities.

Other factors like the smaller size of land plots (the case of Mumbai by Mukhija, 2001), the high coverage ratio of plots by building footprints (see ‘Buildable Plot Ratio’ by Patel et al, 2007), high coverage ratio of land by private plots and low quality and quantity of public open spaces (Giusti de Pérez and Pérez, 2008; Sliuzas, 2008, Page 7), meandering street network (Hublin et al., 1996), and unpaved or badly-paved roads and narrow streets with varying widths (Giusti de Pérez and Pérez, 2008, Page 55; Lemma, 2005) can be related to the irregularity of private and public spaces. However, the reported difficulty of movement (Giusti de Pérez and Pérez, 2008) resulting from aforementioned attributes of streets is not physical irregularity itself but is indicative of low accessibility. Therefore, the concept of accessibility will be scrutinized separately in the next section.

The hazardous location of a settlements in the proximity of natural or manmade risky sites is usually a breach of land use regulations and hence a matter of legal irregularity. The land use pattern itself can also be considered as irregular as it develops outside the formal planning frameworks: “In the absence of regulations, the land use pattern of squatter areas develops gradually as the settlements grow, and follows closely the private and collective needs of inhabitants. Hence, most settlements are essentially residential, mixed with small local business.” (Barros, 2004, Page 28). This overwhelmingly residential land use, as space syntax theories hypothesize (see
chapter 5), should be naturally in favor of lower rates of movement and lower accessibly to function properly. Moreover, as Serageldin (1997) observes, the house for the poor has other functions rather than being just a place for living; it is the very nature of informal economic activities in which a house can also be a small workshop, local shop or a recycling warehouse that reflects the substantiality of small scale economic activities for the poor. This multi-functionality of residential plots is somewhat similar to the reviewed idea of Sjoberg about pre-industrial urban fabric that operates at a local scale and with less reliance on modern transport modes (Potter and Lloyds Evans, 1998).

Regarding other aspects of land use in spontaneous settlements, the lack of public amenities (UNCHS, 2003a) such as health and education buildings in spontaneous settlements indicates non-compliance with official standards for the minimum provision of such services that is depends on the national or local regulations. The other local character also discussed earlier is the lack of basic infrastructure such as water and sanitation which is similar to lack of public amenities. It is indicative of irregularity and can also be extended to lack of flood drainage network, electricity, gas and street lighting.

The reviewed aspects of irregularity, however, are related to each other as well as to the category of non-physical factors. Some of these poverty factors might be the outcome of other factors and some others might enforce or relax the other ones. For example, a very dense development pattern might create a condition in which the buildings are blocking the light and ventilation of each other. Similarly, high built up density combined with smaller building size would lead to population overcrowding. Also, as Giusti de Pérez and Pérez (2008) report, the dense and irregular clustering of buildings of different sizes, heights and stability would also cause risky situations in which one collapse would damage the whole cluster. The high density as a result of irregular

46 Factors such as plantation are context related and depend on climate but some researchers have used it to detect slums (for example Kemper and others, 2008).
growth would also leave not enough space for public buildings and public open spaces; this leads to social and economic deprivations as a status poverty factor. A slightly more positive example is when the layout irregularity would allow for adjustment to topography (Hublin et al., 1996), but in areas of landslide or flood risk this can also become a dangerous feature as it allows the settlement to grow on such zones.

Some of these aspects of irregularity also might help with overcoming economic poverty factors. For example, the irregular land use pattern would allow for economic activities to happen at home or it allows commercial activities to locate themselves in areas of higher movement or on more prominent roads. Nonetheless, the irregularity is mostly treated as a negative aspect of spontaneous settlements with low accessibility of streets as the most intuitive result of it. The following section will be an attempt to conceptualize the conventional notion of accessibly that is usually used in the studies of spontaneous settlements and its weaknesses.

Geographic accessibility and spontaneous settlements

Studying two spontaneous settlements in Venezuela, Giusti de Pérez and Pérez (2008) treat the longer time of daily walking trips as a poverty factors for the dwellers. For their first case study, the dwellers had to walk through difficult paths to access the facilities in the surrounding formal city. This was due to the lack of public facility within the settlement. As a result they state: “The lack of internal roads and the difficult pedestrian routes result in a general lack of accessibly to and from Los Claveles [the spontaneous settlements]” (Ibid. Page 73). They used a simple measure of distance from settlements outward edges to measure grades of poverty due to low accessibility. For their second case study because of the its very steep land, they developed another measure of ‘impedance to the pedestrian network’ that combined the effect of steep routes
on walking effort as well as difficulty with upward and downward walking. The other factor affecting this measure was the lack of availability of movement facilitating services such as steps, bridges, walkways and etc. Through calculating this measure for each route segment they could then calculate the difficulty for accessing public facilities and transport nodes outside the settlement for each dwelling.

As Lemma reports, low accessibility has the inverse effect on spontaneous settlements of Addis Ababa (Ethiopia): “Inadequate access on both internal and external access roads is also one of slum characteristics ... The spontaneous development of the city has major effect on inner city [areas]... resulting in inadequate internal access roads that are characterized by irregular, narrow and blocked routes prohibiting vehicular access. Consequently, such settlements are inaccessible during like fire, flood, hazard and other emergency cases... Moreover, solid wastes are not collected occasionally because the tracks cannot access the areas. Laying out and maintenance of infrastructure are also a problem and that is one of the reasons the physical services are not provided readily in those areas.” (Lemma, 2005, Pages 62-3)

These examples show that accessibility in the case of spontaneous settlements is usually associated with difficulty in two respects; Firstly, reaching the internal areas of a settlement for service-provision especially by vehicular means (also see UNCHS 2003a, Page 85) and secondly difficulty in reaching the surrounding formal city (or its facilities) by the dwellers. While both these aspects are assumed to cause further poverty, the lower accessibility is expressed through difficult paths that make it hard to reach different places for certain activities (e.g. using a transport node).

Both cases can be related to the general concept of accessibility in geography that is based on the ease of reaching different places from an origin (Torrens,
In this way, the ‘ease’ is decreased with ‘frictions’ caused by impeding factors and the more energy or time consumption to traverse the distance in reaching different destinations. For each destination also, an index of attraction can be defined based on its importance or ‘weight’ (e.g. population, land use attraction or etc.). As Jiang et al. (1999) argue, geographic measures of accessibility deal with locations as points and generally are not delicate enough to deal with urban layouts where the geometry (especially the linearity of streets) is important.

One implication of applying geographic accessibility to spontaneous settlements is that considering the mentioned road irregularity that makes it difficult to reach their internal parts, even placing an attractive activity there (such as a market) would result in inaccessibility to it. This again leads to the dilemma of local centers that need good connections to the larger city. Interestingly, such centers (or markets) can be found in the internal parts of spontaneous settlements; Budiharto (2003, 2005), for instance, report the existence of internal linear markets in spontaneous settlements. UNCHS (2003a) emphasizes that internal markets are likely to be found in large spontaneous settlements with attractions for city-wide customers.

Couldn’t it be the case that spontaneous settlements have areas with higher accessibility from the surrounding city within them? Such measure of accessibility should not rely on sole metric distance from settlement edges because the location of informal markets within a settlement cannot be explained by it. So there is a need for a measure of accessibility that can explain higher accessibility, its resulted higher movement ratio and location of commerce regardless of metric distance. Having such measures at hand, it is still possible that such inner markets are subtly more accessible in the local level for the dwellers though still less accessible from the city-wide to serve

47 The distance unit in such calculations is the metric length of the actual route that should be traversed or alternatively the direct line between two points in space.
the dwellers’ territorial preference. The existence of such internal markets can indicate the existence of a structure or ‘order’ in terms of accessibility that connects the inner parts of a spontaneous to the formal city which can then facilitate consolidation. However, the proper concept of accessibility still needs to be introduced. As Hillier and others (2000) show, commercial activities on highly accessible roads on the edge of small informal settlements can facilitate their consolidation. They use a topologic or ‘geometric’ concept of accessibility that could explain the economic gain of commercial land use (as movement demanding activity) through predicting movement ratios. This concept of accessibility will be introduced in the 5th chapter on space syntax approach.
Conclusion

This chapter has drawn a theoretical framework to explain the consolidation of spontaneous settlements as a category of slums. The theoretical framework synthesized and extended different existing approaches to slums and urban poverty to take into account the inter-relation and interaction of poverty factors that leads to consolidation or otherwise degradation. The major categorization includes physical and non-physical poverty factors that are of spatial nature while the major non-spatial factor is the time (reflected in settlement age). The key notion that explains the interaction mechanism between major physical and non-physical categories was the preferences of the poor to overcome poverty factors. The strong preference for overcoming income-poverty (as a non-physical factor) requires city-wide accessibility to job opportunities in central urban areas that can be satisfied by dwellings in inner-city areas or settling alongside main arterial routes where spontaneous settlements usually grow on vacant land. The central inner-city locations, although have higher risk of eviction, have a higher potential for consolidation especially when time goes by and the larger city expands.

Moreover, due to the illegal or invading initiation of settlement there exists a strong preference for territorial control and resistance against eviction threats. This requires clustering with like-minded groups in terms of socio-economic status to create a kind of ‘aspatial solidarity’. All in all, when the settlement manages to keep its economic and territorial preferences fulfilled over time, it has tendency to consolidate with simultaneous and inter-related improvement in physical and socio-economic factors. A sign of such process is the emergence of local centres within a spontaneous settlement with higher built-up density and land use diversity. The irregular morphology of spontaneous settlements is partly constituted by these heterogeneities that make the local centres distinct through higher intensity of commercial/public activities and also indicate the history of growth and evolution of that settlement.
Asking the question on the requirement for these local centers to function in a scale wider than the settlement led to the scrutiny of ‘accessibility’ notion in conventional slum studies i.e. ‘geographic accessibility’. In this notion, the irregularity of the street network is considered as the main reason for low accessibly from and to a settlement while accessibility of each dwelling is calculated based on its distance to certain attractor points outside the settlement. Geographic accessibility in this sense could not explain why linear arrangement of shops constitutes the local centers within the settlement that requires another notion of accessibly.

The reviewed issues in this chapter regarding urban poverty and consolidation will be observed for actual case study spontaneous settlements from two respective cities of Zahedan in chapter 3 and Jeddah in chapter 4. I will illustrate that the two cities are presenting most of the aforementioned social, economic and spatial characteristics of Third World cities that contribute to the proliferation of spontaneous settlements in those. Also, in the next two chapters, the variety of irregularity aspects in local level, reviewed in this chapter, will be discussed for the actual spontaneous settlements along with measurements of their consolidation ratios.
Chapter 3: Urbanization in Iran and Saudi Arabia and the spontaneous settlements of Zahedan (Iran)

Introduction

In this chapter and chapter four I will introduce two case studies of spontaneous settlements in the respective cities of Zahedan (this chapter) and Jeddah (chapter 4). This first part of this chapter aims at understanding the national and regional context from which these two cities; Zahedan and Jeddah, along with their spontaneous settlements are chosen for this study. This begins with a brief introduction to the national and international context of the respective Middle Eastern countries hosting the cities of Zahedan and Jeddah (i.e. Iran and Saudi Arabia) which can shed light on the issues affecting urban poverty and housing in these cities which may be similar to other Third World cities mentioned in chapter two. These issues may ultimately influence the growth and condition of spontaneous settlements.

The second part of this chapter will focus on the city of Zahedan in terms of its provincial and urban context especially the consolidation of its spontaneous settlements. Because more socio-economic data is available for the city of Zahedan (compared to the case of Jeddah), the conjectures on consolidation of its spontaneous settlements can be checked with further confidence although not with certainty. Physical evidences such as the formation of local centres - indicative of the consolidation of a settlement- can then be examined against other physical factors (e.g. higher built-up density) and non-physical factors (such as settlement age and residential space per dweller). These conjectures on consolidation can ultimately be qualitatively checked against images of GIS maps of socio-economic indicators.
Through looking at attributes of spontaneous settlements with regard to the rest of the city, the thesis will hypothesize that the fulfilments of dwellers’ preferences (especially in terms of location and time they manage to stay in that location) have contributed to the consolidation while the younger spontaneous settlements have lesser signs of consolidation with socio-economic deprivation. Though the age of a spontaneous settlement in Zahedan seems to play a major role in its consolidation (i.e. the formation of local centres in it), it cannot explain why some of the older case study settlements have failed to develop such internal centres. Moreover, questions will be raised about the accessibility condition for the formation and the performance of such markets.

Outline

The first part of this chapter will introduce the two Middle Eastern countries of IRI and KSA with focus on their urbanization trends. Their demographic trends, rapid pace of urbanization and factors contributing to this pace will be highlighted. Also, issues pertaining to the national economic status and their impacts on urban poverty and wealth distribution will be reviewed which in combination with housing policies can give an indication of why slums and spontaneous settlements emerge in the two respective countries.

The second part will then focus on Zahedan and its spontaneous settlements. Firstly, a brief history and overview of urban poverty and spontaneous settlements in IRI will be given then Zahedan will be located in that national context along with more elaboration on provincial poverty around the city, its border location and its administrative and trading significance in the province. Then the overall economic and employment situation in Zahedan will be reviewed with emphasis on the gap between formal and informal job sectors with the provincial migrants (mostly poor) filling the latter sector. The overall
demographic trends of the city with its implications for the increase of poor population will then be addressed. This is followed by a discussion on the physical expansion of Zahedan in previous years.

The discussion on the urban growth opens up more issues on the physical structure of the city, its land use distribution and major zones including the spontaneous settlements. Further, looking into the land use distribution and diversity and built-up densities will help further understanding of Zahedan major zones especially the centres and the city growing trends. These observations on the city structure will then be summarized as a general schematic model of Zahedan that helps with inferring the preferences of spontaneous settlement dwellers mainly through their distance (or geographic accessibility) from the major urban zones.

The chapter will then focus on the spontaneous settlements of Zahedan and starts with the physical attributes and age of these areas. The location, size and ownership issues will be addressed and then the built-up density and also living area per dweller (as an inferable socio-economic factor) will be examined. Also, land use pattern within the settlements and formation of local centres as areas with higher diversity of activities will be looked at as an indicator of improved socio-economic status of the dwellers and hence an indicators and facilitator of consolidation process. The consolidation of settlements will be measured according to the strength and distinctiveness of these local centres and the outcome would be checked against other factors such as built-up density, residential space per dweller, and settlement age.

Issues under land use matters including the distribution of commerce and public facilities will follow as well as the condition of roads, infrastructure and building construction and the available socio-economic data – mostly in GIS map- all contributing to further cross-checking of the consolidation measurement. The review of Zahedan will end with a description of the
variation amongst the spontaneous settlements and the raised questions on the accessibility condition of the local centres. The chapter will then end with a conclusion summarizing its two sections on introducing IRI and KSA and the spontaneous settlements of Zahedan.

**Zahedan (Iran) and Jeddah (Saudi Arabia) in the Urbanizing Middle East**

This chapter and the next one will introduce some case studies of spontaneous settlements in cities of Jeddah and Zahedan. The two cities are respectively located in Middle Eastern countries of Kingdom of Saudi Arabia (KSA) and Islamic Republic of Iran (IRI) for which the abbreviated names will be used henceforth. Before carrying a general summary of the Middle East its urbanization characteristics should be added. This thesis takes the definition given by Britannica (2009b) for the Middle East region including countries of IRI and KSA (Ibid.)

![Figure 3.1](source: Worldatlas.com (2011))
Figure 3.1 shows the location of these two countries with regards to their neighbouring countries in the region. Urbanization in the Middle East is said to show the same trend as other developing countries in which the very fast growth of urban population has given rise to spontaneous settlements (Held and Cotter, 2000). The two countries of KSA and IRI will be reviewed in more detail for further understanding of their urbanization trend.

The countries of KSA and IRI in brief

As Held and Cotter (2000) state, Saudi Arabia is the largest country in the Middle East, twelfth in the World and the second amongst the Muslim countries. According to Britannica (2009c) KSA has the largest share of known oil reserves of the world (about 20 percent) that ranks it first in international level. It also has the longest coast line on the Red Sea and the second longest on the Persian Gulf (after Iran) according to Held and Cotter (2000).

The same source also indicates: “Iran’s major ranking serve as reminders of the fundamental importance of the country: In the [Middle East] region, it is the second in size, second or third in population, forth in petroleum reserve, first in natural gas reserves, second in total area under cultivation, first in copper output, and otherwise a ranking producer.” (Held and Cotter, 2000, page 487). A brief comparison between the two countries is presented in Table 3.1.

Table 3.1 indicates that these two Islamic countries have a large Muslim population. KSA is also the birth place of Islam with the cities of Mekkah and Medinah that attract hundreds of thousands of pilgrims during hajj (Islamic religious pilgrims) annually. IRI also accommodates some of the holy sites of
Shia Islam mainly in Mashhad and Qom but the number of foreign visiting pilgrims for these sites is not comparable with KSA. Nonetheless, the majority of Muslim population make the two countries similar in some cultural aspects mainly the underlying traditional views that influence social issues such as household structure and size, kinship ties and so on.

<table>
<thead>
<tr>
<th>Country (official name)</th>
<th>Kingdom of Saudi Arabia (KSA)</th>
<th>Islamic Republic of Iran (IRI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (square kilometres)</td>
<td>2,248,000</td>
<td>1,645,258</td>
</tr>
<tr>
<td>Estimated population by 1999 (in 1,000)</td>
<td>21,500 (with 25.6% expat)</td>
<td>61,500</td>
</tr>
<tr>
<td>Muslim Population %</td>
<td>98.8 (mostly Sunni)</td>
<td>98.0 (90.6 Shia and 7.5 Sunni)</td>
</tr>
<tr>
<td>Main exports and its share of the total value (1998)</td>
<td>Oil 93%</td>
<td>Oil 80%</td>
</tr>
<tr>
<td>Capital City and its population by 1999 (in 1,000)</td>
<td>Al-Riyadh 2,800</td>
<td>Tehran 7,700</td>
</tr>
</tbody>
</table>

Table 3.1 - comparison between KSA and IRI according to Held and Cotter (2000).

Demographics and urbanization trends

UN data sources (UN, 2008) estimates that KSA’s population is estimated to be around 26.2 millions in 2010 which is about one third of IRI estimated population of 75.0 million at the same time. Despite the larger area of KSA its, population has been always less than IRI over the last decades and is projected to remain less in future (Figure 3.2). In comparison, KSA maintains a higher population growth in recent years as suggested by Figure 3.3. As the same
figure shows, apart from 1955 when the annual growth rates were almost around 2.5 percents for both countries, KSA increased its growth rate with a faster pace that reached the staggering 6.8 percents in the period from 1980 to 1985 as its maximum.

![Diagram of population growth](image)

Figure 3.2 - Total population of KSA (purple) and IRI (blue). Diagram created by the author using data from The World Bank Group (2011).

The high population growth rate for KSA between 1970s and mid-80s can be related to the economic boom due to oil incomes\(^{48}\) which also attracted a considerable population of foreign labour for further development of the growing industries (Britannica, 2009c). The same period also includes the highest population growth in IRI (Ibid.) that partly overlaps with the era of highest economic growth in 1960s and 70s. It is claimed that during this period the traditional view of households was in favour of larger family size in IRI which changed in the next decade (Gheissari, 2009)\(^{49}\).

\(^{48}\) The oil-boom period is referred to the period between 1974 to 1980 (for example see Riad El-Ghonemy, 1998)

\(^{49}\) Moreover, the continuation of high growth rate after the Islamic Revolution of 1979 is related by Abbasi-Shavazi and others (2009) to the halted family-planning programs and the pro-natalist official
Figure 3.3 - Annual population growth rate of KSA (purple), IRI (blue). The yellow line is representing the annual growth rate of Western Asia and South-Central Asia together where the countries of IRI and KSA belong to. Data source: The World Bank Group, 2011.

A point should be added about the population distribution in both countries. Vast areas of vacant and dry land in both countries are due to climatic reasons. KSA is essentially a dry country with low precipitation, while for Iran the climate is more diverse but again in the south and east of the country the summers are hotter and dryer. This explains part of the tendency to settle in cities for both Jeddah and Zahedan as will be seen in a context of harsh rural life.

approaches during war with Iraq (1980-1988). The population growth rate of IRI falls dramatically in 90s as a result of enacting the family planning policies again (Ibid.) and the shift of households’ priority to invest in health and education rather than having more children (Gheissari, 2009).
Urbanization trends in KSA & IRI

The main reason for reviewing the national demographic trends of KSA and IRI is to further understand the changing demographic trend in their cities that can later be related to the emergence of slums and spontaneous settlements. This is shown by measuring the ‘level of urbanization’ (i.e. the percentage of total population that settle permanently in cities). In the Figure 3.4, an estimation of the urban population percentage is given. Both countries of IRI and KSA show an upward trend reaching urbanization level of 75.5% and 91.6% by 2020, respectively.

![Urbanization trends of IRI & KSA](image)

Figure 3.4 - Level of urbanization for IRI and KSA in three decades according to data from UNCHS (2003a).

According to UNCHS (2003a) the annual urban population growth rate for KSA was reported to be 3.48% compared to the average of 2.36% growth rate for IRI in 2000-2010 that is well above their national population growth ratios. Also, the urbanization figures are proportional to the overall higher national
population growth rate of KSA compared to IRI (i.e. the faster the population
growth of the country the faster its urban population growth). This suggests
that because cities have accommodated more portion of national population in
those, the national growth rates are also influenced more by changes in the
urban population as opposed to rural growth rates.

The increase in urban population can also be checked against the rural figures
that show negative growth (annual growth ratios of -0.062% for IRI and -0.23%
for KSA\textsuperscript{50}). Moreover, it can be inferred that there is a rural to urban flow of
population as in other developing countries. The issue of migration and its
causes will be further discussed for each country and their case cities.

One point related to the aforementioned issue of foreign labour in KSA is its
contribution to the urban population growth as most of the international
workers –along with other migrants from within KSA- were settled in major
cities (Al-Hathloul and Edadan, 1993). In addition, it is reported that some
foreign pilgrims tend to stay around the holy cities either as a religious act of
devotion or due to poverty as an obstacle for their return (Britannica, 2009a).
Foreign labour or pilgrims, however, are not major contributors to population
growth of IRI as compared with KSA.

\textbf{National economic indicators of IRI and KSA}

Both countries of KSA and (to a lesser degree) IRI enjoy oil incomes. According to the World Bank online data bank (2011) the GDP per capita for the countries of IRI and KSA were reported to be 2168 and 9827 US dollars respectively in 2009. Apart from the attempts by the governments of both countries to diversify the economy (as opposed to being mainly relied on oil revenues) and achievements in developing industries and manufacturing, it

\textsuperscript{50} UNCHS (2003a) Page 253.
seems that both countries have economically suffered from fluctuations in the oil market in the past. Further to Iran’s disadvantage one should add its isolation from the international economy due to sanctions and the defensive views amongst its conservative ruling parities with arisen economic challenges for both countries (see respective entries for ‘Iran’ and ‘Saudi Arabia’ at Britannica, 2009c & 2009d).

The evidence that confirms the economic challenges facing both countries of KSA and IRI is high ratio of unemployment in both for 2010. They are reported to be 10.8% and 14.6% for the respective countries according to the World Fact Book (CIA, 2008) although As Fakeeh (2009) reckons the Saudi figure can be as high as 25%. Such economic issues can also be expanded to the issue of poverty and inequality that will be addressed below.

The national economic indicators such as GDP per capita although indicates the total wealth of a country, they do not indicate how the wealth is distributed. In this regard, the measure of Gini\(^51\) is 44.5% for Iran but there is no official calculation for KSA. Despite the lack of data for KSA, signs of inequality such as the population of slum dwellers (see below) indicate the existence of economic inequality amongst its population.

**Slum population in KSA and IRI**

The housing policies of both countries will be discussed in more detail later on. Overall, both cases failed to address the growing need for housing (Jeddah Municipality, 2009; and for IRI see Zebardast, 2006) in recent years especially by exclusionary regulations that prevent foreign or rural migrants from

\(^{51}\)The Inequality in economic terms is measured through Gini coefficient that in simple words takes 0 if in theory the wealth is equally distributed in a perfect sense and becomes 1.0 if the distribution is perfectly unequal. See chapter 5 for more detailed definition.
obtaining ownership rights as well as unrealistic prices in delivering housing that put it above the affordability of the more people have to live in slum areas.

Lack of affordable housing supply in combination with inequality and urban poverty would also leave the less well-off citizens with no choice but to dwell in slums. As mentioned in the previous chapter, spontaneous settlements are a category of slums or informal settlements, but because most of the available data does not distinguish between the categories, the available statistics on slums is presented here.

Assuming the urban population of 19.12 million and slum population of 3.442 million at 2005, UNCHS (2008) concludes that 18.0 percent of urban population in KSA has been living in slums by that time while for IRI the figure is 30.3 percent (these include all the households that have at least one of the slum operational deprivations). This suggests that IRI has a larger population living in slum condition.

The cities of Jeddah in KSA and Zahedan in IRI despite their different national contexts are not exceptions in terms of having considerable ratio of their population living in slums (between 30 to 40 percent of population for both cities). Close inspection of the urban fabric of those slums -in this and next chapter- will show that most of these can be categorized as spontaneous settlements hence makes the two cities proper cases for this study. What follows is an introduction to the first case study of Zahedan and its spontaneous settlements within its larger national and regional contexts. The second case study of Jeddah and its settlements and a summary of comparison between the two cities will be presented in the next chapter (chapter 4).

52 However, there has been various estimations from very optimistic 12.5 percents by the Iranian ministry of housing (IMHUD, 2004) to the seemingly overestimation of 44.2 percent for 2001 (Moreno, 2003) which was never repeated in UN-HABITAT statistics.
The first case study Zahedan, Iran

Urban poverty and Spontaneous settlements in Iran

After this introduction of the Islamic Republic of Iran, this section will examine the roots of spontaneous settlements in more detail relating to the particular reasons behind their expansion mainly the previous trends in regional and urban planning policies in Iran and the history and reasons of the formation of these areas (the next chapter will follow the same process for the case of Jeddah). Zebardast (2006) claims three forth of slums are to be found in the 10 larger cities in the form of spontaneous settlements. He also (2006) refers to Habibi (1993) claiming that the first spontaneous settlement in Iran was ‘Islamshahr’ (in Tehran) going back to 1960s.53.

Zebardast (Ibid.) also summarizes two main reasons for the resorting of urban poor to informal solutions and the expansion of spontaneous settlements:

1- Restrictive planning regulations that sets a minimum residency periods of staying in urban areas and minimum age limits for rural migrants to apply for the ownership of land causing the exclusion of a large proportion of people;

2- The focus of housing and urban development policies on middle-income groups that divert the subsidized aids from lower-income groups.

The next section will deal with the reasons for the attraction of rural migrants to urban areas.

53 Islamshahr with about 300,000 population, was deemed attractive to migrant from both rural areas and also Tehran middle-incomers because of the availability of land with reasonable price and low building costs (Ibid.).
Urban-rural migration and its reasons in IRI

In the aforementioned section on urbanization trends in IRI and KSA a conjecture on rural to urban migration was mentioned. This flow is actually reported by various sources (Molaei et al., 2008; Habibi, 1993). Similar to other developing countries the main motive is explained as the higher income in the cities compared to rural areas that was about 1.5 times in 2006 by Molaei et al (2008). Nonetheless, as Zebardast (2006) argues not all the dwellers of spontaneous settlements are from rural areas but especially in large metropolitan areas like Tehran a considerable ratio of those are from other cities or even Tehran itself. For the case of Zahedan, as will be seen, the rural origin of migrants or the fact that most of them come from smaller cities in the province would clarify their economic preference for income as most of them are job-seekers.

The major increase in rural to urban migration is attributed to the 1950s’ Land-Reforms by Shah -in which the arable lands were split and granted to rural people- weakened the agricultural economy by making it more profitable for a few agribusinesses and landlords (Bayat, 1997; Danesh, 1987). After the revolution the attraction of cities to rural migrants did not decrease. As Fanni (2006) reports while cities have kept an average annual population growth rate of 3.4% between 1976 and 2001, urban population reached 66% of the total population, rural areas have dropped from 53% to 35% of the total population during the same time period. Fanni (2006) mentions different reasons for this trend such as the rural unemployment, concentration of capital and amenities in few cities and (hence their ‘deceptive attraction’ to low-educated labour) lack of birth control schemes and weakness in urban management practice and (mainly Iran-Iraq) war migrants fleeing the conflicted provinces. This has not only resulted in an unequal distribution of population between urban/rural
areas and between cities themselves\textsuperscript{54} but also inequality within the urban areas that resulted in the formation of spontaneous informal areas\textsuperscript{55}.

The city of Zahedan is not one of the large and better-off cities in the country. On the contrary, it is the capital of one of the most deprived regions but most of the causes for rapid urbanization mentioned by Fanni (2006) -such as rural migrants- are observable in Zahedan. In next section, the focus will be on the urbanization trends of Zahedan with regards to its regional and national context and its consequence as spontaneous settlements.

\textbf{Zahedan in its wider provincial context}

The city of Zahedan is located in the southeast of Iran close to the border with Pakistan and Afghanistan. It is the capital of Sistan & Balochestan Province that has been the most deprived provinces in Iran before and after the Islamic Revolution of 1978 (Afrakhteh, 2006; Piran, 2000). Several reasons have been stated for the underdevelopment of the province such as the harsh climate -that hinders agriculture and results in rural poverty. Some people argue the natural resources and climate are not the only reasons for the underdevelopment. As Piran (2000) refers to other writers, Sistan -the northern region of Sistan & Balochestan- used to provide the rest of the country with wheat. As a result he argues that the reason for provincial deprivation should be sought in national policies and other factors such as the border location of the province. It should be reminded that understanding the provincial underdevelopment and its

\textsuperscript{54} By 2001 just 36\% of Iran population was in 9 large cities from which 16\% was in Tehran.

\textsuperscript{55} In explaining the underpinning reason for this imbalanced urban growth in Iran, Fanni (2006, Page 411) states: “In contrast to those developed countries in which urbanization had been evaluated with structural changes in economy and production, urbanization changes in Iran have not been caused by the improvement and betterment of economic and social functions and the methods of production; rather they have been caused by the high income gap between economic sectors and the unavailability of work to rural dwellers.”
causes are important for this chapter due to its impact on the growth of urban poor population.

Sistan & Balochestan was reported to have 1.7 million population by 2000 (Piran, 2000) of which the majority belong to Baluchi ethnic group residing in the southern parts of the provinces. The second ethnic group is ‘Zaboli’ (or ‘Sistani’) who mostly live in the northern areas. The fact that Baluchi people in this province and the people of Balochestan province in neighbouring Pakistan and Afghanistan share a lot of cultural and social similarities also creates a good potential for cross-border trades as well as migration (Afrakhteh, 2006).

With regards to the provincial situation adjacent to the foreign borders, Zahedan is acting as a transit gateway for export/import of goods for the region. The circumstances that give rise to the commercial importance of border cities in the province is summarized by Afrakhteh (2006): “The exchange of goods is the initial basis of trade in the region which - along with the lack of powerful productive institutions caused by the marginal position, climatic conditions, settlement of nomadic tribes, increased urban population and the border situation - has given the urban centres a commercial and business role.” (P. 427). Because of the shortage of job opportunities, most of lower skilled labour are attracted to cross-border trade which usually turn to illegal trafficking (Ibid.) or even drug smuggling from Afghanistan (Piran, 2000). On the other hand, and because of the existence of people of the same ethnic origin on the other side of the border, workforce and family related migration are high that contributes to the flow of population to Zahedan (Afrakhteh, 2006).

Another reason that is pinpointed by different sources (IMHUD/WB, 2003; Piran, 2000; Afrakhteh, 2006) is that Zahedan is favoured by the central governments as the operational centre of the province. This was based on the idea of enforcing a strong provincial administrative centre due to the strategic
location for different purposes such as controlling the long borders of the province and integrating the province to the rest of the country (Afrakhteh, 2006). This intention was actualized by investment in the infrastructure and services also official institutions with their employees coming from other cities in the country\textsuperscript{56}.

After the Islamic Revolution of 1979, the central government has been trying to improve the situation in the province through further investments but just a small proportion of people have harvested the benefits of such interventions. Afrakhteh (2006) introduce this group as “\textit{a minority of self-employed pseudo businessmen (active in illegal extraterritorial trade)}” that then invest their capital in land and housing market in the south of Zahedan leading to the delivery of relatively expensive housing stock concentrated in the south of the city while the majority of poor people do not have other choices but to go to the spontaneous settlements of the north (Ibid.).

**The economy and employment in Zahedan**

The economic shortcoming of Zahedan will be further studied here to understand its impact on employment and deprivation. According to the IMHUD/WD report (2003) the agricultural and industrial activities in Zahedan are hindered by different factors. The most prominent obstacles to the former are the dry climate and unsuitable soil while the latter is weakened by the lack of skilled human capital as well as the shortage of natural resources, infrastructure and up-to-date technologies. In addition, the prevailing form of industrial activities in the Sistan & Baluchistan province is small workshops with a few workers (1 to 5 persons, Piran, 2000), while Zahedan local

\textsuperscript{56} This process of gaining official position was marked by the change of Zahedan’s name from its original name ‘Dozdab’ in 1936. Dozdab as a village had the strategic connection to the Indian sub-continent through railroad since 1918-1919 which made it a favorable spot for traders between Iran and India (IMHUD/WB, 2003).
industries do not have advanced technological products like cars or machineries and are rather limited to brick, food products, woven materials and ceramics (Britannica, 2009e)

These circumstances will make the service sector (i.e. the jobs and entrepreneurs that do not produce goods) the largest employment pole in Zahedan with reported 35 percent share of total employment in the city while the city has become the main focal point of employment and based on service activities in the province: “The basic employment opportunities in the city are social and personal services trade and transport. What this boils down to is that jobs in Zahedan are created either through the government service sector activities or in trade.” (IMHUD/WB, 2003, Page 9).

The ‘trade’ mentioned above refers to informal activities as noted by the above source and confirmed by (Ibid. Page 16): “Zahedan betrays a highly dualistic structure of formal versus informal spaces and economic activities... The largest occupational categories are those of very low skill requirements on the one hand and those classified as specialists on the other. The latter is mainly concentrated in the public sector.” The same report adds that because most of the provincial migrants cannot be absorbed in the formal sector or governmental jobs (that are instead filled by other types of elite migrants from outside the province), they have to work lower salary jobs and live in spontaneous settlements. The informal sector (mainly including smuggling or trade of smuggled goods) constituted 40 percent of Zahedan’s economy according to an estimation by IMHUD/WB (2003, P. 61).
Zahedan urbanization and demographic trends

The provincial circumstances mentioned above especially border proximity and provincial poverty have contributed to a quick population growth of Zahedan. In general, the harsh climate for agriculture and rural poverty in this province accounts for the population flow from villages and smaller cities to the larger cities in search of better living conditions (Ibid.). In addition to the in-migrants, there have been Afghan refugees fleeing their country during the political conflicts of 1980s which mostly deemed as illegal migrants. These factors in conjunction with the natural population growth have pushed Zahedan from a city with 17,000 in 1950s to about 565,000 citizens in 2001 that is depicted in Figure 3.5. The figure also suggests that Zahedan is the major urbanization pole in its province. This quick pace will be further examined in the next section.

Figure 3.5 - The population of Zahedan compared to other cities in the province (source: IMHUD/WB, 2003).
**Zahedan general structure and its schematic urban model**

This section will look at Zahedan with the aim of understanding its overall structure through proposing a generalized schematic model. This will help with locating the spontaneous settlements within their larger urban context to understand the preference of their dwellers in terms of location (mainly the distance or geographic accessibility to the major centres) and land use.

A few points have been made about the provincial climatic context, but it should be stressed again that the Zahedan is not an exception in its province with hot and dry weather and reported occurrences of drought (Saghafian and Shokoohi, 2003). There have also been reported floods which are now under control. The city is overall on a flat plain with a slight slope descending eastward. In the south, the land is fairly flat with a very slight descending slope when approaching the centre and then again upward when reaching the hilly sides in the north.

**Zahedan growth and major zones**

The physical fabric of the city has also expanded in parallel with the demographic growth in a very quick pace in recent decades. The original plan for the city comprised of four streets in north-south and east-west directions and was initially designed by an Indian engineer from Quetta. Figure 3.6 shows the growth of Zahedan since 1940s in relation to the two main obstacles, a natural one in the north (the ‘Ghirestan’ mountain) and a manmade one to the east and south-east i.e. the airport. The municipal limits at each stage are represented by dotted cyan lines. It can be observed that by 2001 the city had

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57 The last flood with damages to the spontaneous settlements in the north of the city happened in 1989 which forced the authorities to make flood channels in these areas, later on turned to garbage dumping sites but flood-risk is claimed to be controlled due to these channels.
already expanded about 43 times larger compared to its original core in 1941 as shown in Figure 3.6. Because of the two mentioned obstacles, the major directions of city growth can be divided into two groups: one towards the south and west comprised of formal and official developments (the white arrow below) and the other to the north and north east that is driven by the spontaneous informal housing areas (the orange arrow).

Figure 3.6 - The physical expansion of Zahedan (based on aerial photo tracing by the author).
Figure 3.7 - Measurement of Zahedan area according to the aerial images by the author. The vertical axis represents the city area in squared kilometres and the horizontal axis shows the year.

It should be noted that this division between the formal and informal developments can be traced back to the initial land quality where each respective development started to grow further. The original areas of the city up to its 1970s limits are surrounded by a ring of spontaneous settlements on the north and north east and formal areas to the south and west. The northern areas have been considered as inherently steep and flood—prone from the past and less favourable for the formal development or originally unfavourable farm lands in the north east that are subdivided and sold later on. These are in contrast with the lands in the south parts of the city that are flat and initially accommodating major formal facilities such as custom offices.
Municipal boundary and spontaneous settlements

A categorization by IMHUD/WB (2003) divides the spontaneous settlements - referred to as ‘irregular’ by that report- to the two groups of within the municipal boundaries\(^{58}\) and the ones that are outside. Both respective groups along with their age and the abbreviated names used throughout the thesis are listed in Table 3.2. As IMHUD/WB (2003) suggests the settlements within the municipal boundaries show less signs of physical poverty compared to the

\(^{58}\) The municipal legal boundary was defined in 1977 after the Master Plan proposed by M. Co-Iran Consultants was approved by the authorities (WB/IMHUD, 2003).
outer ones. The reason for the better condition of inner-boundary settlements is important as an indicator of their more consolidated stage.

<table>
<thead>
<tr>
<th>Irregular settlements outside the city boundaries</th>
<th>Neighbourhood (and the abbreviated name)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darreh Panjshir (DPZ)</td>
<td>35 years</td>
<td></td>
</tr>
<tr>
<td>Chaliab (CHZ)</td>
<td>20 years</td>
<td></td>
</tr>
<tr>
<td>Nukabad (NUZ)</td>
<td>15 years</td>
<td></td>
</tr>
<tr>
<td>Qasemabad (QAZ)</td>
<td>15 years</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Irregular settlements inside the city boundaries</th>
<th>Neighbourhood (and the abbreviated name)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babaeyan (BAZ)</td>
<td>50 years</td>
<td></td>
</tr>
<tr>
<td>Sikhsuzi (SIZ)</td>
<td>40 years</td>
<td></td>
</tr>
<tr>
<td>Poshteh Garage (PGZ)</td>
<td>30 years</td>
<td></td>
</tr>
<tr>
<td>Shirabad (SHZ)</td>
<td>30 years</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.2 - Zahedan spontaneous settlements with their abbreviated names and their age by 2011 (extracted for IMHUD/WB, 2003).

The locations of these 11 areas along with their names were demonstrated on the GIS map of land use (Figure 3.9). Looking at Table 3.2 and knowing that the inner-boundary settlements are better-off, one can predict that the inner settlements are older and more consolidated due to the time factor as the city expands outwards. Supporting such a conjecture needs further understanding of the overall spatial characters of the city regarding land use and built-up density.

**Land use distribution and built-up density in Zahedan**

The aim of this section is to first understand the overall spatial distribution of land use in Zahedan and then to focus on the spontaneous settlements in that context. This will allow for inferring some of the distinct socio-economic
characters of spontaneous settlements. As was demonstrated in the map of Figure 3.9, the major industrial, governmental and commercial activities are coinciding along the two main alignments of north-south and east-west directions the diversity and density of such public activities (especially the commercial ones) increases towards the junction of these two alignments where the old core of the city is located. Larger plots are to be found in the peripheries that are either transport, industrial or vacant plots. A large cluster of industrial activities in the north-west is an example of such large plots that is linearly extended from the inner areas of the city through the corridor of Tabatabaei Street.

Apart from the main corridors with its concentration of public land uses, the area between these alignments is covered with residential areas. For example, the new formal development zones in west and south are predominantly residential but in the vicinity of major urban administrative and other facilities along the University Street. Spontaneous settlements in the north are similar in the same way of being mostly residential although there is no notable diversity of administrative, community, educational or health facilities in those or their vicinity.

More accurate measurement can help complementing the above observation on land use. A summary of main categories of land use is shown in the below Table 3.3\textsuperscript{59}. Residential land uses make up about half of Zahedan municipality lands which makes it the most dominant land use. Transportation and warehouses (that corresponds with terminals, bus and train stations, parking and stores) also comprise about 10 percent of the total land use but this relatively large share is mainly due to a few mega blocks on the peripheral locations. The area calculations in the same table (Table 3.3) refer to the land plots designated for that use while in terms of building footprint area (as a

\textsuperscript{59} The original data on land use was more detailed but for the sake of comparison especially with the other case of Jeddah, this land use categorization deemed more useful in which some close categories are merged.
proxy for built-up area) a parallel trend is observable in which the most dominant categories are residential and commercial (comprising 77.5 and 8.7% of total footprint area respectively, see Table 3.5)

Further to the ratio of each land use, the way different categories of each are mixed or otherwise form a homogenous pattern is important. In addition to demographic and density factors, one indicator of urban centrality as Hillier refers to Batty and others (1998) are “land use concentration and mixes”

Figure 3.9 – Zahedan Land use along with its spontaneous settlements (black outline). The settlements are marked with their abbreviated names. Source: IMHUD/WB (2003).

Land use diversity and centers

Further to the ratio of each land use, the way different categories of each are mixed or otherwise form a homogenous pattern is important. In addition to demographic and density factors, one indicator of urban centrality as Hillier refers to Batty and others (1998) are “land use concentration and mixes”
(Hillier, 1999, Page 5). The work of Batty et al. (1998) although is done in the context of London, still is applicable to the Third World urban cases.

Explaining the methodology that was initially used by Batty and others (1998), Thurstain-Goodwin and Unwin (2000) suggest four main factors to identify urban centres which includes the economy (indicated by the turnover of a business), building density, land use diversity and the amount of facilities such as recreational buildings that attract visitors. Although some of these data are not available for the case studies of this thesis but a simpler methodology proposed by Batty (2003) to measure diversity-density will be used in this chapter and the next chapter. The aim of identifying the centres is to show how the spontaneous settlements are located in a city-wide scale with regards to them and then in a more local level to see how much a spontaneous settlement have developed its own centre as a sign of consolidation. To find out if the applied density-diversity measure is a fair reflection of consolidation, I will compare it with some other physical and socio-economic factors related to the case study spontaneous settlements later on in this chapter.

A more detailed look into the major zones introduced in Figure 3.9 shows a correspondence between the overall function of the zone and the land use distribution at micro level. The north-south alignment of University Street and some other parallel streets in its vicinity enjoy a greater diversity of administrative, educational and transport land uses. A more accurate analysis of such city-wide diversities will be presented after the discussion on built-up density below.
## Table 3.3- Land use categories in Zahedan sorted by land coverage.

<table>
<thead>
<tr>
<th>Function</th>
<th>Hectare</th>
<th>percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>1,743.87</td>
<td>50.08</td>
</tr>
<tr>
<td>Vacant land</td>
<td>453.345</td>
<td>13.02</td>
</tr>
<tr>
<td>Transportation and warehouses</td>
<td>345.521</td>
<td>9.92</td>
</tr>
<tr>
<td>Educational (all age groups)</td>
<td>280.589</td>
<td>8.06</td>
</tr>
<tr>
<td>Recreation and cultural</td>
<td>134.903</td>
<td>3.87</td>
</tr>
<tr>
<td>Industrial and maintenance</td>
<td>99.5023</td>
<td>2.86</td>
</tr>
<tr>
<td>Governmental and administration</td>
<td>96.6242</td>
<td>2.77</td>
</tr>
<tr>
<td>Commercial</td>
<td>64.7049</td>
<td>1.86</td>
</tr>
<tr>
<td>Park and green spaces</td>
<td>57.9578</td>
<td>1.66</td>
</tr>
<tr>
<td>Installation &amp; public infrastructure</td>
<td>57.6614</td>
<td>1.66</td>
</tr>
<tr>
<td>Social &amp; governmental services</td>
<td>45.0131</td>
<td>1.29</td>
</tr>
<tr>
<td>Medical services</td>
<td>38.9019</td>
<td>1.12</td>
</tr>
<tr>
<td>Religious</td>
<td>33.648</td>
<td>0.97</td>
</tr>
<tr>
<td>Cemetery</td>
<td>19.572</td>
<td>0.56</td>
</tr>
<tr>
<td>Truism &amp; Hotels</td>
<td>10.5218</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>Total calculated land uses</strong></td>
<td>3,482.335</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total area of Municipality boundary including restricted zones</strong></td>
<td>6,467.599</td>
<td></td>
</tr>
</tbody>
</table>

### Commercial land use in Zahedan

As mentioned before, commerce and trade can be considered as one of the very reasons for the establishment of Zahedan. In this regard, Fanni (2006) points to the markets that go back to the origin of the city such as “The Sikh Bazaar in
the central parts of the City, the Yazdi Bazaar and the Birjand Bazaar...” From a different perspective, Piran (2003) observes the prevalence of commercial activities in Zahedan and considers it as an evident of existing capital in the city although not equally distributed.

Consequently, the commercial activities can be observed almost all around the city of Zahedan with various densities and distribution patterns. The concentration of commercial activities in the old core of the city goes back to the first trading areas or ‘bazaars’ while the overall pattern there is more like a region or cluster that stretches towards the major streets making a pattern similar to what Hillier (1999) describes as a ‘spiky potato’. The commercial cluster also accommodates a diversity of other non-residential land uses such as small workshops and warehouses. Moreover, it can be observed that in the central parts of Zahedan the concentration of commercial land use coincides with higher diversity of other non-residential land uses.

The concentration of commercial land use in the centre of Zahedan is something explainable by the classic urban models in the second chapter. For example, as was mentioned in the bid-rent model the commercial activities are valuing the higher geographic accessibility in a central location compared to residential land use. However, what cannot be easily understood using such general models is the local variations in commercial land use distribution especially their intensive linear arrangement along some streets. This as will be discussed in the 5th chapter is an underlying weakness with the notion of geographic accessibility that will be exacerbated when dealing with the finer scale and irregular geometry of spontaneous settlements.
Built-up area density and land use diversity in the city

As was mentioned in the previous chapter, built-up density can indicate the overall growth history and direction in a city while at a more local level like for spontaneous settlements, it can reveal which parts have been consolidated or likely to be so in future. One point should be made here before proceeding about difference between built-up density and population density and their relation. A character of degrading slums is their overcrowding that usually results from high population density with low built-up area per person or low residential built-up density.

In the absence of accurate data on residential built-up and the number of floors (e.g. the case of Zahedan) a close proxy could be the footprint area of residential buildings; for a spontaneous settlement a measure of population density can be simply calculated by dividing its total population by its total residential building footprint area. For measuring built-up density, the Kernel methodology will be used that is based on the area aggregation of building foot-prints in a region (or ‘kernel’) around each point. The radius is called kernel band-width and it allows for turning the discrete pattern of building footprints to a continuous surface that can then be visualized proportional to the measured density in that kernel.

For example, Figure 3.10 shows the density in 7.065 hectare circles (or kernel band widths of 150 meters) cantered on each point. The total building foot-print area within each kernel is calculated in GIS environment and then is divided by the kernel area to calculate the density per hectare that is then assigned to the centre point of that circular kernel. The centres are spread on a 50m by 50m grid with different values that can be visualized to reveal the

\[60\] Moreover it can be observed that the city is overall very low-rise with most of the multi-story buildings in the central areas while for spontaneous settlements the dominant building height is single floor. This suggests that especially for these areas, the building footprints can give an acceptable measure of built-up area.
variation in density pattern. The choice of band-widths is also important and the radius of 150 meters in this calculation is arrived at after different experiments to reflect the very local variations in built-up density.

Illustrating local built-up density, Figure 3.10 indicates that the older central part of the city is denser while the expanding peripheries especially the northern parts are sparser. Also, it can be observed that spontaneous settlements present a variety of density patterns with clear formation of a density cores (i.e. areas with higher measure compared to their surrounding) for settlements within the municipal boundary. This suggests that the latter group - that includes older settlements- have reached a more mature stage of growth and internal intensification as a sign of their consolidation. However, the observed density cores per se cannot indicate the existence of local centres within the settlements as the land use diversity is not considered in the built-up density analysis.

\footnote{For discussion on the basics of KDE (Kernel Density Estimation) see O’Sullivan and Unwin (2003).}
Figure 3.10 - Building footprint density (band widths 150 meters) with cell size of 50 meters by 50 meters (natural break colour range). Spontaneous settlements within the municipal boundary are marked by dashed line. The black polygon is the city core.

For detecting the formation of local centres the method mentioned by Batty and others (2003) is used in combination with density. They add: “As we aggregate some places in suburban areas, these remain homogenous while other areas, particularly city centres, become more heterogeneous” (P. 4). Accordingly, they put forwards various mathematical formulas to measure diversity and density of land use simultaneously. The underlying concept behind all their formulas is to sum up the ratio of different land uses for the region around a point similar to the kernel method. The ratio of each activity is measured as the amount of that land use (e.g. plot area, built-up area or building footprint area) relative to a maximum observed in that place whole...
studied area\textsuperscript{62}. Based on the same concept, the thesis measures density-diversity at each point $i$ by summing up the amount of each activity $k$ in the place $i$ compared to the maximum possible of that activity observed in the whole study region (i.e. $\text{reg max } a(k)$):

$$d(i) = \sum_k \left( \frac{a(i,k)}{\text{reg max } a(k)} \right)$$

in which $d(i)$ is the density-diversity in $i$-th cell, $k$ is an activity or land use out of $K$ that is the total number of land uses, $a(i,k)$ is the amount of activity $k$ in cell $i$ and $\text{reg max } a(k)$ is the maximum observed of that particular activity in the whole studied region.

This formula seems to be capable of capturing the aspects of diversity and density at the same time while it normalizes the distribution of values over the study region. In practice $d(i)$ never reaches $K$ (or the number of all activities) but the value for all places can be scaled between zero and one to compare different urban systems.

Using the above method in two different band widths the following result would emerge. The analysis is done with band widths of 500 and 200 meters (see Figure 3.11, left and right images) so the analyses reflect two global and local levels. As the global analysis shows, density and diversity in the old core of Zahedan –outlined by a thick polygon- is high that is marked with warmer colours. These areas can be understood as more central spots that are stretched

\textsuperscript{62} The classic formula for density suggested by Batty and others (2003, Page 3) is:

$$D(i) = \sum_k \left( a(i,k)/\text{max}_i a(i,k) \right)$$

Here $D(i)$ is the classic density-diversity in $i$-th location, $k$ is a land use (always equal to or less than $K$ that is the total number of land uses in the studied region), $a(i,k)$ is the amount of activity $k$ in the $i$-th location and $\text{max}_i a(i,k)$ is the maximum observed activity in $i$-th location.
over the two main east-west and north-south axes. In the 200 meters band-width the cross-shape arrangement of local centres along the two main spines of the city can be observed.

Looking at the spontaneous settlements in the global analysis of density-diversity (Figure 3.11, upper tile), one can see that these areas tend to be found as close as possible to the major centre of Zahedan with more homogeneous pattern due to their overall residential function and lack of public and official buildings. The local analysis (200 meters band-width) would also show the existence of local centres as hot spots of density-diversity in older spontaneous settlements such as Babaeyan and Karimabad (Figure 3.11, below tile). These observations can confirm the settlement dwellers’ preference for proximity to the major urban centres while the existence of more localized centres can be an indicative of an ongoing consolidation process especially in the settlements within the municipal boundary. More accurate measurement of consolidation for each settlement will be done in coming sections through assessing the strength of diversity-density cores.

**The proposed schematic model for Zahedan**

From the above review of land use and densities various similarities can be observed between Zahedan and the reviewed Griffin-Ford model for third World cities in the previous chapter. The city centre of Zahedan although is not similar to the CBDs of large Latin American cities for the absence of high-rise buildings but it has a higher density and concentration of office buildings. The centre also has a clear dominance in terms of higher ratio of commercial and other non-residential land uses over the rest of Zahedan. The ‘spine’ can be clearly identified with concentration of commercial, offices, higher education and administrative buildings on two main axes of University Street (north-south) and Imam Street (east-west). Elite residential districts though are not on
both sides of these spines, in the south-western interstice between the two spines and the southern residential district. Although the zone of ‘peripheral squatter settlements’ as Griffin and Ford describe can be easily identified as a ring of spontaneous settlements but disamenity zones in form of inner slums cannot be found that can be explained by the smaller size and the shorter age of Zahedan.63

Confirming the assumption of lower socio-economic status of peripheries in Griffin-Ford through looking at data such as literacy rates or household size (Figures 3.20 and 3.21), one can see that apart from the elite zone around the University Street corridor where people are better-off for the rest of the city the more peripheral the location the poorer the people. This is similar to the underlying pre-industrial model of Third World cities with spontaneous settlements accommodating the least advantaged citizens that can be approved through comparison with socio-economic indicators (e.g. Figures 3.20 and 3.21). Looking at the land use map of Zahedan it also seems that the inner location of the old market areas is similar to the consolidated ring of Griffin and Ford model where informal economic activities prevail.

63 In other words, one can imagine that the current peripheral spontaneous settlements of Zahedan would constitute the future inner disamenity zones if the city expands out further.
Figure 3.11- Density-diversity maps for the building footprints by land use. The upper and bottom analyses use band-widths of 500 and 200 meters respectively with natural break thematic ranges for both. The old core of Zahedan (thick outline) and spontaneous settlements within the municipal boundary (thin outline) are marked.
Overall, it can be concluded that the Griffin-Ford model for the Latin American cities can also be applied for describing the city of Zahedan. The physical intensification and better-off socio-economic status of settlements within the municipal boundary compared to the more deprived peripheral areas suggests that time and geographic location might have played a role in the consolidation process. Observing that the spontaneous settlements within the municipal boundary, despite having nearly the same distance (or geographic accessibility) to the centre, show variety of local centre formations suggests that their consolidation cannot be solely explained through their geographic accessibility to the centre. However, establishing the mentioned conjectures on consolidation requires further understanding of the local condition and characters of spontaneous settlements.

The spontaneous settlement characteristics

In the next section, a description of the physical attributes of spontaneous settlements in Zahedan is presented to see the extent to which poverty is reflected in physical sense and the extent it is related to the non-physical mostly socio-economic circumstances and time.

The origin, size and location of spontaneous settlements

As shown before, the age of spontaneous settlements in Zahedan varies but they are all spread over the northern unattractive and low-serviced lands. As IMHUD/WB claims the oldest settlements (i.e. Babaeyan) started to appear since the beginning of the city itself. (IMHUD/WB, 2003) the date of origin amongst the settlements varies from 1950s (for Babaeyan) to more recent ones that are emerging on the outer skirt of the city by the time of this writing.
Agreeing with the theoretical review of chapter two one can also find out that the settlements within the municipal boundary are older than the ones outside as the former group includes more central settlements. This suggests that the older settlements that have become even more central due to the city growth might have been their dwellers’ preferences satisfied for a longer time and hence has more opportunity to consolidate.

Moreover, looking at the centrifuging growth of Zahedan, one can see that the older settlements have also followed the same trend and expand toward the peripheries. This suggests that even within the settlements the priority for growth was the vacant lands that were closer to the existing city except the cases (like Shirabad) where the settlement grew from a rural growth seed and then was met by the expanding city. This issue will be further discussed below in the next section on the settlements growth pattern.

However, two other points should be mentioned before proceeding to the next section on the growth pattern. First is that the overall size of the settlements that have been surveyed by IMHUD/WB (2003) is non-small i.e. each one has more than 10,000 population with more chances for the formation of internal markets (or local centres).

Secondly, the adjacency pattern of settlements with each other is contagious so they form an almost continuous ring. In the east, the settlements of Karimabad, Sikhsuzi and Moradqoli -bounded by the airport wall in their east- are more attached to each other compared to the more standalone area of Babaeyan and Shirabad in the north. The most obvious gap is between the two settlements of Karkhaneh Namak and Poshte Garage in the west and Babaeyan but the former ones two are sharing a boundary. Overall the denser adjacency pattern can indicate competing preferences over central locations at the initial stage of

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64 The Santiago settlements studied by Hillier and others (addressed in chapter 2) have about 1000 population in average that makes the Zahedan cases larger in comparison. As was mentioned in chapter 2, the issue of settlement size is not a clearly defined issue so the thesis just distinguishes between small and non-small cases.
city growth where availability of vacant land can accommodate various growth seeds/cores that would expand until they meet each other. As the city expands outwards, the settlements or their edges tend to get further apart because the locations are less attractive and the more important factors would become the availability of vacant land along diverging transport corridors.

Ownership and land titles

There is no accurate data on land and property ownership in Zahedan but a rough estimation suggests that about 70 percent of owners within the municipal boundaries hold a legal title over their land (IMHUD/WB, Part3). This can be conjectured that most of those who do not have titles mostly dwell informally in spontaneous settlements. The main reason to regard these areas as informal can be related to the way that the plots of land are subdivided and sold ahead of the official planning decisions (Ibid.). As a result of this unclear legal status, the spontaneous areas are growing without considerations of infrastructure provision feasibility that makes it difficult to integrate those to the rest of the formal city network. This growth pattern will be further discussed below.

The growth pattern of spontaneous settlements

The growth patterns addressed in the previous chapter are observable in the spontaneous settlements of Zahedan. Just to remind the reader these patterns where diffusion (when the settlement is not bounded), densification (when it is bounded by natural or manmade obstacles) and finally mixed that is when the core of growth get more consolidated as the edges are diffusing. The example for the first in Zahedan is Qasemabad that is expanding with no dominant
growth core on the farmlands of the north-east. Darreh-Panj-Shir and Nukabad in their current stage make a case for the third growth pattern.

Karimabad provides a case for the second pattern that is densification in a bounded area and finally Babaeyan provides an ample example of a mixed growth pattern as the oldest area. According to aerial photo of Zahedan in 1974 the southern parts of Babaeyan started to appear along the main north-south street of Rajaei and expanded towards the hilly sites in its east with a dispersed pattern. However, as these areas were occupied and bounded by the hills, the settlements started to expand with a lower density towards the north and along the main road. Although today the land under Babaeyan settlement is fully occupied, one can recognize different stages of its growth with the older southern parts getting more and more similar to the rest of the formal city with higher density and clearer formation of a local commercial market (Figure 3.13)

Figure 3.12 - The general growth stages of Babaeyan are marked by numbers (left) and the same area in 1974’s aerial photo.
Figure 3.13 - A major local centre within Babaeyan area (source: Author’s site visit at 2008).

For a fewer number of settlements that are located on the fringes (like Darreh Panjshir) the streets are more meandering and follow the topography, the edge of the settlement is jagged and the urban blocks are more irregular.

Looking at the growth pattern of spontaneous settlements, one can conclude that the settlements mostly started to develop along the main access roads or rural origins with their outward-going direction that agrees with the overall centrifuging growth trend of Zahedan. In many cases, the settlements have reached a saturation point and ran out of land which brings them to the ‘maturing’ stage (see chapter 2) where the growth takes the shape of subdivision and intensification. The older parts of the settlements then show signs of ‘maturing’ or consolidation through distinct cores with higher built-up density. The next section will look into this issue with more details.

The consolidation of Zahedan settlements

This section aims at establishing the consolidation ratio for the case study spontaneous settlements. Because the method is mainly based on measuring the strength of local centres (i.e. the higher density-diversity of land use at an area) as the main indicator, first a brief review of the land use pattern within
the settlements would follow. After calculating the consolidation ratios, then
the results will be examined against other indicators to make sure the results
are reflecting the self-improvement trends.

Land use in the spontaneous settlements of Zahedan

The land use pattern within the spontaneous settlements can be described as
overwhelmingly residential (almost 69% of land plot area according to Table
3.4). This reflects the major functioning of these areas in the informal housing
market as the provider of affordable housing for the urban poor. Comparing the
below table to the percentages for the whole city of Zahedan suggests that the
proportion of residential land use in spontaneous settlements is more than the
whole city average.

The observed higher ratio of vacant land compared to the rest of the city can be
indicative of an ongoing process of transformation of farm lands for
construction due to economic profit. The other issue evident from the above
summary is the lower ratio of governmental facilities along with a lower
provision of health, education, cultural facilities and parks that will be further
discussed below.
<table>
<thead>
<tr>
<th>Land use</th>
<th>Plot Area (hectare)</th>
<th>Percentage of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>597.6</td>
<td>68.99</td>
</tr>
<tr>
<td>Vacant (delimited)</td>
<td>142.4</td>
<td>16.43</td>
</tr>
<tr>
<td>Industrial and maintenance</td>
<td>21.0</td>
<td>2.43</td>
</tr>
<tr>
<td>Transport and warehouses</td>
<td>19.7</td>
<td>2.27</td>
</tr>
<tr>
<td>Educational (all age groups)</td>
<td>19.3</td>
<td>2.23</td>
</tr>
<tr>
<td>Cemetery</td>
<td>18.1</td>
<td>2.09</td>
</tr>
<tr>
<td>Religious</td>
<td>13.5</td>
<td>1.56</td>
</tr>
<tr>
<td>Commercial</td>
<td>13.0</td>
<td>1.50</td>
</tr>
<tr>
<td>Park</td>
<td>7.0</td>
<td>0.80</td>
</tr>
<tr>
<td>Governmental and admin</td>
<td>4.9</td>
<td>0.56</td>
</tr>
<tr>
<td>Installation and infrastructure</td>
<td>3.2</td>
<td>0.37</td>
</tr>
<tr>
<td>medical</td>
<td>3.2</td>
<td>0.37</td>
</tr>
<tr>
<td>Recreational and cultural</td>
<td>2.3</td>
<td>0.26</td>
</tr>
<tr>
<td>Truism and hotels</td>
<td>0.9</td>
<td>0.10</td>
</tr>
<tr>
<td>Social and governmental services</td>
<td>0.2</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>866.2</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 3.4 - Land use summary for the spontaneous settlements of Zahedan.

All in all, considering the higher ratio of residential plot area suggests a more homogenous land use pattern in Zahedan spontaneous settlements. However, the more important question would be about the building footprint area for each land use (and not the plot area designated to that activity). When comparing land use categories within spontaneous settlements according to their building footprints percentages (Table 3.5), residential category is still the most prevailing use (260.1 hectare or 86.0% of total) with commercial building footprint ranked as second with 6.71 hectare (6.7% of total) while all the rest of the categories make up 7.3% of total building footprint.
<table>
<thead>
<tr>
<th>Building footprint (spontaneous areas)</th>
<th>% of total footprint area in spontaneous set.</th>
<th>Building footprint (whole Zahedan)</th>
<th>% of total footprint area in Zahedan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>85.96</td>
<td>Residential</td>
<td>77.46</td>
</tr>
<tr>
<td>Commercial</td>
<td>6.71</td>
<td>Commercial</td>
<td>8.67</td>
</tr>
<tr>
<td>Industrial &amp; maintenance</td>
<td>1.57</td>
<td>Administration</td>
<td>2.42</td>
</tr>
<tr>
<td>Religious</td>
<td>1.49</td>
<td>Prim./Secnd. education</td>
<td>2.38</td>
</tr>
<tr>
<td>Transport &amp; warehouses</td>
<td>1.38</td>
<td>Transport &amp; warehouses</td>
<td>2.10</td>
</tr>
<tr>
<td>Prim./Second. education</td>
<td>1.31</td>
<td>Industrial &amp; maintenance</td>
<td>1.60</td>
</tr>
<tr>
<td>Administration</td>
<td>0.47</td>
<td>University</td>
<td>1.42</td>
</tr>
<tr>
<td>Medical</td>
<td>0.36</td>
<td>Medical</td>
<td>1.01</td>
</tr>
<tr>
<td>University</td>
<td>0.18</td>
<td>Religious</td>
<td>0.93</td>
</tr>
<tr>
<td>Hygiene</td>
<td>0.18</td>
<td>Sport</td>
<td>0.51</td>
</tr>
<tr>
<td>Unknown</td>
<td>0.10</td>
<td>Truism and hotels</td>
<td>0.46</td>
</tr>
<tr>
<td>Truism and hotels</td>
<td>0.09</td>
<td>Unknown</td>
<td>0.37</td>
</tr>
<tr>
<td>Cultural</td>
<td>0.08</td>
<td>Civil services</td>
<td>0.30</td>
</tr>
<tr>
<td>Cemetery (structures)</td>
<td>0.03</td>
<td>Cultural</td>
<td>0.19</td>
</tr>
<tr>
<td>Sport</td>
<td>0.03</td>
<td>Hygiene</td>
<td>0.10</td>
</tr>
<tr>
<td>Park (structures)</td>
<td>0.03</td>
<td>Park (structures)</td>
<td>0.07</td>
</tr>
<tr>
<td>Civil services</td>
<td>0.03</td>
<td>Recreation</td>
<td>0.01</td>
</tr>
<tr>
<td>Recreation</td>
<td>0.00</td>
<td>Cemetery (structures)</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Total percentage</strong></td>
<td>100.00</td>
<td><strong>Total percentage</strong></td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Total Area (Hectare)</strong></td>
<td><strong>302.51</strong></td>
<td><strong>Total Area (Hectare)</strong></td>
<td><strong>1108.98</strong></td>
</tr>
</tbody>
</table>

Table 3.5- Building footprint of spontaneous settlements against the whole city of Zahedan (including spontaneous settlements) sorted by land use percentages.

These ratios reconfirm that in terms of footprint area designated to different land use, the spontaneous settlements are predominantly residential –even more than average for the city- while the only major buildings that change this homogenous pattern are of commercial uses (this can also be true for the whole city to a lesser degree). It should be noted that for the whole city of Zahedan (including spontaneous settlements) residential footprint is also the highest.
rank (859.0 hectare or 77.4% of total) followed by commercial (96.1 hectare that is 8.7%) but differently the third rank is for industrial and workshops.

The measurement of local centres strength

The above conjecture about the homogeneity of built-up area in spontaneous settlements can be confirmed by going back to the density-diversity analyses with both long and short band-widths in which both measures are relatively low for the settlements compared to the city (Figure 3.11). For magnifying the differences, the same analysis of diversity-density for band-widths of 200 meters is conducted just for the spontaneous settlements in Figure 3.14. Using the natural break visualizing scheme for the cells within the boundary of spontaneous settlements, the latter figure can give a clearer image of the local centre formation as hot spots of density-diversity. A particular case is the group of settlements including Karkhaneh Namak and Poshteh Garage in which the high values on the edges are mostly due to the occurrences of warehouses and small industrial activities but there is no considerable local centre formation in the internal parts of the two areas.

For measuring the strength of local centres (i.e. the hot spots of high density-diversity measure with 200 meters band-width) the mean of density-diversity values of the cells within each spontaneous settlement was calculated. Comparing Table 3.6 with the visual map (Figure 3.14) suggests that the mean values corresponds better with the strength or intensity of local centres as compared to other statistical values which also agree with intuition.
As a result the mean of cells’ Density-Diversity values with 200 meters bandwidth will be called ‘local centre strength’ here. Table 3.6 suggests that the older settlements especially the ones within the municipal boundary have developed stronger local centres as correlation between local centre strength and age for all of the spontaneous settlements results in Rsquare of 0.661 (p=0.0491).
<table>
<thead>
<tr>
<th>Settlement Name</th>
<th>Number of cells</th>
<th>Min (Scaled D&amp;D 200m)</th>
<th>Max (Scaled D&amp;D 200m)</th>
<th>Mean (Scaled D&amp;D 200m)</th>
<th>SD (Scaled D&amp;D 200m)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNZ&amp;PGZ</td>
<td>1,116</td>
<td>0.169</td>
<td>0.675</td>
<td>0.372</td>
<td>0.071</td>
<td>20</td>
</tr>
<tr>
<td>Babaeyan</td>
<td>1,003</td>
<td>0.009</td>
<td>0.594</td>
<td>0.342</td>
<td>0.151</td>
<td>40</td>
</tr>
<tr>
<td>KAZ,SIZ,MOZ</td>
<td>1,294</td>
<td>0.015</td>
<td>0.517</td>
<td>0.316</td>
<td>0.124</td>
<td>30</td>
</tr>
<tr>
<td>Shirabad</td>
<td>871</td>
<td>0.005</td>
<td>0.417</td>
<td>0.231</td>
<td>0.115</td>
<td>20</td>
</tr>
<tr>
<td>CHZ,DPZ,NUZ</td>
<td>357</td>
<td>0.006</td>
<td>0.379</td>
<td>0.133</td>
<td>0.090</td>
<td>12.5</td>
</tr>
<tr>
<td>Qasemabad</td>
<td>768</td>
<td>0.001</td>
<td>0.215</td>
<td>0.054</td>
<td>0.044</td>
<td>5</td>
</tr>
<tr>
<td>Zahedan</td>
<td>23,016</td>
<td>0.000</td>
<td>1.000</td>
<td>0.270</td>
<td>0.198</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 3.6 - The Density-Diversity statistical summary for each area with band-widths of 200 (cell size 50m*50m) that is scaled between zero and one. The list is sorted according to the Mean column as a direct indicator of consolidation ratio.

A caveat should be made here that by excluding the group of ‘Poshteh Garage’ and ‘Karkhaneh Namak’ settlements this correlation coefficient would improve to Rsquare of 0.94 (p=0.0051). Being an outlier in the correlation is mainly due to the particular condition of the latter two mid-age settlements that is caused by their overall high density-diversity due to the prevalence of small workshops on their outward edges. This condition brings up the conjecture that the settlement age cannot explain the ratio of consolidation as properly as the ‘local centre strength’ can; this conjecture will be tested meanwhile the following analyses to see if ‘Poshteh Garage’ and ‘Karkhaneh Namak’ show other signs of consolidation despite their relatively younger age.

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65 This is a briefed name for the two settlements of ‘Poshteh Garage’ and ‘Karkhaneh Namak’. For the rest of the abbreviated names in this table the reader should consult Table 3.2
Figure 3.15 - Bivariate correlation between the age and mean of density-diversity measurement for the 6 groups of spontaneous settlements. The group of Karkhaneh Namak and Poshteh Garage settlements stands as an outlier.

Nonetheless, the correlation between age and density-diversity is in line with the theoretical framework of the thesis that assumes that time plays a major role in the consolidation of spontaneous settlements. In this way, the reason for the emergence of such local centres can be seen as an ongoing economic fulfilment of dwellers’ preferences over time. This better-off population can presumably reinvest their economic benefits back into the local centres by increasing the quality and quantity of the commercial and public buildings.

Going back to the cases of Karkhaneh Namak and Poshteh Garage one can see that despite their overall high density-diversity, it is not easy to find any internal core or centre in those but instead there are hot spots of density-diversity on their outward edges. Is density-diversity is still a fair reflection of consolidation in such cases where an internal concentrated centre is absent? Such question can be answered by looking at other measurable factors indicative of consolidation such as built-up density and residential built-up area per person and comparing those to the density-diversity measure.
The analysis of built-up density for the whole city was presented before reflected in Figure 3.10. It could also be observed that the overall density varies for different settlements while some of those have areas with higher densities within themselves (or ‘density cores’). As mentioned earlier, the existence of density cores can reflect the stage of morphologic maturity in a settlement where after spreading over the available land, a process of intensification begins that reflects the more consolidated status of a settlement\textsuperscript{66}. However, building footprint density is closely correlated with diversity-density measure as both are based on kernel estimation method for aggregating building footprint area.

As a result, another measure of built-up density will be used that is the proportion of all (defined) land plots covered by total area of building footprints in a settlement in Table 3.7. Again, it seems that settlements’ age plays a major role in the increase of its plot coverage ratio (Rsquare of 0.76 \( p=0.0217 \)) with Karkhaneh Namak and Poshteh Garage as an outlier. The latter group of two settlements seems to have increased its residential built-up density much faster than a settlement with similar age such as Shirabad and its exclusion from the correlation would result in Rsquare of 0.93 (\( p=0.007 \)). Interestingly the correlation between the local core strength and plot coverage (including all settlements) results in Rsquare of 0.952 (\( p=0.0009 \)) that suggests the factor of age has weaknesses in explaining consolidation ratios compared to the main value of density-diversity (BW=200m). The next section will look at population related indicators for further testing the above conjectures on consolidation.

\textsuperscript{66} Also Greene (2000) suggests that adding to the built-up area (in form of second floor for the Chilean cases) is a sign of consolidation. The other point is that high built-up density is mostly resulted from longer age of a settlement that is another sign that a settlement has been consolidated as the theoretical framework discussed.
Population density and residential space per dweller

Consolidation is driven by the fulfilment of socio-economic preferences in a gradual manner. An indicator of slum condition that can impede consolidation is overcrowding that originates from the lower economic status of dwellers (see chapter 2, ‘operational definition of slum’). In other words, overcrowding happens when the poor cannot afford to have enough residential space that results in higher population density and low residential space per dweller. In this section, the socio-economic issues inferable from these matters will be discussed aiming at further understanding the consolidation process.

GIS map illustrating the survey results in IMHUD/WB (2003) suggests that spontaneous settlements have higher than average population density. This can point to the mechanism (discussed in chapter 2) through which the poor makes land and property affordable for themselves. On the other hand, and considering the building footprint density (Figure 3.10), it can be discerned that spontaneous settlements do not have a generally high built-up density compared to the rest of Zahedan except for certain spots within older settlements. High population density and low built-up area can be then an indicative of lower residential space per dweller.

The conjecture on low residential space per dweller can be supported by looking at Table 3.7 that indicates residential building footprint area (or ‘residential footprint’ in brief) per dweller is in general lower for spontaneous settlements compared to the average for Zahedan. Moreover, the table suggests that the group of settlements within the municipal boundary is better-off in residential area provision for its dwellers that points to their better socio-economic status. The measure of residential footprint per dweller though does

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67 Because this map and the other maps from the same report are in raster format, those cannot be used for quantitative measurements.

68 Again, it should be emphasized that building footprint areas is taken as a proxy for built-up area in the absence of building floor height data.
not show any significance correlation with the age of the spontaneous settlements (Rsquare=0.37, p=0.19), it correlates significantly with the local core strength (Rsquare=0.76 p=0.024) that suggests the latter factor could reflect the consolidation better than age. Moreover, residential footprint per dweller and plot coverage ratio for Zahedan spontaneous areas correlates with Rsquare of 0.75 (p=0.0249) that reconfirms the overwhelmingly residential functioning of these settlement.

Figure 3.16 – Net population density of Zahedan expressed as persons per hectare of each urban block (Source: IMHUD/WB: 2003).
A point worth regarding the low residential footprint per dweller in Babaeyan settlement is that there is a very sharp difference between the residential building density in the south and north of this settlement and because the population estimate is available for the whole settlement, the measure of footprint per dweller would mask the better-off condition of its southern part in terms of more availability of housing area for dwellers. The southern part of Babaeyan as mentioned by IMHUD/WB (2003) is particularly well-established as the oldest spontaneous area while the northern part is more recent—about a decade old by 2001 when the data was surveyed—with less access to infrastructure and concentration of poorer citizens (Ibid.).

<table>
<thead>
<tr>
<th>Spontaneous settlement</th>
<th>Plot coverage ratio</th>
<th>Residential Footprint per person (sqm)</th>
<th>Population (2001)</th>
<th>Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside the municipal boundary</td>
<td>Shirabad</td>
<td>0.293</td>
<td>9.5</td>
<td>40,694</td>
</tr>
<tr>
<td></td>
<td>KAZ, SIZ, MOZ(^{69})</td>
<td>0.408</td>
<td>12.3</td>
<td>71,764</td>
</tr>
<tr>
<td></td>
<td>KNZ, PGZ</td>
<td>0.421</td>
<td>12.1</td>
<td>45,801</td>
</tr>
<tr>
<td></td>
<td>Babaeyan</td>
<td>0.446</td>
<td>10.6</td>
<td>56,733</td>
</tr>
<tr>
<td>Outside the municipal boundary, Zahedan</td>
<td>CHZ, DPZ, NUZ</td>
<td>0.238</td>
<td>9.8</td>
<td>10,413</td>
</tr>
<tr>
<td></td>
<td>Qasemabad</td>
<td>0.079</td>
<td>8.2</td>
<td>8,000</td>
</tr>
<tr>
<td>The whole city, Zahedan</td>
<td>NA</td>
<td>19.63</td>
<td>565,000</td>
<td>(unofficial)</td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>15.84</td>
<td>700,000</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 3.7 – Plot coverage ratio, residential building footprint per dweller, population and age are listed for Zahedan spontaneous areas.

\(^{69}\) See Table 3.2 as the reference for abbreviated settlement names.
Figure 3.17 illustrates the higher residential building foot-print density in the older southern part of Babaeyan. Comparing this condition with the relatively even population density per block for whole the whole settlement (Figure 3.17, left) then one can infer that southern Babaeyan has a higher provision of residential building area for its dwellers hence is better-off in socio-economic terms. This is also the area where strong local centre emerged within the settlement (see Figure 3.18, the mentioned centre is also pictured in Figure 3.14). The next section will elaborate on the observed local centres through highlighting their overall land use pattern that is overwhelmingly commercial.
**Commercial land in spontaneous settlements**

Referring back to Table 3.5, it was argued that the main cause of land use diversity in the overwhelmingly residential spontaneous settlements is the occurrence of commercial buildings. In other words, what constitute the local centres in the settlement are the higher concentration of shops, stalls and other providers of goods and services. Considering the informal nature of economic activities and the multi-functionality of buildings in spontaneous settlements, (see the pre-industrial land use character of third World cities in chapter 2) it can be understood that most of the commercial activities help with the economic gain of the dwellers. Considering the economically poorer condition of dwellers, one might except to find smaller scale and lower ratio of commercial built-up area in spontaneous settlements.

To support these conjectures, the lower proportion of commercial building footprint area in spontaneous settlements comparing to the average for the whole city was already illustrated in Table 3.5. Moreover, the average commercial building footprint area of 36.9 square meters in spontaneous settlements can be compared against the average 77.15 square meters for the whole city. Despite this smaller scale of commercial activities in spontaneous settlements, it is a major contributor to the fulfilment of dwellers’ economical preferences. The lower restriction on land use on the other hand allows for the placement of shops based on individual decisions in local level (i.e. each owner can place its shop on the basis of his/her assessment of accessibility and movement ratios). As a result, one might find commercial buildings with various densities and on different parts of Zahedan spontaneous settlements (i.e. within or on the outward-facing edges) as are illustrated in Figure 3.18.
An observable character of commercial land use pattern in the spontaneous settlements, especially when their intensity is higher, is their linear arrangement. This linearity can be found on either the edge or within the settlement which suggests that if shops are clustered due to a first-order effect, the attractive factor for their clustering (e.g. accessibility or movement flows) should be high at least for most parts along the same street alignment. This is contrary to what the geographic notion of accessibility suggests based on the ease of access to locations as points in large scale geographic space. Using this notion would then predict the concentration of shops around such highly accessible spots in convex shape clusters. As will be explained in chapter 5, another notion of accessibility is required to explain the linear arrangement of shops within the spontaneous settlements (i.e. the internal markets) which is more sensitive to the geometry of the urban layouts in fine-scale. Also in chapter 5, it will be illustrated that as a spontaneous settlement grows larger and its perimeter to area ratio falls, it will hypothetically require further
development of commercial land use within itself (as opposed to its outward edges). Next section will look into another consolidation related issue pertaining to land use.

**Public facilities**

Regarding the aforementioned lack of public amenities in spontaneous areas (i.e. health, educational and recreational land uses) and pointing to the prevailing deprivation in these areas IMHUD/WB (2003) go into further detail and highlight the under-provision of each facility regarding the standard set in the national standards. Through comparison of the settlements, the latter report (Ibid.) also concludes that the spontaneous settlements inside the municipal boundary are better-off in terms of access to three types of public amenities (i.e. non-university education, healthcare and cultural/recreational/sport facilities). The calculation is repeated by the author in Table 3.8 according to more general categorization and also a more accurate land use base map.

<table>
<thead>
<tr>
<th>Spontaneous settlement</th>
<th>Educ. sqm/head</th>
<th>Health sqm/head</th>
<th>Cult-Recr. sqm/head</th>
<th>Total public facility sqm/head</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qasemabad</td>
<td>0.07</td>
<td>0.00</td>
<td>0.00</td>
<td>0.07</td>
<td>5</td>
</tr>
<tr>
<td>CHZ,DPZ,NUZ</td>
<td>0.59</td>
<td>0.01</td>
<td>0.07</td>
<td>0.67</td>
<td>12.5</td>
</tr>
<tr>
<td>Shirabad</td>
<td>0.52</td>
<td>0.08</td>
<td>0.08</td>
<td>0.68</td>
<td>20</td>
</tr>
<tr>
<td>KNZ, PGZ</td>
<td>0.33</td>
<td>0.26</td>
<td>0.29</td>
<td>0.88</td>
<td>20</td>
</tr>
<tr>
<td>KAZ,SIZ,MOZ</td>
<td>0.82</td>
<td>0.13</td>
<td>0.18</td>
<td>1.13</td>
<td>30</td>
</tr>
<tr>
<td>Babaeyan</td>
<td>1.14</td>
<td>0.08</td>
<td>0.08</td>
<td>1.3</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 3.8 - Public land use per dweller in Zahedan spontaneous settlements.

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70 Check Table 3.2 for the abbreviated settlement names.
In this regard, it seems that Babaeyan and the group of Karimababd, Siksuzi and Moradqoli enjoy a higher level of public amenities while Qasemabad (outside municipal boundary) is the most deprived. This can be reconfirmed by correlating the total area of public facilities per head – the fifth column in Table 3.8- with settlements’ ages that results in Rsquare of 0.89 (p=0.0044). Also, correlating the local centre strengths (the mean value of density-diversity measure in Table 3.6) with public facility per head gives an Rsquare of 0.761 (p=0.0233) while removing Garage and Karkhaneh improves the Rsquare for the same correlation to 0.915 (p=0.0108) that is mainly because of the particular condition of the two latter settlements that will be explained later on.

As was mentioned in chapter 2, the availability or lack of public amenities as a physical factor can influence the course of consolidation in long-term but the decision to provide such facilities is not directly in dwellers’ hands. The next section will look at other –mostly physical- aspects of Zahedan spontaneous settlements indicative of their consolidation rates.

**The roads, infrastructure and construction quality in the settlements**

Three of the operational factors –reviewed in the second chapter- indicate that a spontaneous settlement is in slum condition if there is unavailability of water, lack of sewerage network or substandard construction. These three factors will be reviewed here for Zahedan spontaneous settlements along with closely related factor of access road availability and condition. This is also to see if these factors can be related to the assessed consolidation ratios base on the strength of local centres.

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71 In other words, although the existence of public amenities can help with a settlement’s socio-economic improvement (and hence consolidation) in long term but such existence are not preferred by the dwellers as much as the gain from informal economic activities and proximity to major urban centers as was discussed in the previous chapter.
The road condition of spontaneous settlement was reported to be poor by IMHUD/WB (2003) with no proper paving and asphalt. The access roads for the settlements outside the municipal boundary were reported to be nonexistence which makes them even the worst than their counterparts within the boundaries. In terms of road width, a simple inspection can reveal irregularities in terms of width variation along the same alignment with occurrence of very narrow passages with ‘bottleneck’ effect (almost 1 meter) along non-death end roads while the width of many cul-de-sacs is usually between 1 to 2 meters that makes the vehicular movement very difficult.

This situation makes it difficult for the provision of public services such as garbage collection or the access of fire tracks, police cars and ambulances to reach areas within spontaneous settlements while in other cases construction and upgrading operations can become hard to pursue. Further issues regarding the roads accessibility of these areas will be addressed in chapter 5. The lack of official attention and investment reflected in the road condition could also be found in the case of basic infrastructures.

Apart from electricity that is almost available to all spontaneous settlements, there is reported inaccessibility of water to some areas due to absence of water-pipe network (e.g. in Qasemabad) or lack of maintenance that leads to water waster (e.g. Babaeyan). The variation in infrastructure level are summarized by IMHUD/WB (2003) that is reflected in the below table (Table 3.9).

The same report summarizes (Ibid.) the condition is much worst for the outer settlements while the ones within the municipality boundary are better-off. Again, the variation amongst the inner settlements in the latter group seems to follow the age as the older ones especially Babaeyan, show an overall better condition. Poshteh Garage and Karkhaneh Namak in the inner city group of settlement shows the lowest level of public services while a fair level of access roads. Due to the qualitative nature of this assessment it is not possible to the
correlation with consolidation ratios. It should be noted that there is no plot-by-plot data available for the spontaneous settlements of Zahedan regarding building material or access to basic infrastructure. However, the survey conducted by IMHUD/WB (2003) suggests that spontaneous settlements are majorly comprised of buildings with non-durable materials (almost 44% of all buildings) or compared to about 25% for the whole Zahedan.

<table>
<thead>
<tr>
<th>Settlement name</th>
<th>Access Roads*</th>
<th>Water-Pipe Network</th>
<th>Electricity Network</th>
<th>Public Services*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within the municipal boundary</td>
<td>Babaeyan</td>
<td>2</td>
<td>existing</td>
<td>existing</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Karimabad</td>
<td>1</td>
<td>existing</td>
<td>existing</td>
<td></td>
</tr>
<tr>
<td>Sikhsuzi</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moradqoli</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poshteh Garage</td>
<td>2</td>
<td>existing</td>
<td>existing</td>
<td></td>
</tr>
<tr>
<td>Karkhaneh Namak</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shirabad</td>
<td>1</td>
<td>existing</td>
<td>existing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside the municipal boundary</td>
<td>Darreh Panjshir</td>
<td>-</td>
<td>existing</td>
<td>existing</td>
</tr>
<tr>
<td>Gharibabad</td>
<td>-</td>
<td>existing</td>
<td>existing</td>
<td></td>
</tr>
<tr>
<td>Chaliabad</td>
<td>-</td>
<td>-</td>
<td>existing</td>
<td></td>
</tr>
<tr>
<td>Nukabad</td>
<td>-</td>
<td>-</td>
<td>existing</td>
<td></td>
</tr>
<tr>
<td>Qasemabad</td>
<td>-</td>
<td>-</td>
<td>existing</td>
<td></td>
</tr>
</tbody>
</table>

* include municipal and civil services such as garbage collection, ambulance, police cars and fire truck.

Table 3.9 - Qualitative assessment for Zahedan spontaneous settlements compared to average services available to the rest of the city (source: IMHUD/WB, 2003).
In the absence of fine level data, the only attempt is done by IMHUD/WB (2003) in which areas within and outside the legal municipal boundary are respectively categorized according to being acceptable in terms of services or otherwise being ‘in critical\textsuperscript{72}’ condition based on their field surveys. Inspecting the location of these critical patches (Figure 3.19) suggests that these are mostly less dense areas and away from the local centres mainly on the edge of the settlements. Although the deprivation patches delineated by the previous report are more based on qualitative assessment, it still suggests that more consolidated parts of settlements are the parts that are denser in terms of built-up area and got higher land use diversity due to concentration of commercial activities.

\textsuperscript{72} From the report it could be understood that ‘critical condition’ refers to area with further needs of intervention that is indicative of slum condition.
What can be understood from the above review on physical condition suggests that spontaneous settlements are overall in a poorer condition compared to the rest of the city with older settlements (or their older parts) showing more improvements over time. The physical deprivation and various consolidation ratios might bring about the question about the socio-economic condition of these areas. Have the dwellers of more consolidated areas improved their socio-economic status as the theoretical framework suggests?

### The socio-economic characteristics of spontaneous settlements

#### Housing affordability and coping mechanisms

The first issue that can be understood about the socio-economic status of people living in Zahedan spontaneous settlements can be inferred from the land and property value that they are dwelling in. During in his in-depth social and economic study, Piran (2003) shows that while the average price of urban land and building construction has quickly increased in Sistan and Balochestan province, an informal settlement like Shirabad could offer really cheap accommodation for lower income people of Zahedan.

Piran uses this almost three folds difference between formal/informal housing prices to maintain that informal housing solutions comprise the very affordable and effective way that urban poor prevent aggravation of their situation that would otherwise be resulted from their lack of shelter\(^73\). His conclusion is also compatible with the thesis theoretical framework that suggested the preference for cheap shelter is one of the main priorities for the dwellers of spontaneous settlements. This conjecture could also be confirmed by aforementioned lower  

\[^73\text{At the time of his observation in 1999-2000 the price of land and building together in the spontaneous settlement of Shirabad was about 230,000 Rials. This figure should be compared to the provincial trends presented by the same writer that suggests an average price of a square meter of building including its land price to be over 600,000 after 1996. Piran mentions the minimum price of a 130 square meters house in Shirabad spontaneous settlement as 20,000,000 Rials which goes up when the building materials get more permanent (Ibid.)}\]
residential building footprint per dweller in spontaneous settlements compared to the average figure for the city. The inevitably rise questions on the population leaving in each settlement and the pace the population changes.

**Demographic trend**

As mentioned earlier the population of Zahedan was reported to be 565,000 in 2001 while unofficial figures suggested 700,000 as the total population including the illegal migrants (IMHUD/WB, 2003). The spontaneous settlements of Zahedan accommodated about 233,000 in 2001 which made about 33 percent of the total population if the unofficial estimation is considered. The growth rate of their population is also relatively quicker compared to the city showing 51,000 increases in four years period that is about 28.14%. In the same time, the overall population of the city has increased from 430,000 to 565,000 (according to the official figures). This shows an increase of 23.89%.

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>(1996/97)</th>
<th>(2000/01)</th>
<th>Population Growth</th>
<th>Average Annual Growth %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babaeyan</td>
<td>49,333</td>
<td>56,733</td>
<td>7,400</td>
<td>3.0</td>
</tr>
<tr>
<td>Shirabad</td>
<td>25,828</td>
<td>40,694</td>
<td>14,866</td>
<td>11.5</td>
</tr>
<tr>
<td>Karimabad, Sikhsuzi and Moradqoli</td>
<td>57682</td>
<td>71,764</td>
<td>14,082</td>
<td>4.9</td>
</tr>
<tr>
<td>Karkhaneh Namak and Poshteh Garage</td>
<td>39,827</td>
<td>45,801</td>
<td>5,974</td>
<td>3.0</td>
</tr>
<tr>
<td>Darreh Panjshir, Chaliabad and Nukabad</td>
<td>9,388</td>
<td>10,413</td>
<td>1,025</td>
<td>2.2</td>
</tr>
<tr>
<td>Qasemabad</td>
<td>-</td>
<td>8,000</td>
<td>7,900</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>182,058</strong></td>
<td><strong>233,405</strong></td>
<td><strong>51,247</strong></td>
<td><strong>5.6</strong></td>
</tr>
</tbody>
</table>

Table 3.10 - Population growth trend for spontaneous settlements of Zahedan
(Source: IMHUD/WB, 2003).
This is an indicator of an increase in the lower-income groups of the city for which the reasons –mainly migration- was reviewed before and is a main reason behind the formation of spontaneous settlements. However, no significant correlation can be found between the settlements’ age and the population growth rates (Rsquare of 0.03 excluding Hematabad). Neither is there any significant correlation between consolidation rate (i.e. local centre strength) and population growth rate.

**Other socio-economic indicators**

According to the theoretical framework set in chapter two, socio-economic or non-physical poverty constitute a main character of life in spontaneous settlements. Moreover, during consolidation, the non-physical and physical factors related to poverty would improve in parallel. This means that the consolidated settlements usually accommodate better-off amongst the poor. However, in the case of Zahedan there is no fine-scale data available in quantitative formats and the only GIS data in this regard, has been obtained as images from the IMHUD/WB report\(^7\) (that can be used for qualitative comparison). As a result, a viable quantitative comparison between the settlements in socio-economic terms is not possible and the following paragraphs just help with making overall comparison between spontaneous settlements and the rest of Zahedan.

The IMHUD/WB report indicates that the literacy rates in Zahedan as opposed to national rate are low; it indicates 70% literate amongst the people older than 6 years old in 1996 according to the census. The same source also reports that

\(^7\) As the author requested the raw GIS data gathered through surveys he was told that due to privacy issues the data cannot be given to him.
the lowest ratios of literacy are to be found in spontaneous settlements.\textsuperscript{75} The basis for this claim can be seen in the figure below taken from the same report. Furthermore, the same map shows that the outer edge of settlements (i.e. where the analyses found lower built-up densities, Figure 3.12) consists of poorer literacy status. It can also be observed that the southern part of Babaeyan settlements with the strongest local centre is better-off in literacy rates while the worst condition can be seen in Shirabad, Poshete Garage and Karkhaneh Namak. This suggests that there might be a relation between literacy rates and consolidation in Zahedan spontaneous settlements but such hypothesis cannot be quantitatively tested.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image.png}
\caption{GIS representation of adult literacy rates in Zahedan (Source: IMHUD/WB, 2003). The five grades of red spread with equal ranges from the darkest red (representing 20\% literacy rate and lower) to the brightest red (representing 80\% literacy rate and higher).}
\end{figure}

\textsuperscript{75} It adds: “A host of factors, a major of part of which are due to poverty and lack of access, are responsible for the low levels of literacy in these [spontaneous] areas.” (Ibid. Page 11)
The other factors with socio-economic implication are the household size and the age mix. As a World Bank publication (Haughton and Khandker, 2009) indicates, it is more common to find the poor living in larger households with larger proportion of younger members. Reminding that Zahedan population is overwhelmingly young and the households are larger compared to the national averages, IMHUD/WB (2003) observes that its spontaneous settlements have even a larger concentration of larger households as can be seen in Figure 3.21. Furthermore, it can be seen in the same map that eastern parts of Moradqoli and southern parts of Babaeyan are similar to the rest of the city in terms of household size.

Figure 3.21 - GIS representation of household size in Zahedan (Source: IMHUD/WB, 2003).

76 The above report found a larger household size (about 8 persons) in these areas comparing to Zahedan average that is about 6.
Further to the above characteristics, the dwellers of spontaneous settlements in Zahedan are reported to be suffering from unemployment, social problems such as occurrence of crime and addiction. Looking through the aforementioned socio-economic issues, the thesis supports the conclusion by IMHUD/WB that the spontaneous settlements are accommodating larger proportion of deprived citizens in them. Observing that the older and more consolidated parts of spontaneous settlements (especially where stronger local centres have emerged), show socio-economic indicators not worse than the rest of the city confirms the interaction of socio-economic and physical factors hypothesized by the theoretical framework of this thesis.

**Discussion for Zahedan spontaneous settlements**

The second part of the chapter focused on Zahedan spontaneous settlements. The official importance – due to border proximity – on one hand and the context of provincial and rural poverty on the other, has made Zahedan as the fastest urbanizing city in its region. This situation is also reflected in the population and employment structure of the city, making it a city with two contrasted strata of official employees and the low-skilled (and mostly migrant) job-seekers coming from the rest of the province. Due to the weak productive institutions, the latter group has been usually found job in the informal sector including service activities or cross-border trading while in terms of housing they got no affordable choice except for the spontaneous settlements. This reflects the two preferences by the later group as economic gain from the urban job market (mostly of informal and service nature) and also having an affordable and secure shelter.

The urban schematic model- adopted from Griffin and Ford- was deemed useful in explaining the overall duality in Zahedan structure predicting the lower status of citizens on the peripheries coinciding mostly with spontaneous
settlements. It is also notable that the spontaneous settlements are not showing a diverse range of sizes and distances from the city centre that can be attributed to the relatively young age of Zahedan and its small size (compared to the second case of Jeddah in next chapter). Instead the concentration of settlements as a continuous ring on the unattractive lands in the north of Zahedan indicates the preference of the poor for shelter affordability, while their proximity to the major urban centres (spotted as density-diversity hotspots with longer bandwidth of 500 meters) points to the strong economic preference to benefit from major city-wide locations. Assuming that fulfilment of these preferences for affordable shelter and proximity to the urban centres should gradually help with consolidation of spontaneous settlements propose that time (or the age of settlements) might have played a positive role in this process.

Having a more detailed look at different local aspects of the studied settlements, one can observe the effect of time and location on their consolidation especially the difference between the older ones within the municipal boundary and the newer ones outside. In this regard the formation of strong local centre(s) in a context of overwhelmingly residential land use pattern of the spontaneous settlement was taken as an indicator of consolidation and then was checked against other quantifiable factors indicative of consolidation including:

- Time (i.e. settlement’s age)
- Built-up density (i.e. plot coverage ratio)
- Space per dweller (i.e. residential building footprint per dweller)
- Total public facility per head

Significant correlations between the above factors and the strength of local centres were found for Zahedan spontaneous settlements. This suggests that local centres’ strength can reflect the ratio of consolidation as strong as the factor of age can do. In the case of socio-economic performance where the
factor of ‘space per dweller’ showed weak correlation with ‘time’ (Rsquare=0.37, p=0.19), the correlation between local centres’ strength and space per dweller was much stronger (Rsquare=0.76 p=0.024). This suggests that local centres’ strength has some empirical advantages over the factor of time in quantifying consolidation. Moreover and in a spatial sense the former has a locational character that can show the heterogeneous pattern of consolidation in a settlement while the time factor as was discussed in chapter 2 is essentially a non-spatial variable. Overall the analyses conducted in this chapter confirmed the conjecture of the second chapter that the strength of local centres (based on the measurement of land use density-diversity) can capture the level of consolidation in spontaneous settlements.

Regarding the examined factors it can be concluded that the increase of local centre strength happens along with a process of densification reflected in higher coverage of land by building footprints and also improved economic power of dwellers inferable from the higher residential space (or residential building footprint) per dweller. Also, the observed higher availability of public facility in the consolidated settlements can feed-back on the improvement of their socio-economic status as a sign of ongoing self-improvement process. Other factors (including the availability and condition of access roads and the socio-economic indicators such as literacy rates and household size) could not be quantified although qualitative assessments suggested some close relation between these factors and the consolidation ratios.

A point should be made here about the group of settlements including Poshteh Garage and Karkhaneh Namak as the two show the highest ratio of consolidation with the whole settlements appearing as a strong local centre despite the fact that these spontaneous settlements are not the oldest in Zahedan. The reason for this could be attributed to the special location on which these settlements started to grow from, that is, a north-south corridor of intensive industrial activities and small workshops along their eastern limits.
This is also in the relatively high density-diversity value (BW = 200m) on the edge of the two settlements (Figure 3.18, right) that pushes up the mean value for the whole settlement without much variation of the value for the cells.

The existence of such economic pole (despite its non-commercial nature) could have turned the two settlements of Poshteh Garage and Karkhaneh Namak to a kind of workers’ housing areas which provide the mentioned workshops with labour while using the surrounding amenities and facilities have removed the necessity of having local internal centres. As IMHUD/WB (2003) suggest most of the economic activities in these two settlements is done as home-productions by the women while there is a major commercial corridor on their edges along the main street between the two settlements (Figure 3.11, right image) and away from their internal areas. This suggests that Poshteh Garage and Karkhaneh Namak spontaneous settlements have self-improved themselves in different aspects that are mainly reflected in their higher residential foot-print per dweller.

In next chapter the measures of land use density-diversity with various band-widths will be applied to the context of Jeddah with a significantly larger number of spontaneous settlements. Form a methodological point of view the challenge will be to find out how effective the measure of density-diversity can quantify consolidation ratios in the very different context of Jeddah with its significantly larger geographic span compared to Zahedan.

**Conclusion**

The first part of this chapter introduced the urbanizing trends in Saudi Arabia and Iran with the aim to understand the forces that give rise to the spontaneous settlements. Both countries were shown to have experiencing fast urbanizing trends caused by migration from rural areas and in the case of KSA by foreign
immigrants. Also, both countries have signs of dealing with economic challenges in terms of employment as they are heavily relying on oil as the main source for revenue. These challenges are reflected in unequal distribution of wealth and existence of poor population that in combination with inadequate housing policies has led to emergence of slums and spontaneous settlements.

The second part of the chapter focused on the spontaneous settlements of Zahedan. The argument is that national circumstances as presented in the first part of this chapter are also applicable to the city of Zahedan. These circumstances mainly the rural-urban migration and the fast increase of poor urban population in the absence of affordable shelter in the formal market could be identified as the main contributors to the expansion of spontaneous settlement in Zahedan. In other words, while the spontaneous settlements are formed as a result of the city’s dual socio-economic structure, they also have distinct spatial and physical characters that make them appear as relatively large districts with visible signs of poverty and morphologic irregularity. In this way, Zahedan spontaneous settlements constitute a significant element of the whole dual structure as was generalized in chapter two through Griffin and Ford model.

This was followed by consolidation ratios of spontaneous settlements estimated through calculating the strength of local centres formation. It was illustrated that the factor of time plays a major role in consolidation process of Zahedan spontaneous settlements. This was also observed that while the settlements where formed on originally unfavourable and cheap lands to satisfy the dweller’s territorial preference, the existence of commercial land use was a sign of their preference for economic gain from the city. The next chapter will look at the same issue of spontaneous settlement consolidation in the context of Jeddah city.
Chapter 4: Spontaneous settlements of Jeddah

Introduction

This chapter introduces the second group of case study spontaneous settlements in the city of Jeddah in their urban context. These settlements exhibit more diversity than the cases in the previous chapter in terms of size, geographic spread, dwellers’ socio-economic condition and physical poverty. The main aim of this chapter is to establish the consolidation ratio of Jeddah spontaneous settlements similar to what was done for Zahedan. The underlying assumption is that the fulfilment of economic and territorial preferences over time will result in self-improvement in both physical and non-physical poverty matters that is consolidation.

The national context of KSA in which the city of Jeddah is located was discussed in the previous chapter especially its urbanization trends and the economic issues. These features along with more detailed discussion of the particular location of Jeddah in its wider national and international context will further help with understanding the reasons for its rapid expansion. This fast pace, when is considered in the context of affordable housing shortage, will be identified as the main reason for the proliferation of spontaneous settlements in Jeddah. The affordability issue also indicates the (generally) lower socio-economic status of their dwellers.

Compared with Zahedan, The larger size and older history of Jeddah, however, would make the consolidation measurement more challenging as Jeddah settlements are to be found from the very old historic core of the city to its sprawling edges with very different sizes and conditions. Unlike Zahedan settlements, there is no socio-economic data available in a spatial sense for the whole city of Jeddah. For the spontaneous settlements the data is mostly
concerned with the physical and infrastructural issues. This requires a slightly different approach in validating the consolidation measurement but the fundamental method adopted is the same as method used for Zahedan, i.e. measuring the strength of local centres in spontaneous settlements.

**Outline**

The chapter will start by complementing the review of the previous chapter on the urbanization of KSA. In the literature, the major urbanization stages of KSA will be reviewed which are mainly influenced by the economic developments of oil extraction. This will be followed by the relevant issues of migration and urban poverty and finally spontaneous settlements in KSA. Then Jeddah, its history and strategic importance in provincial, regional and even international level will be discussed. This is mainly considered in the light of its role during the Islamic pilgrimage ceremony or ‘Hajj’. The significance of Hajj and other economic activities will also be addressed as well as the resultant employment trends.

The focus will then be on the urbanization trends of Jeddah itself based on the previous review of the wider national context. Moreover, the fast pace of urban population growth and its consequent demand for housing will be explained as a reason for the emergence of spontaneous settlements. Then the focus will shift to the physical and spatial structure of Jeddah with the aim of adopting a general model along with the spontaneous settlements located in the model.

The expansion of Jeddah in a geographic sense will be studied along with major phases paralleled with economic and planning circumstances affecting it since 1940s. Also, the topographic and natural surrounding affecting the growth directions and initial quality of land will be mentioned. Then the chapter will introduce the spontaneous settlements of Jeddah considering the
growth and changes of Jeddah as their wider context. Jeddah’s dual land use pattern with major differences between north and south indicates formal and informal general divisions. This will be the next section. The informal and less well-off southern part is where spontaneous settlements are concentrated. Within the overall discussion on land use pattern, the importance and characteristics of commercial land use will be discussed and its differences in formal and informal (or spontaneous) parts of the city will be highlighted.

The built-up density analysis of the whole city will help with further understanding of the growth stages of Jeddah and the distinct character of spontaneous settlements as hot spots of high density. Then the major urban centres of Jeddah in local and mid-ranges will be delineated through analyses of density-diversity. The next step then would be generalization of the observations on the overall structure of the city which suggests that the best existing model matching Jeddah is still the Griffin and Ford model while spontaneous settlements can be regarded as ‘disamenity zones’ and ‘the ring of peripheral squatter settlements’.

The chapter will follow with focus on the local characteristics of spontaneous settlements with a caveat on the available data used for the study. The growth pattern of spontaneous settlements with regards to their location (i.e. inner-city or peripheral) will be discussed supported by simple analysis. Then the chapter will measure the consolidation of respective spontaneous settlements through summarizing the results of the density-diversity analysis for each area. The measurement is done based on a reminder about the overall residential fabric of Jeddah spontaneous settlements to emphasize that the major cause for diversity-density is the commercial land use. For doing that first there is a need to understand the overall land use pattern of spontaneous settlements per se which will be identified as highly residential followed by commercial activities.
Then the average value of density-diversity in local level will be measured for the examined Jeddah spontaneous settlements as an indicator of their consolidation that also seems to be affected strongly by the settlements age. Observing that the commercial activities can be found on both internal parts and outward edges of the spontaneous settlements the study will then argue that the stronger local centres (or higher consolidation ratio) are caused by the internal clustering but further explanation follows in the next chapter.

Then the chapter continues by looking at issues indicative of social and economic condition in Jeddah spontaneous settlements mainly the availability of public infrastructure and residential building footprint per dweller. It will be shown that residential space per dweller seems to be in relation with the consolidation ratio. Also the built-up and construction quality of urban fabric seems to be influenced positively by the strength of local centres but such correlation cannot clearly be captured by simple statistical summary methods. The overall socio-economic condition of Jeddah spontaneous settlements will also be addressed through reviewing the existing literature in order to prove their less-advantaged condition compared to the rest of the city. The chapter ends by a comparative conclusion summarizing the understandings of spontaneous settlements in Jeddah and Zahedan with focus on the common inferable preferences.

**Jeddah and its spontaneous settlements in urbanizing KSA**

**Urban poverty in Saudi Arabia and spontaneous settlements**

Following the same description for the city of Zahedan as presented in the previous chapter, I will introduce the city of Jeddah within its regional, national and provincial settings. The aim is to understand the reasons behind the formation of spontaneous settlements in Jeddah through looking at a
variety of factors mainly the economic and social condition as well as the city
growth, planning policies and other relevant issues. This will be followed by
more discussion of the city of Jeddah itself and the way its major zones
especially the spontaneous settlements are placed with regards to each other
and its implications for the consolidation (or degradation) of such areas.

Urbanization in KSA and the forces behind it

Urbanization in Saudi Arabia gained ground mainly after World War II.
During this time, most of the nomadic population of the country started to
settle in the cities (Held and Cotter, 2000). Also Al Hathloul and Edadan
(1991) believe oil commercial production in late 1940s speeded up the
urbanization trend in KSA which has been an ongoing trend until now. The
economic impacts of oil production, as they claim, also transformed some of
the insignificant cities along the old pilgrimage and trading routes to major
urban hubs. This ‘economic boom’ –as Britannica (2009c) explains- due to oil
revenues especially during 1970s and 1980s resulted in advanced national
economic indicators at this period with very low unemployment rates and
prevalence of large development projects.

Elaborating on the reasons for this rapid urbanization between 1955 and 1990
Al Hathloul and Edadan (1991) mention the growth of population, more
mobility of labour in geographical terms, enhancement of infrastructure
(especially more developed road networks) and the economic contribution of
the private sector. This was when – they believe- the early spontaneous
settlements in the modern urbanization era started to grow on the edge of the
cities through ‘sedentarisation’ of tribal groups: “These were squatter and
shanty settlements in character and were mostly found in the Central and
Eastern regions. However, they disappeared from the urban areas with the
construction boom which began in the late 1960s.” (Ibid. Page 38).
Nonetheless, it was not just the peripheral urban areas that attracted population. The cities themselves became a destination for population influx. The other contributor to urban population increase was also the natural growth. The KSA natural population growth as was mentioned in the previous chapter has always been above the average for Western Asia and South-Central Asia regions and is evident. Britannica (2009c) elaborates: “Thanks partly to the government's policies promoting large families and partly to its large investment in health care, the country's birth rate is well above the world average. The national death rate is markedly below the world standard. As a result, Saudi Arabia's overall rate of natural increase is more than twice the world average, and its population is extremely young, with roughly two-thirds under 30 years old and about two-fifths younger than 15. Life expectancy averages about 75 years.” This -as will be shown below- is also the case for Jeddah with fast natural increase of population and also migrants’ influx from other countries (Happold, 2007).

Compared to the aforementioned boom period, the economic indicators such as GDP per capita or GNP per capita of Saudi Arabia are not as high as it was in 1970s or 1980s but these are still well above the regional average (WB, 2011) and amongst the top quartile in terms of GDP per capita among 229 world countries in 2010 (CIA, 2011). Regardless of this economic condition, official data regarding the way wealth is distributed or poverty is scarce. This is important when we consider population growth especially in urban areas because an unequal distribution would result in a large number of impoverished people in urban areas.

However, there are unofficial estimates about the population living in poverty in KSA that suggests a figure of 20% to 30% (Murphy, 2003). Whatever the

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77 Amongst the quoted reasons from Al-Hathloul and Edadan (Ibid.) in the previous paragraph the ‘labor mobility’ points to this issue; by this the later writers meant the adoption of expatriate labour due to the very high demand for work force after the governmental programs which was in conjunction with the flow of rural areas to the few large urban centers.
figure, the taboo of discussing the existence of poverty in KSA has been relaxed after a visit by the royals to the poor areas of Riyadh in 2002 (Ibid). However, the thesis would conclude that regardless of the political preference in KSA and lack of official data, urban poverty exist there as evident from the prevalence of slums and the official estimates that confirm it (about 18% of urban population according to UNCHS, 2008).

It should be reminded that the term ‘slum’ in KSA is now widely used to describe self-growing informal areas or spontaneous settlements that are also called ‘unplanned settlements’ (for example see ‘Jeddah Without Slums, Happold, 2007). For the sake of consistency in this thesis the term spontaneous settlement will be used instead of unplanned settlements in the context of Jeddah urban studies. In the following sections the city of Jeddah as an example from the quickly urbanizing KSA will be presented with focus on its spontaneous settlements, the reasons behind their formation and the resulted diversity of their urban forms and conditions. Serious questions are raised in this regard. Can the preference of the dwellers in these areas to overcome poverty be inferred from different aspects of their settlements? Can the settlements’ location within the larger city and with regards to major zone or the overall growth direction reflect their potential for consolidation?

**Jeddah in its region: origin, history and strategic importance**

The city of Jeddah is located on the Red Sea coast and is the second largest city in Saudi Arabia after the capital Riyadh. Due to its strategic location as an entrance gate to the pilgrimage cities of Mekkah and Madinah, Jeddah has had a great importance for a long time in its history. A report on the historic core of Jeddah (Amir, 1990) suggests that the first dwellers of the area to be as early as the civilizations of Egyptian and Mesopotamian. Although there are not many
evidences left from that pre-Islamic period, the wells and cisterns from the Persian dominance era (500 A.D. to about 1080 A.D) can still be found today.

Because of Jeddah’s location on the sea trading routes (for example between the Mediterranean and the Far East), it was not unexpected to have prosperous commerce in it which has been a major source of wealth. The other source of significance for Jeddah that started to emerge after 1081 A.D. was the growing number of pilgrims going to Mekkah through it. It should be noted that the geological advantage of Jeddah in having a gap in an overwhelmingly reef shore – as a natural lagoon – has made it as an entrance point to the main land either for trade or pilgrims (Ibid. Page 106)

In a wider context, Jeddah is located in the Mekkah region one of the 13 administrative regions that KSA is divided to. Although the city of Mekkah is the capital of Mekkah region, Jeddah has a larger population comparing to it that signifies Jeddah’s importance. Overall Mekkah region is one of the most populated regions in KSA after the capital region of Riyadh but as Jeddah Strategic Plan indicates (Jeddah Municipality, 2009) the high concentration of total regional population (about 73 percent) in the two cities of Mekkah and Jeddah also reflect an imbalanced population concentration in these major urban centres that can lead to overstretched infrastructure and amenities. The strategic importance regarding trades, oil and pilgrimages could be recognized as the main reasons for the demographic predominance of the aforementioned two cities in their region.

The economy of Jeddah and employment

Apart from the historic economic significance of Jeddah as a gateway city for the pilgrims, it has a more contemporary importance in national level. Jeddah

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78 According to UNCHS (2003a) Mekkah had a population of 1.8 million people is less than the figure of 3.5 million for Jeddah according to Jeddah Strategic Plan report (Jeddah Municipality, 2009).
Strategic Plan (Jeddah Municipality, 2009) claims that Jeddah’s economy has less reliance on petroleum as a result of its strength in logistic and transport related services for tourists and pilgrims (Page 87). However, it should be borne in mind that the contemporary wave of urbanization in KSA that made Jeddah one of the three main urban poles in KSA along with Riyadh and Dammam (Al-Hathloul and Edadan, 1991) was originally driven by the oil revenues during the economic boom of 1940s. Nevertheless, Jeddah started to accommodate a diverse range of industries including steel plants, cement factories and cloth production units, pottery and smaller husbandry facilities further to its original fishing and catering ones (Britannica, 2009a).

In describing employment sectors in Jeddah, Municipality of Jeddah (Jeddah Municipality, 2009) adds: “Jeddah’s economy currently is relatively diverse, with very little direct dependence on mining and petroleum. However, much of the formal sector employment is concentrated within a few sectors. In 1425 (2004) over 73 per cent of the privately employed formal sector workers in Jeddah were within the trade and construction sectors ... These sectors include commercial activities such as retail, hospitality and leisure induced by millions of tourists visiting Jeddah every year.” (P. 103). The importance of trade and commercial activities in a spatial sense throughout the city will be further discussed in this chapter but a major point is that most of the employees in the above formal sectors – more than 80% as the same report claims- are foreign expatriates.

Despite economic significance of Jeddah, the problem of unemployment especially amongst Saudi citizens and women is confirmed by Municipality of Jeddah (Jeddah Municipality, 2009) in addition to lower participation by the labour force. The unemployment rate is estimated to be 11.5% that is above the estimated national figure (Ibid.). One of the reasons for the reported low participation by the Saudi population is mentioned to be the lack of high skill
workers among them. This makes the employers with no choice but to rely on foreign work forces.

Municipality of Jeddah (Jeddah Municipality, 2009) also points to the economic problems associated with the excessive ratio of expatriate labor force in Jeddah and the difficulties they have with permanent settling for these people: “Jeddah’s strong economy means that it is perceived as a place of opportunity, attracting significant numbers of migrant workers from other parts of the Kingdom and abroad. Many migrant workers are unable to access traditional housing and have few alternative options but to find shelter in the unplanned areas. Similarly, some visiting pilgrims remain in Jeddah and find their new home in the unplanned settlements.” (Page 366)

However, what the previous report does not highlight is the proportion of the expatriates who are working in the informal sector or dwell in spontaneous (or ‘unplanned’) settlements. This issue is highlighted by Happold (2007) who indicates most of the workers in spontaneous settlements of Jeddah are low-skilled expatriates that could not find job in the formal sector. The aspects of work and economy in Jeddah spontaneous settlements will be further discussed in this chapter under socio-economic characters of these areas.

**Jeddah urbanization, population growth and housing demand**

To propose the urban model for Jeddah and locating the spontaneous settlements within that model along with the reasons for their formation, the demographic and housing trends of the city will be examined below.

The recent report on Jeddah Strategic Plan (Jeddah Municipality, 2009) estimated a population of about 3.5 million for the city by 2009 while predicting a 2.2 million increase in next 20 years. This agrees with the estimation of Jeddah’s population change over last two decades and its future
projection according to UNCHS (2003a). The latter source predicted the annual population growth to fall from its average of 1.62% (for the period of 2005 to 2010) to 1.34% (years 2010 to 2015).

One of the major reasons for this increase of population is highlighted by Abdu and others (2002) as the attractiveness of Jeddah to migrants from within the country and immigrants from outside due to economic opportunities. Moreover, they argued that Jeddah population growth rate seems to be closely related with its overall economic circumstances. This parallel trend between demography was also observed in Chapter 2, Figure 2.3 when KSA reached a high annual growth rate of 6.5% between its economic boom of 1980 to 1985. The other issue that could be expected to happen in parallel with the population growth is the physical expansion of Jeddah that will be discussed in the next section along with other issues pertaining to the city overall structure.

**General urban structure of Jeddah**

This section and its constituent parts will look at the general urban structure of Jeddah in a geographical sense and aims at summarizing a simplified model of the city in the light of the reviewed urban models of Third World cities in the second chapter. Such simplified model along with locating the spontaneous settlements in relation with other zones of the city (mainly the major centres) will help with inferring the socio-economic character of spontaneous settlements.

**Physical expansion of the city: its phases, direction and bounding forces**

Understanding the phases of urban growth and the obstacles to it when seen in conjunction with the location of spontaneous settlements in their larger context
can indicate where the older areas with higher potential for consolidation are located. To do so, it is necessary to look at the pace and overall direction of the growth first while highlighting its deriving forces such as major industries, arteries or transport stations. This can be summarized as the major functional zones and corridors (such as elite housing districts) when suggesting the general model for the city.

A couple of points should be added about the climatic and geographical context of Jeddah. Overall, Jeddah is on a plane area and stretched along the Red Sea Coast on its western limits. Jeddah urban footprint is about 170km long and in average 18km wide that is stretched in north-south direction and limited by the Sarwat Chain Mountains on its east. The land on which the city is located is nearly flat with a slight decreasing slope of 0.002% when it reaches the coast line on its west. Beeah (2004) summarizes Jeddah climate as follow: “Jeddah's climate is moderate in winter and most of spring and autumn while temperature and humidity rises the rest of the year. Rain scarcely falls in winter but it usually causes torrential streams. The pleasant north-west winds, which is light-moderate, prevails around the year and becomes active in limited times in winter” (P. 65). This climatic condition, according to Abu-Ghazzez (1994) has had some impact on the orientation of streets in the historic part of the city.

As was mentioned before Jeddah owes its roots to trades based on pilgrimage. As Abdu and others (2002) emphasize the relatively low economic gain from visiting pilgrims in the period before the oil extraction was also proportional to the small size and population of the city until the first oil boom of 1945-1956. The urban fabric within the old wall (currently known as the historic core) has kept some of its architectural characters mainly the vernacular style of buildings, roofed bazaars with narrow and meandering streets. The wall was said to exist by the Persian historian Nasir-i Khosrow in 1050 A.D. For the period from about 900 to 1500 A.D. the city was ruled by Turks when the wall
was reconstructed (by sixteen century) and a garrison was added outside it. Then the city was governed by rulers affiliated with Cairo followed by an era of relations with French and British until 1860 A.D (Amir, 1990)

![Figure 4.1 - The location of Nakutu spontaneous settlement before the old wall demolition (Johnson-Marshall, 2011).](image)

The same report adds that the only parts of the settlement that fell outside the city wall consisted of the Turkish garrison, a few small villages and Nakuta, “a sprawling mass of reed shelters that spread outwards from Bab al-Sharif [one of the main gates of the city] providing a home for Jeddah’s large west African community” (P. 109). Nakutu, (illustrated in Figure 4.1) in this way can be considered as the first spontaneous settlement of Jeddah that was later considered as parts of Sabeel area while the villages of Baghdadiyah and Kandarah became nuclei for other spontaneous settlements with the same name currently (known as ‘unplanned settlements’ by the officials in Jeddah).
walled city is shown in the figure below that is an aerial photo taken by 1942 along with the Nakutu in the south of the wall.

By 1947, the old wall surrounding the city was demolished that led to faster pace of physical and demographic growth for Jeddah. While before this phase the city was about 3 square kilometres with maximum population of 50,000, it started to expand due to the higher economic gain from the oil revenues and its strategic location in international and national level that attracted more investment from the central government.

![Figure 4.2 - The population growth of Jeddah according to Qari (1995).](image)

After the demolition of the old wall in 1947 Jeddah started to grow in exponential rates both in physical and demographic trends (Qari, 1995). Measuring the urban footprint observable in aerial photographs acquired from 8 intervals for the period between the years 1948 to 1994 and using population estimation methodologies, Qari (Ibid.) also reveals the strong correlation
between population size and urban area over this period. The population increase until 1995 as estimated by Qari (Ibid.) is depicted in Figure 4.2.

The exponential rate of Jeddah physical growth after the wall demolition is also confirmed by other studies such as Beeah (2001) that includes more recent areas compared to Qari’s study up to 2001 (Table 4.1). Municipality of Jeddah (Jeddah Municipality, 2009) however, estimates the urban footprint of 1,765 square kilometres that is 3268 times of the walled city in terms of area.

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (sq km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before wall demolition</td>
<td>0.54</td>
</tr>
<tr>
<td>1947</td>
<td>2.8</td>
</tr>
<tr>
<td>1957</td>
<td>32.5</td>
</tr>
<tr>
<td>1967</td>
<td>56</td>
</tr>
<tr>
<td>1986</td>
<td>367</td>
</tr>
<tr>
<td>2001</td>
<td>1378</td>
</tr>
</tbody>
</table>

Table 4.1 - Jeddah increasing urban area over past decades (Beeah, 2001).

Summarizing the reasons that influenced the growth of Jeddah, Abdu and others (2002) mentions two main groups of forces. The primary factors according to them are the determinant of the overall scale and form of the city development including:

1- Jeddah’s location with regards to the old trading and pilgrimage routes especially the passage through the mountains to Mekkah and the deep water as well as more contemporary advantage of being along the oil shipment routes;
2- The economic impact of oil industry mainly during the two boom period of 1945-1956 and 1975-1985 on urban development in KSA and more particularly Jeddah;

3- The governmental recognition of Jeddah as a national urban centre that puts it above lower grades of regional and district centres and villages;

4- The impact of three master plans for Jeddah in 1962, 1973 and 1978 that overall decided on the location of some major facilities and zones (such as the airports and industries), the adoption of grid iron pattern for the streets and the overall direction of the city growth towards north and south along the coastline.

5- The cultural flexibility and tolerance that accepts diversity of people from various socio-economic status and cultures.

In the same paper Abdu et al. (Ibid.) also introduce the group of secondary factors that influenced land use diversity and the urban character of Jeddah that includes:

1- the planning interventions (mainly the allocation of vacant land to different institutions through a royal decree of 1947),

2- the demand for more housing and commercial built area because of the increasing migrant population that created high rise apartment blocks and also spontaneous housing areas 79

3- the impact of major developments such as the refinery and airport on the overall land use distribution of Jeddah and

4- the intensive linear arrangement of commercial land use along the two main axis extending from the historic core to the north (i.e. Medinah Road alignment) and towards the east (i.e. Mekkah road).

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79 They actually point to areas that will be introduced as spontaneous settlements in Jeddah in their description: “Contrasting with this area [i.e. formal apartments] are neighbourhoods (like Sabeel, Al-Bakhariya, Al-Sharifiah and Amaria) which house Bedouins and therefore developed organically with traditional Arabic style building types.” (Ibid. Page 131)
Due to the importance of the third factor of the secondary group, it will be further explained here. Abdu and others (2002) believe that the placement of airport to the north of the historic core have attracted relevant affluent activities such as official amenities, hotels and lower rise expensive housing to itself while the Seaport and oil refinement industries to the south have brought “warehouses, storages, oil dumbs, workshops and electricity station” (Ibid. Page 132) to their vicinity. This contrast, they argue, constitute a dual arrangement: “This pattern consequently affected the social fabric and distribution of the Jeddah population and the building types housing the low income, spontaneous vernacular archetypes and huts are found in the south, while high income, planned developments with villa types of buildings are found in the north.” (Ibid.) This claim would be supported in this chapter by looking at the geographic spread of spontaneous settlements but it also suggests that the dual structure previously observed in Zahedan (chapter 3) and generalized by reviewed Third World urban models (chapter 2) might be applicable to Jeddah as well.

The two aforementioned commercial axes of Mekkah Road to the east and Medinah Road to the north of the historic core pointed by Abdu et al. (2002) are also considered as the two main directions for the growth of Jeddah. This is illustrated by Municipality of Jeddah (Jeddah Municipality, 2009) in which different growth stages of Jeddah since 1853 are outlined, (Figure 4.3). The illustration below is also helpful in determining the age of the spontaneous settlements.
This brief review suggests that the officially recognized economic and locational advantages have played an undeniable role in the exponential growth rate of Jeddah both in physical and demographic terms over the last decades. The natural boundaries have shaped the linear shape of the city while the two
regional connections to the pilgrimage cities of Mekkah and Medinah have defined the main directions for the city growth. Also the dual pattern of socioeconomic and land use distribution was mentioned with the spontaneous lower income settlements to be found in the southern part of Jeddah against the more affluent north. In this regard, the next section will look at the geographic distribution of these settlements in the city-wide level along the factor of time.

Figure 4.4 - Major zones and transport corridors of Jeddah (author’s illustration).


**Spontaneous settlements in the wider Jeddah**

As mentioned earlier the early spontaneous settlements began to grow around the historic core of Jeddah in early 1940s. After the wall demolition these areas began to expand around the historic core and constituted the early settlements. As Municipality of Jeddah (Jeddah Municipality, 2009) points, while the growth of early spontaneous settlements outside the old wall (and hence outside the city) was to accommodate the increasing pilgrim population at late 1940s, by mid 1950s those early spontaneous settlements were within the expanded city. These settlements including 6 settlements are also referred to as the ‘central unplanned settlements’ by different sources such as ZFP (2006) or Space Syntax limited (2006)\(^\text{80}\).

After this phase and by early 1970s, spontaneous settlements started to appear on both the vacant pieces of land within the city and also on its outer peripheries (Ibid.). Some of these peripheral spontaneous settlements such as Dhahban (which was originally a village) are still outside the city while others like Banimalik are surrounded by the city completely. Overall, the spontaneous settlements can be divided into three categories according to their placement with regards to the historic core and the outer edge of Jeddah: 1- central 2- inner-city (non-central) and 3- the peripheral spontaneous settlements.

The table below summarizes the spontaneous settlements of Jeddah in terms of their age, size and population while Figure 4.5 reflects their location. Different reports give slightly various accounts of the number of these settlements mostly around 50 like Happold (2007), Space Syntax limited (2006) and ZFP (2006) but using the data surveyed by ZFP in 2001, there are 52 settlements that could be counted. A brief look at Figure 4.5 also suggests that the outer settlements are larger as the theoretical framework of chapter two also suggested. Also, it is discernible that more land area is under spontaneous

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\(^{80}\) The central spontaneous settlements include: Hindawiyyah, Sabeel, Ammariyah, Kandarah, Baghdadiyyah, Sahifah and Sharafiyah.
settlements of the east and south of the historic core compared to its north, confirming what Abdu et al. (2002) suggested about the dual socio-economic and land use structure of Jeddah.

In this regard and following the exponential growth trend of Jeddah (see Figure 4.3) there is a significant correlation between the age and logarithm of distance to the historic core of Jeddah for the 50 spontaneous settlements ($R^2 = 0.826$ and $p < 0.001$). This leads to the conclusion that the outer settlements in Jeddah are the more recent ones while the growth trend of spontaneous settlements has been following the overall centrifuging growth of their host city.

Figure 4.5 - Current geographic spread of Jeddah spontaneous settlements illustrated by the author using different sources. The same map is shown in two various scales on left and right.
<table>
<thead>
<tr>
<th>ID</th>
<th>Area Name</th>
<th>Area (sqm)</th>
<th>Population (2006)</th>
<th>Age</th>
<th>Building footprint data</th>
<th>Dis. to core (km)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Balad</td>
<td>756,942</td>
<td>50,715</td>
<td>64</td>
<td>Available</td>
<td>0.6</td>
<td>Central</td>
</tr>
<tr>
<td>2</td>
<td>Sahifah</td>
<td>437,276</td>
<td>22,988</td>
<td>54</td>
<td>Available</td>
<td>0.8</td>
<td>Central</td>
</tr>
<tr>
<td>3</td>
<td>Amariyah</td>
<td>470,357</td>
<td>11,579</td>
<td>54</td>
<td>Available</td>
<td>0.9</td>
<td>Central</td>
</tr>
<tr>
<td>4</td>
<td>Hindawiyah</td>
<td>1,028,111</td>
<td>44,385</td>
<td>64</td>
<td>Available</td>
<td>1.0</td>
<td>Central</td>
</tr>
<tr>
<td>5</td>
<td>Baghdadiyah</td>
<td>955,737</td>
<td>19,390</td>
<td>44</td>
<td>Available</td>
<td>1.2</td>
<td>Central</td>
</tr>
<tr>
<td>6</td>
<td>Sabeel</td>
<td>453,529</td>
<td>23,974</td>
<td>54</td>
<td>Available</td>
<td>1.2</td>
<td>Central</td>
</tr>
<tr>
<td>7</td>
<td>Kandarah</td>
<td>823,527</td>
<td>29,973</td>
<td>54</td>
<td>Available</td>
<td>1.6</td>
<td>Central</td>
</tr>
<tr>
<td>8</td>
<td>Sherafiyah</td>
<td>463,362</td>
<td>19,235</td>
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<td>Available</td>
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<td>Central</td>
</tr>
<tr>
<td>9</td>
<td>Thahlbah</td>
<td>102,654</td>
<td>10,745</td>
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<td>Inner-city</td>
</tr>
<tr>
<td>10</td>
<td>Qurriyath</td>
<td>242,896</td>
<td>10,850</td>
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<td>2.3</td>
<td>Inner-city</td>
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<tr>
<td>11</td>
<td>Nuzlah</td>
<td>1,315,857</td>
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<td>Inner-city</td>
</tr>
<tr>
<td>12</td>
<td>Thaghar</td>
<td>534,327</td>
<td>16,674</td>
<td>54</td>
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<td>Ghalil</td>
<td>1,002,448</td>
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</tr>
<tr>
<td>14</td>
<td>Betrumin</td>
<td>882,208</td>
<td>30,044</td>
<td>44</td>
<td>Available</td>
<td>3.6</td>
<td>Inner-city</td>
</tr>
<tr>
<td>15</td>
<td>Ruwais</td>
<td>841,380</td>
<td>28,078</td>
<td>54</td>
<td>Available</td>
<td>3.8</td>
<td>Inner-city</td>
</tr>
<tr>
<td>16</td>
<td>Madaen Al Fahad</td>
<td>1,112,209</td>
<td>29,057</td>
<td>44</td>
<td>Available</td>
<td>4.4</td>
<td>Inner-city</td>
</tr>
<tr>
<td>17</td>
<td>Banimalik</td>
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<td>44</td>
<td>Available</td>
<td>4.8</td>
<td>Inner-city</td>
</tr>
<tr>
<td>18</td>
<td>Moshrefah</td>
<td>555,744</td>
<td>9,388</td>
<td>32</td>
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</tr>
<tr>
<td>19</td>
<td>Jameah</td>
<td>2,915,550</td>
<td>121,590</td>
<td>44</td>
<td>Available</td>
<td>6.6</td>
<td>Inner-city</td>
</tr>
<tr>
<td>20</td>
<td>Aziziyah</td>
<td>964,256</td>
<td>27,251</td>
<td>25</td>
<td>Available</td>
<td>7.0</td>
<td>Inner-city</td>
</tr>
<tr>
<td>21</td>
<td>Rohab</td>
<td>188,212</td>
<td>5,096</td>
<td>10</td>
<td>Available</td>
<td>7.8</td>
<td>Inner-city</td>
</tr>
<tr>
<td>22</td>
<td>Quaizah</td>
<td>1,197,685</td>
<td>20,430</td>
<td>10</td>
<td>Available</td>
<td>8.6</td>
<td>Inner-city</td>
</tr>
<tr>
<td>23</td>
<td>Rawabi</td>
<td>2,123,116</td>
<td>59,135</td>
<td>25</td>
<td>Available</td>
<td>8.7</td>
<td>Inner-city</td>
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<tr>
<td>24</td>
<td>Rabwa</td>
<td>1,735,325</td>
<td>48,426</td>
<td>10</td>
<td>Available</td>
<td>12.1</td>
<td>Inner-city</td>
</tr>
<tr>
<td>25</td>
<td>Salamah</td>
<td>102,457</td>
<td>2,345</td>
<td>10</td>
<td>Available</td>
<td>13.1</td>
<td>Inner-city</td>
</tr>
<tr>
<td>26</td>
<td>Nozhah</td>
<td>482,829</td>
<td>7,973</td>
<td>10</td>
<td>Available</td>
<td>14.7</td>
<td>Inner-city</td>
</tr>
<tr>
<td>27</td>
<td>Montazohat</td>
<td>1,725,494</td>
<td>45,381</td>
<td>10</td>
<td>Available</td>
<td>9.4</td>
<td>Peripheral</td>
</tr>
<tr>
<td>28</td>
<td>Kilo11</td>
<td>534,482</td>
<td>17,955</td>
<td>10</td>
<td>Available</td>
<td>10.5</td>
<td>Peripheral</td>
</tr>
<tr>
<td>29</td>
<td>Khomrah Sorur</td>
<td>130,929</td>
<td>1,757</td>
<td>10</td>
<td>Available</td>
<td>11.0</td>
<td>Peripheral</td>
</tr>
<tr>
<td>30</td>
<td>Khomrah Thahalebah</td>
<td>203,811</td>
<td>2,730</td>
<td>10</td>
<td>Available</td>
<td>12.9</td>
<td>Peripheral</td>
</tr>
<tr>
<td>31</td>
<td>Kilo14 North</td>
<td>2,709,434</td>
<td>43,708</td>
<td>10</td>
<td>Available</td>
<td>13.3</td>
<td>Peripheral</td>
</tr>
<tr>
<td>32</td>
<td>Kilo14 South</td>
<td>1,172,388</td>
<td>15,820</td>
<td>10</td>
<td>Available</td>
<td>13.6</td>
<td>Peripheral</td>
</tr>
<tr>
<td>33</td>
<td>Kilo15</td>
<td>158,029</td>
<td>504</td>
<td>10</td>
<td>Available</td>
<td>14.9</td>
<td>Peripheral</td>
</tr>
<tr>
<td>No.</td>
<td>Location</td>
<td>Population</td>
<td>Area</td>
<td>Age</td>
<td>Status</td>
<td>Distance to Core</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>------------------</td>
<td>------------</td>
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<td>-----</td>
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<td>------------------</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Kilo16</td>
<td>220,921</td>
<td>2,485</td>
<td>10</td>
<td>Available</td>
<td>15.3</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Baryman</td>
<td>1,914,386</td>
<td>13,058</td>
<td>10</td>
<td>Available</td>
<td>16.6</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Kilo18 North</td>
<td>128,361</td>
<td>1,750</td>
<td>10</td>
<td>Available</td>
<td>16.9</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Kilo18 South</td>
<td>274,435</td>
<td>1,694</td>
<td>10</td>
<td>Unavailable</td>
<td>17.5</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Khomrah Gharan</td>
<td>3,341,944</td>
<td>7,980</td>
<td>10</td>
<td>Unavailable</td>
<td>20.3</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Huwaranah</td>
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<td>1,022</td>
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<td>Unavailable</td>
<td>20.7</td>
<td></td>
</tr>
<tr>
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<td>Kilo23</td>
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<td>41</td>
<td>Mahamid Faw</td>
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<td>Hmdaniyah</td>
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<td>Huzeefath</td>
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<td>847</td>
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<td>Morsalat</td>
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<td>Najid</td>
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<td>Bahra Mojahed</td>
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<td>Tual</td>
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<td>10,906</td>
<td>10</td>
<td>Unavailable</td>
<td>80.3</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>56,183,876</strong></td>
<td><strong>985,125</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.2 - List of Jeddah spontaneous settlements for which the population data is extracted from ZFP (2006). For the age estimation two different maps from Jeddah Municipality (2009) and Beeah (2001) are used.\(^{81}\)

---

\(^{81}\) ‘Distance to core’ is measured between the centroid of each settlement boundary to the centroid of the historic core boundary polygon.
Land use distribution and built-up densities in Jeddah

The aforementioned dual pattern of land use (i.e. affluent north versus the poorer south) can also be further confirmed by looking at the quantities of land use and comparing it between whole Jeddah and spontaneous areas. To this end, the categories for areas of each land use are summarized in Table 4.3 querying in GIS environment.

An initial observation is that the predominant land use is residential for spontaneous settlements while for whole Jeddah it ranks third after vacant and governmental categories. Although for this summary just the land plots not farther than a kilometre from the available building footprints are selected, there is a considerable amount of vacant land in the city -also confirmed by Jeddah Municipality (2009) - that is resultant from an ongoing sporadic growth pattern. Moreover, a high proportion of the governmental land in whole Jeddah (7,477 out of 10,428 hectares) belongs to a single site that is the airport in the north of Jeddah. The fact that the overall non-vacant land use of city is dominated by the official governmental intervention in the north – as Abdu and others (2002) indicated- marks the sharp difference between the formal north and the (generally) informal south. Confirming that, for the spontaneous settlements the land plot area under residential function comes up first followed by commercial category. This suggests that, in the absence of planning intervention in spontaneous settlements and the lack of governmental, administrative and public facilities, these are the residential and commercial functions that are in turn preferred by the dwellers of these areas.

This trend is repeated in building footprint measurement of spontaneous settlements where the first and second ranks are residential and commercial building footprints, respectively while for the whole city, the residential footprint area is followed by industrial category as the second rank. This indicates that although the residential building footprint is the predominant
category for both Jeddah and spontaneous settlements, the spontaneous settlements got a more intensive residential function compared to the rest of the city. These observations will be further interpreted in an upcoming section “The proposed urban model for Jeddah” in this chapter.

<table>
<thead>
<tr>
<th>All land plots</th>
<th>% of total</th>
<th>Spontaneous settlement plots</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacant</td>
<td>26.1</td>
<td>Residential</td>
<td>64.8</td>
</tr>
<tr>
<td>Administration &amp; governmental</td>
<td>21.8</td>
<td>Commercial</td>
<td>14.0</td>
</tr>
<tr>
<td>Residential</td>
<td>19.8</td>
<td>Vacant</td>
<td>6.5</td>
</tr>
<tr>
<td>Unknown</td>
<td>13.3</td>
<td>Unknown</td>
<td>4.3</td>
</tr>
<tr>
<td>Industrial and maintenance</td>
<td>5.6</td>
<td>Transport and warehouses</td>
<td>3.3</td>
</tr>
<tr>
<td>Transport and warehouses</td>
<td>4.7</td>
<td>Educational</td>
<td>2.2</td>
</tr>
<tr>
<td>Commercial</td>
<td>2.8</td>
<td>Industrial and maintenance</td>
<td>1.4</td>
</tr>
<tr>
<td>Educational</td>
<td>1.8</td>
<td>Religious</td>
<td>1.3</td>
</tr>
<tr>
<td>Park</td>
<td>1.3</td>
<td>Administration &amp; governmental</td>
<td>0.8</td>
</tr>
<tr>
<td>Religious</td>
<td>0.8</td>
<td>Cemetery</td>
<td>0.4</td>
</tr>
<tr>
<td>Recreation</td>
<td>0.6</td>
<td>Social &amp; governmental services</td>
<td>0.4</td>
</tr>
<tr>
<td>Installation and infrastructure</td>
<td>0.5</td>
<td>Park</td>
<td>0.2</td>
</tr>
<tr>
<td>Truism and hotels</td>
<td>0.4</td>
<td>Medical</td>
<td>0.2</td>
</tr>
<tr>
<td>Medical</td>
<td>0.2</td>
<td>Installation and infrastructure</td>
<td>0.2</td>
</tr>
<tr>
<td>Historic</td>
<td>0.1</td>
<td>Truism and hotels</td>
<td>0.1</td>
</tr>
<tr>
<td>Cemetery</td>
<td>0.0</td>
<td>Recreation</td>
<td>0.0</td>
</tr>
<tr>
<td>Social &amp; governmental services</td>
<td>0.0</td>
<td>Historic</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total (Ha)</strong></td>
<td><strong>47,738.0</strong></td>
<td><strong>Total (Ha)</strong></td>
<td><strong>2,134.9</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>All building footprints</th>
<th>% of total</th>
<th>Spontaneous building footprints</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>53.2</td>
<td>Residential</td>
<td>72.2</td>
</tr>
<tr>
<td>Industrial and maintenance</td>
<td>10.9</td>
<td>Commercial</td>
<td>17.1</td>
</tr>
<tr>
<td>Transport and warehouses</td>
<td>8.9</td>
<td>Unknown</td>
<td>2.9</td>
</tr>
<tr>
<td>Commercial</td>
<td>8.1</td>
<td>Transport and warehouses</td>
<td>2.3</td>
</tr>
<tr>
<td>Unknown</td>
<td>7.1</td>
<td>Educational</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>-----</td>
<td>----------------------</td>
<td>-----</td>
</tr>
<tr>
<td>Administration &amp; government</td>
<td>5.2</td>
<td>Religious</td>
<td>1.5</td>
</tr>
<tr>
<td>Educational</td>
<td>2.2</td>
<td>Industrial &amp; maintenance</td>
<td>1.2</td>
</tr>
<tr>
<td>Religious</td>
<td>1.4</td>
<td>Social &amp; governmental services</td>
<td>0.3</td>
</tr>
<tr>
<td>Recreation</td>
<td>0.7</td>
<td>Administration &amp; governmental</td>
<td>0.2</td>
</tr>
<tr>
<td>Medical</td>
<td>0.6</td>
<td>Medical</td>
<td>0.2</td>
</tr>
<tr>
<td>Installation &amp; infrastructure</td>
<td>0.6</td>
<td>Truism &amp; hotels</td>
<td>0.1</td>
</tr>
<tr>
<td>Truism &amp; hotels</td>
<td>0.5</td>
<td>Installation &amp; infrastructure</td>
<td>0.1</td>
</tr>
<tr>
<td>Historic</td>
<td>0.4</td>
<td>Cemetery</td>
<td>0.0</td>
</tr>
<tr>
<td>Park</td>
<td>0.2</td>
<td>Park</td>
<td>0.0</td>
</tr>
<tr>
<td>Social &amp; governmental services</td>
<td>0.1</td>
<td>Recreation</td>
<td>0.0</td>
</tr>
<tr>
<td>Cemetery</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (Ha)</strong></td>
<td>7,800.7</td>
<td><strong>Total (Ha)</strong></td>
<td>1,406.7</td>
</tr>
</tbody>
</table>

Table 4.3 – Four-sectioned table summarizing land use for Jeddah land plots (upper left), spontaneous settlements land plots (upper right), Jeddah building footprints (lower left) and spontaneous settlements building footprints (lower right).

**Commercial land use in Jeddah**

As discussed earlier, commercial activities and trade were in the core of Jeddah city since its early years due to be along the pilgrimage routes and trading gateway. In more recent time, Jeddah still has a considerable commercial aspect as summarized by Murad (2003): “Jeddah city is considered as the major commercial city in Saudi Arabia because it has the largest seaport of the country as well as the availability of large transportation network that links the city with its surrounding regions. In addition, Jeddah is a unique industrial city, which produces different retail products for the whole country. All of these factors lead to the expansion and growth of many commercial centres at different parts of the city.” (P. 329) This can be supported by an estimation made by Municipality of Jeddah (Jeddah Municipality, 2009, P. 102) indicating that about 59.6% of employed labour in private sector work in trade and commercial activities.
The claim about the dispersion of commercial land use is in line with the observation by Abdu and others (2002) that commercial land use has a higher intensity alongside the two main axes of Medinah Road and Mekkah Road. Moreover, there are some other major commercial corridors parallel to Medinah road as well as perpendicular to it (e.g. Tahlia Street) that makes Medinah Road a stronger commercial corridor within the affluent north Jeddah.

However, the large scale commercial centres in Jeddah such as formal shopping malls and retail centres are only one end of a spectrum. On the other end there are small daily shops, groceries and local markets that are more of informal nature. The latter group is mostly can be found on the edge of spontaneous settlements or within them. This is reflected in the Table 4.4 where the commercial building footprints from Jeddah are compared against the spontaneous settlements. The smaller size of commercial footprints in spontaneous settlements can be a reflection of their local functioning compared to the large retail places in formal areas with vehicular access from a city-wide range.

Another considerable point in Table 4.4 is the large proportion of Jeddah commercial buildings falling within the spontaneous settlements (more than half) that points to the economic role of these areas within the larger city. In terms of total area, spontaneous settlements constitute about 37% of the whole city commercial building footprint. These observations lead to a presumption that spontaneous settlements might form hot spots of land use density and diversity (or centres) at least in the local level but investigating such issue requires further understanding of the built-up density pattern that follows in the next section.
<table>
<thead>
<tr>
<th>Commercial building footprint</th>
<th>count</th>
<th>Mean size (sqm)</th>
<th>Total area (ha)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeddah</td>
<td>15,559</td>
<td>406.8</td>
<td>633</td>
<td>1,011.2</td>
</tr>
<tr>
<td>Spontaneous settlements</td>
<td>8,418</td>
<td>285.0</td>
<td>240</td>
<td>468.9</td>
</tr>
</tbody>
</table>

Table 4.4 - Commercial building footprint area for Jeddah compared to the 36 spontaneous settlements for which the footprint data was completely available\(^{82}\).

**Built-up density and land use diversity in Jeddah**

This section will first look at built-up density pattern in Jeddah and then focus on the combined measures of density and diversity to highlight the urban centres in different scales from local to the very city-wide with focus on the local scale analysis as a measure of consolidation. The statistical summary will be done on the 36 spontaneous settlements for which the building footprint data is available to quantify their consolidation ratios.

To create the built-up density map the same Kernel method applied to Zahedan based on the aggregation of building footprints were used. The kernel bandwidths is 150 meters and the area of building footprints is summed up within each kernel. The result is shown in Figure 4.6. It should be noted that the unavailability of building footprint data in the east and south east of the city results in blank areas.

As Figure 4.6 indicates, the density pattern does not explicitly follow the concentric pattern observable in Zahedan. However, the historic core (where major spines of Mekkah Road and Medinah Road meet) and spontaneous settlements exhibit higher densities compared to the rest of the city. The overall shape of high density zones seems to be stretched along the two major

\(^{82}\) The building footprint data availability for spontaneous settlements was already illustrated in Table 4.2.
spines towards the north (i.e. Medinah Road) and south-east (i.e. Mekkah Road). A more accurate inspection also suggests that for the spontaneous settlements in central parts of the city (or the older areas) the density is higher while for the peripheral settlements the hot spots of high density are limited to smaller cores that highlight the older parts of a settlement. A regression analysis of the two variables of distance to the historic core and the coverage ratio by building footprints results in Rsquare of 0.58 (p<0.0001) for the 36 spontaneous settlements.

![Footprint density](image)

**Figure 4.6** - Building footprint density (band widths 150 meters) with cell size of 100 meters by 100 meters. The black oval in the south of city marks the major industrial, warehouse and transport developments.
Land use density-diversity and major centers of Jeddah

The previous density analysis although helpful in understanding the structure of Jeddah, is not enough to locate the urban centres of different level. Considering the overwhelming homogenous residential land use pattern of the city the question would be where the major centres or the cores of intensive mixed activities are located. This is important in terms of understanding the reasons behind the placement of spontaneous settlements while drawing a general model for the whole city.

Performing the same density-diversity analysis used for the city of Zahedan in the previous chapter would help with identifying the centres of Jeddah. However, because of the size of Jeddah (more than 25 times as big as Zahedan compared in urban footprints), there are some concerns with the analyses. Firstly, performing the density-diversity analysis with cell size of 50 meters by 50 meters is not computationally affordable so the cell size of 100 by 100 meters is chosen. Secondly, to facilitate comparison of the analyses, the values of cells are scaled between 0 and 1 and the same colour ranges used for Zahedan will be applied to Jeddah.

As the density-diversity analyses (Figure 4.7, lower tile) show, in local level (band-width of 200 meters) spontaneous settlements especially the more central ones come up as strong spots of activity. This seems intuitive as the grain of building footprints is fairly dense in these areas and hence the occurrence of non-residential land use (mainly commercial activities as the second dominant land use after residential as reflected in Table 4.3) would strengthen the local centres of spontaneous settlements.
Figure 4.7 - Density-diversity maps for the building footprints with land use. The upper and lower analyses use band-widths of 500 and 200 meters respectively. The spontaneous settlements and the major spines are marked.
In a more global level this (band-width of 500 meters, Figure 4.7, upper tile) would result in a less fragmented pattern of centres showing the historic core and its surrounding spontaneous settlements as major spots while the overall pattern around the northern spine of Medinah Road seems to have some strong cores in a background with generally higher values (indicated by yellow colour). If the same analyses are applied with larger band width of 2500 meters (not shown here), the predominant central core of Jeddah would be highlighted as it stretches from the historic core towards north (along Medinah Road) and more limited towards south-east (i.e. Mekkah Road direction) suggesting that the northern area of Jeddah has a stronger city-wide role in terms of activities.

A qualitative assessment of spontaneous settlements in terms of density-diversity measure with 500 meters band-width (Figure 4.7) suggests that these areas especially the central ones are within or very close to the major urban centres. In more local level of 200 meters, the settlements due to their higher footprint density and high ratio of commercial land use are forming strong local centres themselves. It can be speculated that the strong local centres in spontaneous settlements are responses to the lower economic power of their dwellers and hence their preferences for using local markets –although of informal nature- rather than making long vehicular trips to use the facilities in the formal major urban centres. This issue will be further discussed after proposing the urban model for Jeddah.

The proposed urban model for Jeddah

Jeddah exhibits a highly dual structure in terms of land use and growth. While a wide and sprawling low-density zone along the Medinah Road alignment accommodates better quality housing, retail and governmental land uses on suitable flat land, the corridor of Mekkah Road has a high density of smaller commercial activities and spontaneous settlements limited by topographic
obstacles and in close distance from this alignment. Moreover, the southern part of Jeddah around the Seaport although does not have a clear transport artery, it has an overwhelmingly homogenous industrial character (Figure 4.4). The existence of these functionally distinctive developments stretching like wedges from centre to peripheries led Daghistani, (1993) to the idea that Jeddah is conforming to the Hoyt’s sectoral model rather than Burgees’s concentric model (already reviewed in chapter 2).

However, this study argues that the declining built-up densities when moving to the peripheries and the sharp socio-economic contrast between north and south of Jeddah as two distinct wedges require elements of both the concentric and sectoral models to be understood. Moreover, the overall declining socio-economic status of urban population when moving to the peripheries of south Jeddah (or the poorer sector of the city) is similar to a pre-industrial urban pattern that was reviewed in chapter 2. These characteristics together suggest that the best model to generalize the structure of Jeddah that combines the sectoral, concentric and pre-industrial attributes of Third World cities together is the Griffin and Ford model.

Following Griffin and Ford’s model (1980) then the Medinah Roads alignment can be described as the main spine with the elite housing in its vicinity while the urban fabric along Mekkah Road can be regarded as the disamenity zone expanding form the centre to the edge of the city. The Seaport and industries in the south also constitute an economic pole with the kind of workshops and warehouses attracted to those (see the second chapter, Figure 2.3).

In the absence of a clear CBD, it could be concluded that the main centre of Jeddah is towards the north of the historic core (see density-diversity analysis, Figure 4.7) while the historic core and its immediate spontaneous settlements are acting as a kind of central informal market. This was also generalized by the Griffin and Ford model reviewed in the second chapter. The element of
Peripheral squatter settlements can also be identified as the outer spontaneous settlements in Jeddah. As will be shown later on these outer spontaneous settlements there exists a worse condition in terms of infrastructure and physical urban fabric compared to the inner ones that match the underlying pre-industrial urban structure of Griffin and Ford model while the most affluent housing is to be found in the very north of Jeddah again similar to the elite sector in Griffin and Ford’s model.

The dual structure of Jeddah (i.e. poor versus reach) as quoted from Daghestani (1993) can be traced back to the intrinsic attractiveness of flat seaside lands in the north that resulted in more official and private investment such as the airport. The less attractive lands in the south and east then attracted industries and less well-off housing and created the ‘disamenity zones’ (Ford, 1996) that also remained less serviced and received less infrastructure mainly due to the informal nature of their development. As a result, the land and property value in the south and east is lower compared to the north (LLL, 2009). This suggests that the clustering of the poor citizens in the south and south-east of Jeddah is a reflection for their preference for more affordable shelter.

A point should be made about the Mekkah Road alignment. Although there is a clustering of spontaneous settlements along this road, the road itself is a major regional connection with a high intensity of commerce alongside it although not as expensive as their north Jeddah counterparts. This also can highlight the preference of the dwellers of those south-eastern spontaneous settlements for higher geographic accessibility and the economic advantages of it (e.g. easily reaching the inner city and the central areas) while settling on hilly and less favourable lands. Nonetheless, the fulfilment of such economic and residential preferences of spontaneous settlements should have resulted in various degrees of consolidation amongst those. The next section an attempt is made to establish the consolidation ratios through focusing on the characteristics of spontaneous settlements in a more detailed local level.
The spontaneous settlement characteristics

After addressing the location of spontaneous settlements and understanding their overall socio-economic condition through literature, this section will deal with their local attributes mainly their consolidation ratios. As was argued in the previous chapter, the best indicator of consolidation ratio for Zahedan settlements—as also the literature review of the second chapter suggested—was the strength of local centres measured through density-diversity of land uses with short band-widths (i.e. 200 meters).

The same method developed for Zahedan will be used here and then the estimated consolidation ratios will be checked against other indicators of consolidation such as space per dweller, age and built-fabric quality. It should be reminded that although there have been 50 spontaneous settlements reported to exist in Jeddah but the availability of building footprint data will exclude 14 of the outer settlements from the analyses done in this chapter. Before measuring consolidation ratio a crucial point should be made about the growth process of Jeddah spontaneous settlements, its diverse resultant uneven built-up density and irregular land use patterns along with its implications for the measurement.

The growth pattern of settlements and reflection in built-densities

The density of urban fabric around the spontaneous settlements of Jeddah reveals an intuitively predictable trend. The outer settlements (or the younger ones) have less urban fabric in their surrounding as is shown in the correlation below. This can be even supported by qualitative browsing of the map but the correlation reported also help with understanding this trend. The correlation (Figure 4.8) compares the distance from the historic core in logarithmic scale.
against the outside to inside ratio of urban footprints for 36 spontaneous settlements with complete building data.

Figure 4.8 - Regression analysis between the ratio of built-up area outside the settlement to the inside area (dependent variable) and distance to the historic core (independent variable).

This analysis also puts forward the idea that the inner-city central settlements should have gone through the process of densification as a result of bounding forces around them, while the outer settlements present a sprawling growth pattern due to land availability. This claim will be further examined in the
upcoming section on built-up density but a quantitative proof is the significant correlation between the building footprint density within the settlements (i.e. total area of footprints to the area of settlement’s boundary) and the distance to historic core of Jeddah (Rsquare of 0.584 and p<0.001). The difference between the central and peripheral settlements in terms of density can also be observed through Figure 4.9 that shows a more dispersed pattern for the sample from the peripheral area compared to the example from the central spontaneous settlement with more pronounced irregularity of street grid and urban block shapes.

![Figure 4.9 - Building footprints in the peripheral spontaneous settlement of ‘Kilo 14’ (left) and the central settlement of ‘Sahifah’ (right).](image)

Similar to Zahedan, the resulted urban fabric from the unplanned growth of spontaneous settlements can be described as irregular in different terms. As pointed out by ZFP (2006, Page 4) some of these aspects of irregularities can be attributed to the “narrow, winding, unpaved… streets” while the “lack of building regulations” and “mixed land uses, especially residential, commercial, warehouses and industrial [uses]” are mentioned as some of the characteristics of spontaneous settlements in Jeddah.
Regarding the issue of mixed land use as a part of the above description of irregularity, the study supports the prevalence of the aforementioned mix (see Table 4.3). However, I would like to add that with regard to the lack of public buildings such as health facilities or education facilities in the spontaneous settlements, the main contributor to the increase of land use diversity is the commercial activity, knowing that this category itself includes a myriad of subcategories ranging from small grocery shops to daily markets that offer wide range of products.

Another considerable aspect of irregularity not directly addressed by ZFP (2006) is the issue of high built-up density or the very uneven density pattern in the spontaneous settlements\textsuperscript{83}. As reviewed in chapter two, the higher built-up density areas are more likely to be the older parts of a spontaneous settlement where proximity to certain elements (e.g. transport arteries/nodes, infrastructure access or major land uses) have attracted the first dwellers to construct their houses. The variation of built-up density, however, can be examined in parallel with land use to see where the local centres of a settlement are located and how strong they are as a reflection of consolidation ratios. This is the subject of the next section.

**Consolidation of Jeddah spontaneous settlements**

The main requirement for performing the consolidation analysis and other measurements such as plot coverage ratio by building footprints is the availability of building footprint data for the whole settlement. In this way, the following settlements should be excluded from the analyses that are mostly on the edge of the data map. The main idea is to understand the relation between different factors related to the consolidation of the studied settlements. The

\textsuperscript{83} Jeddah Municipality (2009) points to the issue of overcrowding and high population density that will be reviewed in the last section of this chapter under the socio-economic aspects.
underlying hypothesis is that the strength of local centres (or average density-diversity with short band-width) can predict other factors indicative of consolidation mainly built-up area per dweller, plot coverage ratio and built-up quality. In addition, the two very powerful factors of settlement age and distance to the historic core will be compared with local centre strength in terms of their predictive power regarding the consolidation matters; this is to show that strength of local centres –if not better than age and distance to historic core- which can predict the consolidation aspects with an equal efficiency.

**Land use in the spontaneous settlements**

Comparing the land use summary for spontaneous settlements and the average for the whole Jeddah, one can argue that these areas (like the whole city) have a distinct residential function. However, the spontaneous settlements have a higher proportion of residential land plots as shown in Table 4.3. In terms of building footprint area also the highest surface for whole Jeddah is covered by residential category followed by the industrial buildings that is slightly different from the spontaneous settlements where residential buildings footprint area is followed by commercial ones in terms of total area.

Lack of public facilities and buildings (such as community, health or educational buildings) is reported by ZFP (2006), however, looking at Table 4.3, one might find out that in both footprint and land plot area of health and educational buildings, the spontaneous settlements are not worse than the average for the whole city. However, the quality of public buildings (and their offered services) in spontaneous settlements might be quite lower than the rest of the city but confirming this presumption requires further surveys. However, lack of public parks and recreational/cultural facilities could also be seen from Table 4.3 when the settlements are compared with the wider city.
Consolidation measurement and local centre strength

For measuring the strength of local centres the analysis visualized in Figure 4.4. The group of cells within the boundary of each settlement is selected and the aggregated statistical summary for density-diversity analyses with each respective band-width (i.e. 200m and 500m) is calculated for them. The result is illustrated in the Table 4.5.

<table>
<thead>
<tr>
<th>Settlement Name</th>
<th>Number of cells</th>
<th>Mean (Scaled D&amp;D 200m)</th>
<th>SD (Scaled D&amp;D 200m)</th>
<th>Distance from core</th>
<th>Settlement age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ba'яд</td>
<td>88</td>
<td>0.539</td>
<td>0.084</td>
<td>0.64</td>
<td>64</td>
</tr>
<tr>
<td>Hindawiyah</td>
<td>117</td>
<td>0.526</td>
<td>0.086</td>
<td>0.99</td>
<td>64</td>
</tr>
<tr>
<td>Sahifah</td>
<td>51</td>
<td>0.500</td>
<td>0.066</td>
<td>0.80</td>
<td>54</td>
</tr>
<tr>
<td>Jameah</td>
<td>322</td>
<td>0.486</td>
<td>0.066</td>
<td>6.59</td>
<td>44</td>
</tr>
<tr>
<td>Kandarah</td>
<td>100</td>
<td>0.480</td>
<td>0.077</td>
<td>1.61</td>
<td>54</td>
</tr>
<tr>
<td>Sabeel</td>
<td>53</td>
<td>0.466</td>
<td>0.105</td>
<td>1.25</td>
<td>54</td>
</tr>
<tr>
<td>Ghalil</td>
<td>122</td>
<td>0.455</td>
<td>0.105</td>
<td>3.50</td>
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</tr>
<tr>
<td>Betrumin</td>
<td>101</td>
<td>0.452</td>
<td>0.113</td>
<td>3.58</td>
<td>44</td>
</tr>
<tr>
<td>Sherafiyah</td>
<td>56</td>
<td>0.436</td>
<td>0.056</td>
<td>2.17</td>
<td>44</td>
</tr>
<tr>
<td>Madaen Alfahad</td>
<td>135</td>
<td>0.428</td>
<td>0.136</td>
<td>4.37</td>
<td>44</td>
</tr>
<tr>
<td>Moshrefah</td>
<td>69</td>
<td>0.424</td>
<td>0.066</td>
<td>5.73</td>
<td>32</td>
</tr>
<tr>
<td>Thahlbah</td>
<td>16</td>
<td>0.421</td>
<td>0.057</td>
<td>1.75</td>
<td>44</td>
</tr>
<tr>
<td>Amariyah</td>
<td>53</td>
<td>0.418</td>
<td>0.076</td>
<td>0.91</td>
<td>54</td>
</tr>
<tr>
<td>Ruwaïs</td>
<td>99</td>
<td>0.416</td>
<td>0.062</td>
<td>3.78</td>
<td>54</td>
</tr>
<tr>
<td>Qurriyath</td>
<td>33</td>
<td>0.410</td>
<td>0.082</td>
<td>2.30</td>
<td>44</td>
</tr>
<tr>
<td>Nuzlah</td>
<td>155</td>
<td>0.403</td>
<td>0.075</td>
<td>2.94</td>
<td>44</td>
</tr>
<tr>
<td>Thaghar</td>
<td>68</td>
<td>0.398</td>
<td>0.076</td>
<td>2.96</td>
<td>54</td>
</tr>
<tr>
<td>Rabwa</td>
<td>190</td>
<td>0.396</td>
<td>0.061</td>
<td>12.07</td>
<td>10</td>
</tr>
<tr>
<td>Banimalik</td>
<td>151</td>
<td>0.391</td>
<td>0.066</td>
<td>4.77</td>
<td>44</td>
</tr>
<tr>
<td>Aziziyyah</td>
<td>114</td>
<td>0.366</td>
<td>0.100</td>
<td>7.04</td>
<td>25</td>
</tr>
<tr>
<td>Rawabi</td>
<td>247</td>
<td>0.360</td>
<td>0.118</td>
<td>8.66</td>
<td>25</td>
</tr>
<tr>
<td>Baghdadiyah</td>
<td>106</td>
<td>0.360</td>
<td>0.089</td>
<td>1.18</td>
<td>44</td>
</tr>
<tr>
<td>Salimah</td>
<td>14</td>
<td>0.333</td>
<td>0.055</td>
<td>13.11</td>
<td>10</td>
</tr>
<tr>
<td>Montazohat</td>
<td>200</td>
<td>0.317</td>
<td>0.087</td>
<td>9.35</td>
<td>10</td>
</tr>
<tr>
<td>Quaizah</td>
<td>135</td>
<td>0.313</td>
<td>0.087</td>
<td>8.60</td>
<td>10</td>
</tr>
</tbody>
</table>
An initial comparison with the age of the settlement suggests a direct positive relation between the mean values for diversity-density in all three band-widths. The summary for correlation is presented in Table 4.6 below. This suggests that time (and its close proxy that is distance from the historic core) plays a major role in strengthening the centres of different band-widths.

However, the reader should remember that while the impact of longer range centres (the ones picked by 500m and 2500m band-widths) on the spontaneous settlements can originate from outside these areas, the effect of short range density-diversity measurement (i.e. in 200m) is strongly caused by the urban fabric of these areas themselves. As a result, in spite of the slightly stronger correlations for the longer band-widths presented in Table 4.6, the shorter range of 200 meters can be used as a more accurate indicator of consolidation of spontaneous settlements. Another inferable point from Table 4.6 is that ‘distance to the (historic) core’ as an independent variable is a better predictor of density-diversity measure compared to the ‘age’ which can be attributed to

<table>
<thead>
<tr>
<th>Settlement</th>
<th>Age (Years)</th>
<th>Density (0.001)</th>
<th>Diversity (0.001)</th>
<th>Correlation (r)</th>
<th>Significance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilo 11</td>
<td>70</td>
<td>0.300</td>
<td>0.086</td>
<td>10.53</td>
<td>10</td>
</tr>
<tr>
<td>Rohab</td>
<td>30</td>
<td>0.297</td>
<td>0.033</td>
<td>7.78</td>
<td>10</td>
</tr>
<tr>
<td>Kilo 14 South</td>
<td>143</td>
<td>0.261</td>
<td>0.094</td>
<td>13.59</td>
<td>10</td>
</tr>
<tr>
<td>Kilo 14 North</td>
<td>315</td>
<td>0.226</td>
<td>0.108</td>
<td>13.25</td>
<td>10</td>
</tr>
<tr>
<td>Nozhah</td>
<td>69</td>
<td>0.225</td>
<td>0.086</td>
<td>14.73</td>
<td>10</td>
</tr>
<tr>
<td>Khomnah_Sour</td>
<td>20</td>
<td>0.183</td>
<td>0.057</td>
<td>11.00</td>
<td>10</td>
</tr>
<tr>
<td>Kilo 16</td>
<td>30</td>
<td>0.182</td>
<td>0.054</td>
<td>15.28</td>
<td>10</td>
</tr>
<tr>
<td>Baryman</td>
<td>218</td>
<td>0.163</td>
<td>0.062</td>
<td>16.58</td>
<td>10</td>
</tr>
<tr>
<td>Kilo 15</td>
<td>21</td>
<td>0.148</td>
<td>0.034</td>
<td>14.85</td>
<td>10</td>
</tr>
<tr>
<td>Khomnah</td>
<td>30</td>
<td>0.122</td>
<td>0.048</td>
<td>12.88</td>
<td>10</td>
</tr>
<tr>
<td>Thahakebah</td>
<td>19</td>
<td>0.090</td>
<td>0.031</td>
<td>16.91</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 4.5 - The Density-Diversity statistical summary for each spontaneous settlement with band-widths of 200 (cell size 100m*100m) that is scaled between zero and one. The list is sorted according to the Mean column as a direct indicator of consolidation ratio.
the finer grading of the former, while for the latter most of the settlements falling within the same growth boundary of the city (Figure 4.3) are estimated to have the same age. At this point, the question then goes to the main factor that causes density-diversity increase in the majorly residential fabric of these areas.

<table>
<thead>
<tr>
<th></th>
<th>Mean (Scaled D&amp;D 200m)</th>
<th>Mean (Scaled D&amp;D 500m)</th>
<th>Mean (Scaled D&amp;D 2500m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settlements’ age</td>
<td>0.712</td>
<td>0.781</td>
<td>0.767</td>
</tr>
<tr>
<td>Distance to the core</td>
<td>0.762</td>
<td>0.789</td>
<td>0.821</td>
</tr>
</tbody>
</table>

Table 4.6 - Correlation measurement between two groups of variable related to the 36 Jeddah spontaneous settlements. Rsquare values for simple linear regression are presented in the table cells (p<0.0001 for all).

**Commercial land in spontaneous settlements**

As mentioned earlier, the second major land use in the spontaneous settlements (in terms of total building footprint area) is the commercial activity that ranks after residential centres. It should be recalled that the size of the commercial building footprint in the spontaneous settlements is about the 0.7 of an average for the whole city (Table 4.4). This is again an indicator of the informal nature of commercial activities in the spontaneous settlements. Confirming this interpretation, Happold (2007) reports that the most prominent economic activities in spontaneous settlements of Jeddah are in turn service provision, food industry and retail where most of the workers are low skill foreigners.

A brief look at the land use distribution in spontaneous settlements of Jeddah also suggests that the commercial buildings can be found in 35 out of the 36 areas with available building footprint data. Regarding the distribution of commercial activities in spontaneous settlements a variety of patterns exist ranging from major concentration of shops on the outward edges (like in
Thaghar area) to the very clustering on the internal parts (e.g. Kilo 11) or a combination of both (Jameah). However, the overall ratio of commercial building footprints in term of their count, seems to correlate slightly with the distance to the historic core for the settlements (Rsquare of 0.43 and p<0.0001 for 35 settlements). This goes in line with intuition that the central and older settlements are more likely to accommodate larger number of commercial buildings.

The intensity of commercial activity in the overwhelmingly residential context, as discussed before, is a major contributor to the strength of local centres and an indicator of settlements’ consolidation ratio. At this point one might ask why just the overall commercial ratio of a settlement is not taken as an indicator of consolidation. The answer lies in the distribution of commercial activities as the distribution of shops on the outward edges of an area does not necessarily lead to the formation of local centres. On the contrary, such formation requires the clustering of shops in the internal parts of a settlement that will be further addressed in the next chapter while showing the capacity of outward edges to accommodate shops falls as a settlement grows larger and the perimeter to area ratio for it falls with an exponential rate. The next section will look into the aspects of land use that was considered as an indicator of physical and spatial poverty i.e. lack of public buildings and facilities.

**Availability of public infrastructure per dweller**

The calculation for measuring the availability of the three main categories of public infrastructure in this section is done in the same way as for Zahedan. The results are depicted in Table 4.7 below. The last column in the same table sums up the total area of public infrastructure per head of dweller for the 36 studied spontaneous settlements.
<table>
<thead>
<tr>
<th>Spontaneous settlement</th>
<th>Educ(sqm)/head</th>
<th>Health(sqm)/head</th>
<th>Cultur-Rec(sqm)/head</th>
<th>Total public facility (sqm)/head</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilo16</td>
<td>5.76</td>
<td>0.00</td>
<td>0.00</td>
<td>5.76</td>
</tr>
<tr>
<td>Amariyah</td>
<td>2.33</td>
<td>0.18</td>
<td>0.18</td>
<td>2.68</td>
</tr>
<tr>
<td>Baryman</td>
<td>2.43</td>
<td>0.05</td>
<td>0.05</td>
<td>2.53</td>
</tr>
<tr>
<td>Madaen Alfahad</td>
<td>1.29</td>
<td>0.31</td>
<td>0.31</td>
<td>1.92</td>
</tr>
<tr>
<td>Baghdadiyeh</td>
<td>1.12</td>
<td>0.10</td>
<td>0.10</td>
<td>1.32</td>
</tr>
<tr>
<td>Nuzah</td>
<td>1.01</td>
<td>0.06</td>
<td>0.06</td>
<td>1.14</td>
</tr>
<tr>
<td>Kandah</td>
<td>0.94</td>
<td>0.06</td>
<td>0.06</td>
<td>1.07</td>
</tr>
<tr>
<td>Khomrah Thahalbah</td>
<td>1.02</td>
<td>0.00</td>
<td>0.00</td>
<td>1.02</td>
</tr>
<tr>
<td>Banima lik</td>
<td>0.94</td>
<td>0.03</td>
<td>0.03</td>
<td>1.01</td>
</tr>
<tr>
<td>Ruwa is</td>
<td>0.93</td>
<td>0.03</td>
<td>0.03</td>
<td>0.98</td>
</tr>
<tr>
<td>Kilo14 South</td>
<td>0.95</td>
<td>0.00</td>
<td>0.00</td>
<td>0.95</td>
</tr>
<tr>
<td>Kilo14 North</td>
<td>0.75</td>
<td>0.05</td>
<td>0.05</td>
<td>0.84</td>
</tr>
<tr>
<td>Rawabi</td>
<td>0.47</td>
<td>0.02</td>
<td>0.02</td>
<td>0.51</td>
</tr>
<tr>
<td>Jameah</td>
<td>0.33</td>
<td>0.09</td>
<td>0.09</td>
<td>0.50</td>
</tr>
<tr>
<td>Kilo 11</td>
<td>0.45</td>
<td>0.02</td>
<td>0.02</td>
<td>0.49</td>
</tr>
<tr>
<td>Montazohat</td>
<td>0.46</td>
<td>0.01</td>
<td>0.01</td>
<td>0.48</td>
</tr>
<tr>
<td>Betrumin</td>
<td>0.29</td>
<td>0.09</td>
<td>0.09</td>
<td>0.48</td>
</tr>
<tr>
<td>Hindawiyah</td>
<td>0.32</td>
<td>0.01</td>
<td>0.01</td>
<td>0.35</td>
</tr>
<tr>
<td>Aziziyah</td>
<td>0.26</td>
<td>0.03</td>
<td>0.03</td>
<td>0.32</td>
</tr>
<tr>
<td>Sabeel</td>
<td>0.31</td>
<td>0.01</td>
<td>0.01</td>
<td>0.32</td>
</tr>
<tr>
<td>Ghaliil</td>
<td>0.25</td>
<td>0.02</td>
<td>0.02</td>
<td>0.28</td>
</tr>
<tr>
<td>Sherafiyah</td>
<td>0.17</td>
<td>0.01</td>
<td>0.01</td>
<td>0.20</td>
</tr>
<tr>
<td>Thaghar</td>
<td>0.17</td>
<td>0.00</td>
<td>0.00</td>
<td>0.17</td>
</tr>
<tr>
<td>Qurriyath</td>
<td>0.00</td>
<td>0.05</td>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>Rabwa</td>
<td>0.05</td>
<td>0.00</td>
<td>0.00</td>
<td>0.05</td>
</tr>
<tr>
<td>Balad</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Quaizah</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Sahifah</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Moshefah</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Thahlbah</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Sakmah</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Rohab</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Nozhah</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Khomrah Sorur</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Kilo15</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Kilo18_North</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 4.7 - Public land use per dweller in the 36 spontaneous settlements of Jeddah with available footprint data.

Moreover, a simple regression analysis shows that there is no correlation between the total public infrastructure per head and any of the three variables (i.e. distance to the historic core, settlement age and strength of local core). This can be attributed to the influence of official decisions to invest certain area or the fact that some of the public buildings were built before the formation of its surrounding spontaneous settlement or regardless of it. An example is ‘Kilo 16’ area that is small but has large plots of educational land which is definitely more than what is required for its dwellers and are operating in a range beyond the settlement.

Density issues: Space per dweller and plot coverage

While the population for each settlement is available from ZFP (2006), the total residential building footprints in the 36 spontaneous settlements can be calculated using GIS software. Dividing the latter to the former can give the measure of residential building footprint area per dweller as a socio-economic indicator (as was discussed in the previous chapter).

Looking through the above table, one can argue that there is an inverse trend between the distance to the historic core and the residential footprint per dweller. The regression analysis between the mentioned two variables for the 36 settlements results in Rsquare of 0.60 (p<0.001). This means the further the settlement, the more residential space can be afforded by dwellers. This seems opposite to the case of Zahedan but it can be explained by the wider spread of
settlements in Jeddah compared to Zahedan in the context of probable sharp contrast between the valuable central and cheap peripheral lands in Jeddah. Moreover, this observation is in line with the aforementioned mechanism through which the poor people make the central land affordable (chapter 2). This issue will be further explained towards the end of this chapter when the differences between the two studied cities are summarized.

The regression analysis between residential building footprint per dweller and local core strength also results in slightly weaker correlation of 0.50 ($p<0.001$) that suggests the more consolidated settlements in the inner zones of Jeddah offer less residential space to their dwellers mainly because of the higher land value attributed to their advantageous locations.

Regarding the measure of built-up density i.e. plot coverage ratio by building footprints, again the calculation is done for the 36 spontaneous settlements and the results along with some other factors were also included in Table 4.8. Correlating plot coverage ratio with the three variables of settlements age, distance to the historic core and the local core strength results in Rsquares of 0.54 ($p<0.001$), 0.65 ($p<0.001$) and 0.86 ($p<0.001$) respectively for the 36 spontaneous settlements. This suggests that the consolidation measure of local core strength calculated through averaging density-diversity with short band-width (200 meters) can explain the built-up density better than other factors.

<table>
<thead>
<tr>
<th>Spontaneous settlement</th>
<th>Pop 2006</th>
<th>Age</th>
<th>Total resi. footprint (sqm)</th>
<th>Plot coverage ratio</th>
<th>Resi Footprint per person (sqm)</th>
<th>Avg. built-up quality</th>
<th>Distance to core (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balad</td>
<td>50,715</td>
<td>64</td>
<td>227,829.0</td>
<td>0.910</td>
<td>4.5</td>
<td>2.43</td>
<td>0.6</td>
</tr>
<tr>
<td>Sahifah</td>
<td>22,988</td>
<td>54</td>
<td>101,357.2</td>
<td>0.893</td>
<td>4.4</td>
<td>2.32</td>
<td>0.8</td>
</tr>
<tr>
<td>Amariyah</td>
<td>11,579</td>
<td>54</td>
<td>82,966.5</td>
<td>0.714</td>
<td>7.2</td>
<td>1.96</td>
<td>0.9</td>
</tr>
<tr>
<td>Hindawiyah</td>
<td>44,385</td>
<td>64</td>
<td>347,423.5</td>
<td>0.846</td>
<td>7.8</td>
<td>2.37</td>
<td>1.0</td>
</tr>
<tr>
<td>Baghdadiyah</td>
<td>19,390</td>
<td>44</td>
<td>169,432.7</td>
<td>0.656</td>
<td>8.7</td>
<td>1.72</td>
<td>1.2</td>
</tr>
<tr>
<td>Sabeel</td>
<td>23,974</td>
<td>54</td>
<td>173,329.6</td>
<td>0.829</td>
<td>7.2</td>
<td>2.65</td>
<td>1.2</td>
</tr>
<tr>
<td>Settlement</td>
<td>Population</td>
<td>People/SqM</td>
<td>Footprint Area (SqM)</td>
<td>Building Footprint Area (SqM)</td>
<td>Coverage Ratio</td>
<td>Building Area Density</td>
<td>Urban Land Use Density</td>
</tr>
<tr>
<td>--------------</td>
<td>------------</td>
<td>------------</td>
<td>----------------------</td>
<td>-------------------------------</td>
<td>---------------</td>
<td>-----------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Kandarah</td>
<td>29,973</td>
<td>44</td>
<td>253,132.0</td>
<td>121,971.9</td>
<td>0.821</td>
<td>1.9</td>
<td>1.6</td>
</tr>
<tr>
<td>Thahlbah</td>
<td>10,745</td>
<td>44</td>
<td>33,001.5</td>
<td>16,290.1</td>
<td>0.642</td>
<td>2.4</td>
<td>1.8</td>
</tr>
<tr>
<td>Sherafiyah</td>
<td>19,235</td>
<td>44</td>
<td>186,726.3</td>
<td>93,363.2</td>
<td>0.843</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Qurriyah</td>
<td>10,850</td>
<td>44</td>
<td>112,971.9</td>
<td>56,495.9</td>
<td>0.851</td>
<td>1.9</td>
<td>2.3</td>
</tr>
<tr>
<td>Nuzlah</td>
<td>49,210</td>
<td>44</td>
<td>493,479.5</td>
<td>246,240.7</td>
<td>0.761</td>
<td>1.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Thaghar</td>
<td>16,674</td>
<td>54</td>
<td>206,390.1</td>
<td>103,195.0</td>
<td>0.697</td>
<td>2.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Ghalil</td>
<td>39,785</td>
<td>44</td>
<td>355,844.8</td>
<td>177,922.4</td>
<td>0.727</td>
<td>2.2</td>
<td>3.6</td>
</tr>
<tr>
<td>Betrumin</td>
<td>30,044</td>
<td>44</td>
<td>306,479.9</td>
<td>153,240.0</td>
<td>0.813</td>
<td>2.0</td>
<td>3.8</td>
</tr>
<tr>
<td>Madaen Alfahad</td>
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<td>44</td>
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<td>194,093.5</td>
<td>0.689</td>
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<td>374,929.2</td>
<td>187,465.0</td>
<td>0.701</td>
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<td>0.820</td>
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<td>621,852.4</td>
<td>0.370</td>
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<td>174,931.3</td>
<td>0.757</td>
<td>2.0</td>
<td>7.0</td>
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<td>69,769.8</td>
<td>34,884.9</td>
<td>0.656</td>
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<td>10</td>
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<td>224,234.1</td>
<td>112,117.1</td>
<td>0.705</td>
<td>1.9</td>
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<td>Khomrah Sorur</td>
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<td>323,261.4</td>
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<td>71,278.5</td>
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</tr>
<tr>
<td>Kilo15</td>
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<td>18,327.6</td>
<td>9,163.8</td>
<td>0.300</td>
<td>36.4</td>
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<td>49,536.1</td>
<td>24,768.1</td>
<td>0.370</td>
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<td>14,364.0</td>
<td>0.457</td>
<td>16.4</td>
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Table 4.8 - Residential building footprint area per person and plot coverage ratio (i.e. the total area of building footprint divided by total are of a defined land plots) for the 36 Jeddah spontaneous settlements.
Construction quality and consolidation

The issue of building construction was surveyed for the spontaneous settlements of Jeddah under the title of ‘building condition’ and was recorded for each land plot in GIS format (ZFP, 2006). In this survey the building condition was ranked qualitatively in 4 degrees that are ‘good’, ‘fair’ ‘bad’ and ‘very bad’.

For calculating the average building quality, the values of 4,3,2 and 1 were assigned to each respective category from ‘good’ to ‘very bad’ and then the value of each plot was multiplied by the built-up area within that plot to gain the quality-by-area for that plot. After summing up the quality-by-area, the value for the plots of each settlement was divided by the total built-up area of that settlement to gain the average built-up quality for that settlement. The results are illustrated in Table 4.8.

Statistical regression analysis between average building quality and local centre strength for the Jeddah settlements does not show any significant results (Rsquare of 0.00) while distance to historic core and settlements age show no correlation with building quality (Rsquares of 0.01 and 0.00 respectively). Despite this, visual inspection of built-up quality Kernel maps show coincidence of higher quality built-up areas with stronger local centres within spontaneous settlements. Two examples of such overlapping are shown in Figure 4.10 and 4.11 below. The upper images in both figures represent the average built-up quality for the spontaneous settlements ranging from bright purple (‘good’ quality) to black (‘very bad’) with Kernel band-width of 200 metres. The lower images in both figures also show the local core strength (diversity-density with band-width of 200 meters).
Figure 4.10 - Average built-up quality with kernel band-width of 200 meters with brighter colours indicating better quality urban fabric (upper tile) and local density-diversity measure with band-width of 200 meters (lower tile) showing the central spontaneous settlements.

As can be observed in both cases of central spontaneous settlements (Figure 4.10) and the peripheral areas of Kilo 14 (Figure 4.11), there is a visual correspondence between the built-up quality map and the local centre strength. The reason this correspondence cannot be captured with simple summarizing methods such as averaging the value of cells for each settlement might be related to the spatial and statistical distribution of values but it suffices to conclude that local centres strength (or diversity-density with 200m band...
width) can explain the built-up quality better than other two major factors of settlement age and distance to the historic core as it corresponds with variations within each settlement.

Figure 4.11 - Average built-up quality with kernel band-width of 200 (upper tile) and local density-diversity measure with band-width of 200 meters (lower tile) showing the peripheral spontaneous areas of Kilo 14 north and Kilo 14 south.
The socio-economic characters of Jeddah spontaneous settlements

Unlike Zahedan, there is no socio-economic data in a spatial format available for Jeddah. However, there are different reports indicating the deprived condition of these areas in different aspects such as crime, unemployment and other social pathologies (ZFP, 2006; Jeddah Municipality, 2009). The most comprehensive research on the socio-economic issues of spontaneous settlements in Jeddah until the time of this writing was conducted by Happold Consultants (Happold, 2007) that was done on 8 areas\(^\text{84}\). The findings of this report can be summarized as:

- The higher proportion of foreign workers and the their illegal situation, the lower level of education
- The insufficient infrastructure especially water supply network and low road capacity
- The unattractive condition of spontaneous settlements to businesses because of poor amenities and poor purchasing power of dwellers

According to the aforementioned survey on 8 spontaneous settlements by Happold (2007), the main reason for the lack of willingness to pay for the improvement of spontaneous settlements of Jeddah is the fact that most of the dwellers are expatriates who send large proportion of their income to their place of origin outside Jeddah.

In terms of employment, according to the same report (Ibid.), there are four major sectors in the studied spontaneous settlements which are ranked as follows: services (half of the employment) beverage and food (about one third of employment), retail and intermediate products (the rest). Moreover,

\(^{84}\text{The areas include: Aziziyah, Dhahban, Ghalil, Kilo 14 (north), Montazohat, Ruwais, Sahifah and Thaghar (Ibid.)}\)
according to a survey conducted by Jeddah Municipality (2009) the gain from these rather casual works is not enough to cover the living costs.

The other issue addressed by Happold (2007) is the young age mix of population in spontaneous settlements. In a wider sense, Jeddah also accommodates a young population (Jeddah Municipality, 2009) as more than half of the whole population are under 19 years old (Ibid. page 27) that requires enough provision of educational facilities.

The issue of crime is also studied by Happold (2007) indicating that although spontaneous settlements (or ‘slums’) of Jeddah are usually related to generation of criminal activity, their dwellers are usually the victims of crime themselves and support more security. Although the surveys done by the previous report (Ibid.) is based on a questionnaire distributed among the dwellers of the 8 studied areas –as the report indicates- it is not compared to the planned areas of the city.
Conclusion for chapters 3 and 4

In the last two chapters, the two respective cities of Zahedan and Jeddah with their spontaneous settlements were introduced. Although both cities have started to experience modern urbanization since 1940s in their respective oil-rich countries, the higher national and regional importance of Jeddah has resulted in a much faster growth compared to Zahedan while both cities are major provincial centres in their context.

The generalized models of both cities (adopted from Griffin and Ford) then could reflect their overall structure considering that the smaller size of Zahedan makes it a special case of Third World city in its initial growth stage. Both cases exhibit a dual pattern in terms of socio-economic issues by having poor versus better-off areas with spontaneous settlements representing –mostly- the deprived side. The socio-economic and physical deprivation of spontaneous settlements was confirmed for both cities according to the existing studies. In Zahedan the spontaneous settlements appeared as a peripheral ring (or the ‘peripheral squatter settlements’ as Griffin and Ford (2009) generalise while in Jeddah they are located in a wider centre-to-edge spread with major concentration along Mekkah Road similar to a wedge in Griffin and Ford model. The choice of the area that accommodates the better-off official and public land uses seems to be rooted in the initial quality of land and the resultant planning decisions: in both cases with less favourable and hilly areas left for spontaneous settlements.

Spontaneous settlements in both cities seem to follow the overall centrifuging growth pattern of their host city with higher built-up density in old central parts. Because Jeddah has had a much faster expansion pace, its peripheral spontaneous settlements are contrasted with the central areas in having a much sparser urban fabric. This again shows that time and the resulted city-wide location of spontaneous settlements play a major role in physical densification.
of settlements as a sign of consolidation in Jeddah. In Zahedan, although the geographical spread is just limited to the periphery, again time seems to be able to explain the built-up density ratios with older settlements having a denser fabric as an aspect of consolidation.

Another major issue resulted from the different sizes of Jeddah and Zahedan is the spread of urban major centres (spotted by density-diversity analyses). While Zahedan shows a single and integrated core in 500 meters range (or the ‘medium’ range), Jeddah has various centres stretched along its major arteries of Mekkah and Madinah Roads. Based on this observation it is also evident that while spontaneous settlements in Zahedan are located as close as possible to the local and mid-range centres, while in Jeddah they show a variety of situations: the older settlements (close to the historic core) actually constitute powerful centres themselves that is in contrast with the –usually–weak centre formation in the peripheral areas.

This suggests that in Jeddah, the larger size of the city results in a more diverse range of strengths in local and mid-range centres. Because most of these centres are parts of the spontaneous settlements, a higher ratio of density-diversity ratios in older districts indicates a higher consolidation ratio for the central spontaneous settlements. It should be emphasized that time seems to play a major role as an underlying factor as local core strength seems to increase further for older settlements in both cities but as was shown for Zahedan (in the case of ‘Shirabad’ area) or for Jeddah (e.g. for ‘Rabwa’ spontaneous settlement) there are relatively young areas that has developed strong local centres (i.e. become consolidated).

From the study of the two cities it can be hypothesized that the dwellers of spontaneous settlement would prefer two main issues in locating their neighbourhood:
- First is the availability of cheap or unattractive land but preferably close to main transport arteries that reflects an economic preference of the dwellers. This is to be followed by the high density clustering of built fabric with overwhelmingly residential land use with narrow and irregular roads that makes spontaneous settlements distinct from its urban surrounding and defines it as an isolated territory with less supervision from the outside city.

- Second is the prevalence of commercial activity in the spontaneous settlements on both edges and internal areas that reflects the economic preference of their dwellers. However, the formation of local centres (as hot spots of density-diversity) as an indicator if consolidation seems to depend on the clustering of commercial activities within the settlement rather than on the edges (will be illustrated hypothetically in the next chapter).

Now the question would be if the accessibility of street network in spontaneous settlements reflects the above preferences. Is the accessibility of internal areas low to fulfil the territorial preference of a residential neighbourhood? Then how would the clusters of commercial activity accessed from outside the settlement to function effectively? In other words, the next chapter will see if the dual (and to some degree contradictory) residential and commercial functions of spontaneous settlements is arranged by the underlying factor of spatial accessibility.
Chapter 5: Accessibility analysis of the case study spontaneous settlements

Introduction

The chapter aims at investigating the effect of accessibility on the emergence of local centres in the introduced case study spontaneous settlements of Zahedan and Jeddah. The two previous chapters showed that the case study spontaneous settlements exhibit various degrees of consolidation reflected in the strength of their local centres identifiable with high mean value of density-diversity measure for each settlement. Because the settlements with higher density-diversity were shown to have overcome their poverty in both physical and non-physical terms, it was suggested that the formation of local centres is an indicator of consolidation.

Regarding the consolidation ratios, the underlying factor of time was shown to play a considerable role in strengthening the local centres (or consolidation) but there is a question about the areas with more or less same age that exhibits various degrees of consolidation. In other words, the settlement age does not seem to be reasonable enough in explaining why some of these centres are stronger and some of those are weaker despite having almost the same age especially in Jeddah (Figure 5.1). For Zahedan the question would be if there is any other factor that can predict consolidation ratio better than time.

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85 Comparing Figure 5.1 with Table 4.5 in the previous chapter show there are several settlements in Jeddah with age 10 but a variety of consolidation ratios.

86 As was shown in chapter three, correlation between age and mean density-diversity for 6 groups of Zahedan spontaneous settlements results in Rsquare of 0.661 (p=0.0491).
Figure 5.1 - The consolidation of 36 case study spontaneous settlements of Jeddah (vertical axes in both graphs) plotted against their age in years (left graph, horizontal axe) and their distance to centre in kilometres (right graph, horizontal axe). The settlements of age 10 are highlighted in both graphs.

As illustrated in the third and fourth chapters, since the main land use that constitutes the local centres in the homogenous residential context of spontaneous settlements is commercial activity then the question is about the spatial logic behind the distribution of commercial buildings as the main contributor to the formation of centres. Is there any reason why commercial
land use appears with higher linear intensity in the inner area of some settlements especially around their local centres?

Assuming that commercial land use by default is preferred to be in higher accessibility locations according to the reviewed classical urban models such as bid-rent theory (and other theories such ‘movement economy’ that will be explained in this chapter), then the answer should be sought through looking at the accessibility of commercial land use. A review of the conventional concept of accessibility (or ‘geographic’) suggests that this concept has shortcoming in explaining the commercial land use location within the spontaneous settlements especially the observed linear arrangement of shops (reported in chapters 3 and 4) so the topologic notion of accessibility will be introduced to overcome this problem. The topologic concept or ‘geometric accessibility’ calculates the street accessibility of an urban settlement with regards to its simultaneous relation with all other streets in the urban system or their ‘configuration’.

Using the topologic approach to accessibility in this thesis developed in the field of space syntax (see Hillier and Hanson, 1984) has another advantage because it hypothetically predicts the emergence of an internal spatial structure-a set of connected streets that are more accessible compared to their adjacent routes- within the large human settlements that is termed ‘deformed wheel pattern’ (Hillier, 2001). Such structure attracts the commercial land uses around its main spines in a linear arrangement and can explain why one might find local centres mainly comprised of commercial activities deep in the internal fabric of spontaneous settlements.

It should be stressed that the impact of commercial land use on consolidation of informal settlements has been reported by Hillier and others (2000). In other words, the efficient placement if commercial activities on more accessible routes on the outward edges of small informal settlements in Santiago is
reported to increase their benefit from higher movement flows and hence contributes significantly to the socio-economic and physical improvement of their dwellers.

The thesis would built upon the above idea (i.e. the impact of commercial land use on consolidation) but argues that the aforementioned Santiago research was conducted for small settlements in which no highly accessible route passes through each settlement and hence the most advantageous location for shops was on the outward edges of the settlement. Instead, the chapter suggests that for larger spontaneous settlements, because there is a possibility for internally accessible routes (or the mentioned internal spatial structure) then there the commercial land use clustering within the settlements should be possible that is turn strengthen the local centres and hence consolidation\textsuperscript{87}.

The underlying theoretical relation between consolidation and commercial land use should be clarified here: while strong local centres (mainly comprised of commercial land use in the inner parts of spontaneous settlements) are indicators of consolidation, the commercial land use itself is reported to be the main facilitator of consolidation as reviewed Santiago research (Hillier et al., 2000). The more accessible the commercial land use, the more contribution to consolidation it makes according to the same source. It can be then induced that the more accessible internal areas increases the contribution of commercial land use and hence increases the consolidation ratio.

\textsuperscript{87} This hypothesis can be supported through the reviewed claim by UNCHS (2003a) that internal markets can provide large spontaneous settlements with socio-economic advantages in terms of job and service provision which in turn –the thesis infer- can facilitate consolidation. The issue of settlement size was already discussed in the second chapter.
The hypothesis

This chapter therefore has a core hypothesis: spontaneous settlements with more accessible internal street structure should have stronger local centres (i.e. are more consolidated). Proving the main hypothesis requires two separate stages then. Firstly it should be shown that the emerging internal street structure within the spontaneous settlements does exist and has an impact on the denser distribution of commercial land use. The higher concentration of commercial land use on the more accessible parts of the internal spatial structure can be expressed as ‘efficient’ distribution that is the opposite of a random or equal distribution. The second part of the hypothesis should investigate that –although the spontaneous settlements tend to be generally less accessible from a city-wide level- the higher accessibility of their internal spatial structure in medium or meso-level would results in more consolidation. This is especially important for settlements with same age in Jeddah with various consolidation ratios.

Outline

The chapter consists of two interrelated parts. The first part will review the notion of accessibility mainly in relation with poverty and spontaneous settlements. The notion of geometric accessibility, its methodology and analytical techniques will be introduced along with the more advanced and fine-scale definition of topo-geometric accessibility (see below) and its relevant method of segment angular analysis. The theoretical review will hypothesize that a non-small spontaneous settlement should develop an

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88 Defining what constitutes the city-wide accessibility as opposed to local level and also the in-between level of ‘meso’ is dependent on the metric radii used for the accessibility calculation. This will be further explained in the upcoming section ‘Space syntax and geometric accessibility in urban studies’.
internal street structure that attracts and organizes the commercial activities within the settlement leading to the emergence of local centres.

The second part will investigate the above hypothesis for the case study spontaneous settlements of Jeddah and Zahedan. After studying the overall accessibility of the case study cities and examining the major zones and corridors (see schematic models in third and fourth chapters) including the spontaneous settlements, the settlements themselves would be looked at within their wider urban context in terms of accessibility. While I will show that these areas are overall less accessible from the formal city in line with their overall residential function (and the territorial preference of their dwellers) in the next stage, the accessibility of their internal streets will be examined. I will also show that the internal spatial structure is observable within most of the studied spontaneous settlements along with its impact on the distribution of commercial land use. Moreover, I will show that despite the low city-wide accessibility to the internal areas of spontaneous settlements, the medium or meso-level accessibility to these areas plays a considerable role in their consolidation that is stronger than the impact of time (or settlements’ age) when dealing with settlements of same age but different consolidation ratios. The chapter will end with some speculations on the preferences of spontaneous settlement dwellers in terms of accessibility and putting forward the idea that the observed pattern might be influenced by the irregularities of the urban fabric.

**Configurational measures of accessibility**

**The notion of accessibility**

This section will introduce the conventional notion of accessibility mainly used in geographical studies including transport and land use analyses (also called
‘geographic accessibility’, see below). It should be reminded that the idea of conventional accessibility was addressed in the second chapter regarding spontaneous settlements and question was posed using this notion. The main concern was if the conventional accessibility can explain the emergence of internal markets in spontaneous settlement especially its linear arrangement along the streets. Here some further explanation regarding the conventional notion of accessibility will be given to understand its shortcomings in the studies of spontaneous settlements especially regarding the location of commercial land use within these areas and its effect on consolidation. Because of this limited scope many applications of accessibility notion that are not relevant to such purpose will be briefly addressed and the reader will be referred to their sources. As will be shown the conventional notion of accessibility (most usually based on direct metric distance between origin and destinations) has some shortcomings in explaining issues pertaining to spontaneous settlements.

Because of these limitations the term accessibility will be reviewed in urban and regional studies (and their related fields such as transport or housing) although the term is widely used in other fields such as computing, telecommunication sciences and inclusive social policies regarding disability. The term accessibility in general means “capable of being reached” (Merriam-Webster Free Online Dictionary, 2011).

As mentioned in chapter 2, in urban and transportation studies the concept of accessibility generally involves the easiness of reaching activities -as destinations- from an origin point and considering specific transportation modes; the “ease” in this regard refers to lower travel time, lower expenses and more convenience (Torrens, 2000). Torrens then carries on with reviewing different mathematical definitions of accessibility that in their very basic essence take the form of: “... a function of opportunities in a destination zone and the cost of travel between an origin and that destination—accessibility as
a function of the attraction of the destination and the ease of reaching it.” (Ibid. Page 50).

A key element of this definition is the ‘cost’ that is reflected as the energy, time or distance for the travel. In cases where the distance is taken as the proxy for cost, in geographic studies, it is usually taken as a direct metric distance between points or the actual route length (e.g. the path that should be traversed through streets and alleys). However, as will be discussed in the due course and explaining the concept of geometric accessibility, there are other measures of distance that can underlie the formulations of accessibility in order to makes it closer to the empirical observations in the real cities.

In the context of residential neighbourhoods the concept of accessibility usually refers to the availability of amenities and public services, job opportunities or shops to a residential location (Barton, 1999). The main factor in this regard is the distance between those facilities and the residences which should be –for the convenience and ease of use- the walking distance from the origin residence (5 to 10 minutes). This concept of accessibility seems to underlie some of the studies of spontaneous settlements was already mentioned in the second chapter especially the work by Giusti de Pérez and Pérez (2008).

In their paper, Jiang and others (1999) refer to the above conventional notion of accessibility as ‘geographical’. Reviewing the mathematical formulations used to represent this notion they highlight the point that this group of accessibility measures are accounting for the proximity of ‘places’ (i.e. areas) or their proxies that are represented as points: “In this form, it is not used to measure the accessibility of lines or routes. It is not usually defined in this form for spatial systems whose geometric properties are critical and thus we will refer to the measures … as geographic accessibility.” (Ibid. Page)

As opposed to the notion of geographic accessibility then Jiang and others (Ibid.) introduce ‘geometric accessibility’ that operates in the finer scale of
streets and buildings as the proximity of locations in this scale is ‘more structured’ and hence geometric accessibility is assumed by them as the equivalent of geographic accessibility in the finer urban scale: “what is dramatically absent are tools for developing accessibility measures at the spatial scales which involve the geometry of urban structure in terms of streets and buildings in contrast to the measurement of accessibility at the geographic or thematic level” (Ibid. Page)

Further explanation will follow regarding the measurement of geometric accessibility but as a brief introduction to geometric accessibility is generally the focus of ‘space syntax’ as a research field rooted in the architectural studies (Hillier and Hanson, 1984). In space syntax approach the main idea is to represent urban or architectural space as a set of local elements (such as line or polygons) and then to investigate the inter-relation between these elements through transforming their set into a graph. In this way the relation between each local space represented as an element -mainly its accessibility from the whole system- can be quantified. Because the basic elements representing space such as axial lines (see below) are based on the way an individual perceives a space, then space syntax analyses of accessibility are claimed to reflect aspects of the human cognition of their surrounding that can help with predicting their movement in an aggregated level (Hillier and Iida, 2005).

Considering the importance of accessibility as a major theme in space syntax one point should be made about its relation with the concept of centrality. For example, in the mentioned model of cities proposed by Alonso-Muth-Mills -reviewed according to Torrens (2000) in the second chapter- the amount that each land use is willing to pay for a location is determined by its higher accessibility in the centre. In other words, the centrality and accessibility are

89 “At a finer scale where buildings and streets form the system of interest, the relative location and nearness of locations one to another is more structured and we, therefore, need to define an analogous concept to geographic accessibility which we will call geometric accessibility”
proxies for each others. This is also the case for the more specific case of geometric accessibility in space syntax field where Hillier and Iida (2005) estates that the central areas are more accessible. This issue will be further discussed below when explaining the quantitative measures of accessibility.

**Accessibility in the context of Third World urban studies**

Regarding the question of this thesis about the consolidation of spontaneous settlements and socio-economic issues pertaining to that process the notion of accessibility should be examined in this context. Remembering that consolidation is a process triggered by socio-economic improvements the question is then if accessibility has any impact on such circumstances. Accessibility (in general and not the geometric concept) is discussed in the literature regarding poverty in urban Third World in the second chapter but the embedded notion in those discussions is the geographic accessibility. As a result, the urban models of Third World cities (i.e. the reviewed Griffin and Ford model in chapter 2) can explain the location of spontaneous settlements in their city-wide location but are not helpful in dealing with the aspects of the areas in local level such as the formation of local markets.

Regarding the geographic notion of accessibility, one should consider the particular economic situation in the Third World cities; the poor, living in spontaneous settlements, might not afford commuting to the major urban centres (or the CBD) even for its job opportunities. This is best described through what Bryceson and others (2003) describes as the less mobility of the poor who rely on informal economic activities. In other words, it is not just how far the poor are from the urban centres but also how much movement flows (pedestrian and vehicular) from the rest of the city would pass by them or through their neighbourhood so they can set up their commercial activities (even hawking or vending) according to such opportunities.
As a result a great source of livelihood and overcoming poverty would be the aggregated movement flow through or close to a settlement. Theses flows can then contribute to the performance of commercial activities as illustrated in the mentioned space syntax research in Santiago (Hillier et al., 2000). The later research uses the geometric concept of accessibility as a predictor of movement flows in a finer and more local urban level that is different from the notion of geographic accessibility that underlies most of studies in the context of Third World urban poverty (for example Godefrooij and Snoeren, 2010).

It should be reminded that the accessibility of facilities as ‘being within reach’ as reviewed has a notable impact on the course of poverty in spontaneous settlements but it mainly concerns the distance to health and educational facilities or in other cases the transport nodes (Giusti de Pérez and Pérez, 2008). In other words, it seems that the above geographic approach to accessibility is affected by the provision of amenities that is beyond the direct control of dwellers while as was pointed in the second chapter the main priorities (or preferences) of the poor are economically related that can be to find job opportunities or to set up local commercial activities.

While the former preference (i.e. proximity to jobs) can be explained to some degrees by the geographic definition of accessibility considering affordable means of transport, distance and availability of roads the latter (i.e. setting up local commercial activities) is more related to how much movement and activities occur in the proximity of a settlement. Such preference to gain commercial benefit from the movement without commuting from the spontaneous settlement can be justified by the lower mobility power of the poor.

The mono-centric urban model of Alonso-Mill-Muth (reviewed in the second chapter) can be regarded as a manifestation of geographic accessibility concept in which the closer a location to the CBD (or the centre) the more accessible it
presumably is. The commercial land use then would be the activity that can afford to occupy the central land. This assumption on measuring accessibility in geographical studies is questioned by Chiardia and others (2009)\textsuperscript{90} manly taking the direct distance between the CBD and an urban area as an indicator.

Extending the above criticism to the urban studies in developing world\textsuperscript{91} the geographic concept of accessibility then can be presumed as problematic as it ignores the micro condition of spontaneous settlements (especially the geometry of their street layout) and the potential of emerging local markets within them. This is because such notion of accessibility ignores the local condition necessary for the formation of such markets. Furthermore, as the geographic notion of accessibility takes a central point in the urban system as the most accessible location it cannot explain the observed linear arrangement of commercial plots within spontaneous settlements (see chapter two on accessibility) and this is regardless of the distance calculation method applied in accessibility measurement (i.e. the direct distance or the actual route length). As a result the next section will explain the fundaments of geometric accessibility calculation as defined in the field of space syntax to be applied to the case study spontaneous settlements.

**Space syntax and geometric accessibility in urban studies**

The urban studies of geometric accessibility are the focus of space syntax as a research field in which the social and economic aspects of urban space is examined with regards to its configuration. The underlying idea in this field is

\textsuperscript{90}“The distance to the CBD is taken as a key spatial accessibility variable in most studies in the field; it is understood as a rough proxy for location advantage differentials. While locations deemed almost equal, especially when approximated by the distance from the CBD, can have substantial disparities in accessibility and other microlocational aspects, one of the strongest criticisms is that the emergence of a CBD location itself is exogenous to the model” (Ibid. Page 2)

\textsuperscript{91}This also includes the reviewed Griffin and Ford model of the Third World city that is based on other classic urban models.
that social behaviour in an aggregated sense is spatial and is in interaction with urban and architectural space. By interaction the thesis means a two-ways effect by which the social and economic forces can shape the space and also are shaped by space as theorized by space syntax research (Hillier and Hanson, 1984). The way this effect can be detected is to treat the urban/architectural space in an aggregated way and consider the relation of each individual space with regards to all other spaces as a configuration.

One of the basic space syntax theories that relate the configuration of urban spaces to the social behaviour is the ‘natural movement theory’ (Hillier et al., 1993). This theory indicates that configurationally more integrated (or accessible) streets and urban spaces would carry more movement through themselves when the movement generating functions such as major public buildings and transport stations are evenly distributed. Consequently the theory of ‘movement economy’ indicates that the movement flows largely influenced by configuration of urban spaces would affect the distribution of land uses with ‘movement demanding’ land uses tend to be found on more integrated streets (Hillier, 1996). This distribution of land uses is also observable in sufficiently large urban systems when a few long radial streets are connecting the settlement core and the bulk of shorter streets together and to the system’s edges (called ‘deformed wheel pattern’). As a result of this spatial pattern shops and public activities favour the integrated radial streets and the settlement integration core while residential areas would fill the rather spatially segregated interstices between the radials (Hillier, 2001). In other words, the deformed wheel constitutes a foreground of highly accessible streets in a background of less accessible residential areas.

Space syntax research has also studied the relation between poverty and geometric accessibility. Reviewing these studies is helpful for this thesis with its focus on the spontaneous settlements as areas with generally deprived condition. One of the most prominent works is the study of historic poverty
maps in the UK mainly with focus on the community of minorities or immigrants by Vaughan (1997) and Vaughan and Penn (2001). The main hypothesis underlying this tread of studies is the idea that the where a settlement is located within the larger urban context (both in terms of local and global accessibility) can have major socio-economic impact on the community in long term especially their integration with the larger city or otherwise their segregation as a poverty cluster or ghetto.

As mentioned in the second chapter, the reviewed Santiago study of informal settlements by Greene (2003) and Hillier et al. (2000) in which the ‘edge oriented commercial activity’ was identified as the main contributor to the consolidation. As was previously argued, their research showed that the effective placement of commercial activity on topologically accessible routes can increase their gain from higher ratios of passing-by movement flows but because of the small size of their studied settlements the possibility of internal clustering of shops was very low. The idea put forward by the thesis will overcome this particularity by looking at the internal parts of large spontaneous settlements.

Subsequently this study accepts the above idea put forward by the Santiago study that commercial activities can contribute to the consolidation of spontaneous settlements through their effective location on more accessible routes. However, because in large spontaneous settlements there might be an internal network of highly accessible routes (as the ‘deformed wheel pattern’ requires) then the efficient location of commercial land use within the settlement –and not just on its outward edges- should be considered when their effect on consolidation is considered.

As a result the case of consolidation of small settlements in Santiago through commercial activities can be regarded as a particular condition where due to
the small size of the settlement there is no internally accessible route exist and hence there is no internal clustering of commercial land use.

Furthermore, it can be argued that by increasing the size of a spontaneous settlement, the capacity of its outward edges to accommodate commercial activities falls. To illustrate this one can imagine a very hypothetic scenario in which the dwellers of a spontaneous settlement tend to establish their shops on the outward edges and keep the non-edge plots for sole residential use. In a settlement comprised of 9 plots in a square layout of 3 by 3 there are 8 plots facing the outward edges of the settlement and hence the commercial to residential ratio would be 8 to 1 (Figure 5.2, left). By increasing the number of plots to 16 (a 4 by 4 layout) the ratio would fall to 3 and so on. As illustrated in Figure 5.2 (right), the number of shops falls exponentially when the number of plots increases or in other words the capacity of edge as the sole location to accommodate commercial activity drops. This illustration is helpful when assuming that the ratio of commercial plots to the residential plots has some bearing on the economic gain of the dwellers (or simply how many residential plots are benefiting from commercial plots).

Although the capacity of large settlements to accommodate commercial activities on their outward edges is limited, one should be reminded that the sole placement on the outward edges is not the only efficient location for the shops. On the contrary, the key issue is the placement of commercial land use on more accessible routes and as the large settlements can have such high accessibility in their internal parts (as the emergence of deformed wheel pattern provides) then it can be concluded that the efficiency of internal commercial activities is even more important than the edge-oriented ones.
Figure 5.2 – (right) A hypothetic square settlement of 9 plots and the commercial to residential ratio calculation. (left) the chart illustrates the commercial to residential ratio against the total number of plots in a log-log scale.

This concentration of commercial activities on the internal parts of spontaneous settlements is also observed empirically by Budiarto (2003). He first refers to others regarding the ‘Kampung’ (or the term for spontaneous settlement in Jakarta): “Different from what one would commonly expect in an open public space, in Kampung it functions more likely a semi-public/private space that is used as an outdoor living room for a number of households rather than being entirely open to strangers” (Ibid. Page 8). He then observes that open public spaces in the spontaneous settlements are the foci of local markets, shops and vendors. He explains that the local markets in his studied spontaneous settlements tend to happen along locally accessible routes in the neighbourhood level but not along the main formal arteries with city-wide function.
Based on such empirical evidences about the existence of internal commercial activities along the more accessible routes and based on the effect of efficient commercial land use placement on the consolidation this chapter tests the hypothesis that first accessibility within a settlement play a major role in the distribution of commercial activities in spontaneous settlements and second the more accessible internal street network results in stronger local centres (or indicators of consolidation).

**Geometric accessibility, the basic space syntax method**

Testing this hypothesis requires calculation of geometric accessibility of streets for the spontaneous settlements and their wider urban context (or their respective host cities). As a result the fundamentals of calculation methodology will follow. To transform the street network of a city to a graph in order to calculate the geometric accessibility of each street first the street network should be represented as an axial model. The axial model or ‘axial map’ (Turner et al 2005) is the set of number of longest lines that traverse through all streets and other public spaces such as squares or plazas.

The axial model is then transforms to a graph in which the junctions are edges and the axial lines are nodes. In this way the depth of each node (i.e. street) can be calculated from the rest of the nodes as the steps required reaching them in the graph (see Bafna, 2003). Following this procedure, each step is a ‘turn’ that is required to go from an axial line to another. The depth from other axial lines defines the line’s overall topologic ‘depth’ from the whole system (the shallower a line from the whole system the more integrated or accessible it is). Alternatively the depth can be calculated in a certain radius that is the depth of the sub-system from each node in the graph; in conventional axial analyses it is the number of turns to reach a certain target axial line. Having this definition, the depth of each axial line with regards to all other lines is termed total depth.
in radius infinity or ‘Rn’ while for example if the depth calculation is done for all axial lines three steps away from a certain line it is called total depth radius 3 or ‘R3’. By dividing total depth by the number of all axial lines (or nodes) within the defined radius from an axial line (excluding the axial line itself), the value of mean depth is calculated for it. Mean depth value can then go under normalisation to relax the effect of axial map size and make it possible to compare values across different systems. The normalised value of mean depth then can be inversed to give the value of integration\(^92\).

However, in such calculation of axial integration the same value is assigned to the whole axial line regardless of the fact that it is divided to different segments on its intersections with other axial lines. Moreover, in such conventional axial calculations –because the distance unit is just the number of turns- there is no consideration of the extent of change of direction in each turn\(^93\) (Dalton, 2001) nor there is any consideration of metric properties of the network when measuring the topologic depth (Ratti, 2004).

**The topo-geometric accessibility or segment angular analysis**

These above criticisms of the conventional axial analysis are overcome by using a more advanced syntactic analysis of accessibility called ‘segment angular’ or ‘topo-geometric’ (Hillier et al, 2007). In topo-geometric analysis first each axial line is divided to segments between intersecting lines and treated as nodes in the graph individually while the angular change between

\(^{92}\) The normalization method is done by using a denominator called the d-value. Iida (2006) gives the following definition for it: “A d-value for the axial map of size n is equivalent to the relative asymmetry of the root vertex of a ‘diamond-shaped’ graph with n vertices”. He then put forwards the following equation for a map of n axial lines (Ibid.):

\[
D-value = \frac{2 \left\{ n \left[ \log_2 \frac{n + 2}{3} - 1 \right] + 1 \right\}}{(n - 1)(n - 2)}
\]

\(^{93}\) Or change of direction when moving from an axial line to another.
these segments can be used to ‘weight’ the depth calculation between nodes i.e. the more change of direction required to reach other segments from single segment makes it deeper (or less accessible) from the rest of the system. The other advantage of segment angular analysis is the possibility of various definitions for radii: it can be topologic (like classic axial analysis), metric (where segments up to a certain distance from a segment is included in the analysis) or angular (segments reachable within a limited change of direction are included in the depth calculation).

The mathematical formulation for segment angular measures of accessibility is proposed by Hillier and Iida (2005) and is comprehensively explained by Iida (2006) that is reviewed in appendix 1. It should be noted that there are two major definitions for street network accessibility in space syntax measurements that are ‘closeness’ (or integration) and ‘betweenness’ (or choice) which reflect different aspects. While the former reflects how deep each segment is from all other segments, the latter indicates how many times a segment would be traversed as a proportion of all the trips between every two other segments in the system. For more detailed mathematical detail see appendix 1.

It should be noted that in calculating the aforementioned accessibility measures (i.e. choice and integration), the radii can be defined in different ways according to the same source: the number of turns, the total angular change of direction and the metric distance. Therefore, for calculating these measures for each axial segment (e.g. the target segment), the subset of other segments connected to it within the defined radii would be selected and this will be repeated for all other segments in the system. For example if the angular radius of 120 degrees is set, all the segments that can be reached with total angular change of direction less than or equal to 120 degrees are selected (the same for the number of turns, e.g. segments within 5 changes of direction would be selected).
Likewise, for metric radii also the same procedure is followed: to calculate the measures with radius 2000 meters, then the segments that their mid points are within the radius of 2000 meters of the target segment are selected to define a subsystem\textsuperscript{94}. Although Depthmap application has the three definitions of radii, using metric radii has a main advantage: the metric radius can be related to the actual behaviour of people or vehicles because it sets the radius by which they limit their trip in the actual situation. In this way the walking distance of 400 to 800 meters (5-10 minutes) can be taken as local radii, the maximum convenient walking distance of 2000 meters can be taken as the meso-radius and the higher radii of 5000 meters and more can be regarded as city-wide. In this way while the metric distance is considered, the measures of accessibility (i.e. choice and integration) is calculated using the angular weight as a basis for depth calculation between segments; this segment angular analysis according to Hillier and others (2007) can predict actual movement flows in cities better than when the depth is directly calculated as the least metric distance between two points. As a result of this empirical advantage, segment angular analysis with metric radii will be used consistently throughout the thesis for the measurement of geometric accessibility\textsuperscript{95}.

The next part of this chapter will apply space syntax method to the case study spontaneous settlements of Jeddah and Zahedan to look at their accessibility within their larger urban context as well as their internal accessibility pattern especially to see if there is any internal spatial structure of streets. Because the focus is on the formation of local centres within the settlements, there will be a specific enquiry to see if the commercial land use in internal areas -and not on the outward edges- is affected by the accessibility pattern of the streets. If the

\textsuperscript{94} The distance here is calculated as the length of the path that traverses a sequence of connected segments and not the as-the-crow-flies (see the definition of ‘geodesics’ in appendix 1).

\textsuperscript{95} Space syntax theories allow for social and economic interpretation of accessibility levels in spontaneous settlements; it can be investigated if the consolidation (as a process that includes socio-economic issues) is affected by accessibility pattern. As a result the use of topo-geometric accessorily with its measurement method (i.e. segment angular analysis) is justifiable for this study.
latter conjecture holds true and the commercial land use are structures around accessibility of streets, then the task will be to see if the higher accessibility can contribute to more consolidation.

The accessibility analysis of the case studies

To perform the segment angular analysis for both cities of Jeddah and Zahedan the axial models for both cities should be prepared. For Zahedan, the whole model was drawn by the author using the CAD basemap of 2003 surveyed by IMHUD/WB (2003). In the model each potential path for movement (regardless of walking or vehicular or simultaneous) was traversed by axial lines that makes it a low resolution model for general movement flows. Moreover, separate vehicular lanes in highways are modelled as separate axial lines. For Jeddah the low resolution model was received from Space Syntax limited. In total the Zahedan axial model is comprised of about one tenth of axial lines in Jeddah model in terms of count and total length (see Table 5.1).

<table>
<thead>
<tr>
<th>City</th>
<th>Axial line count</th>
<th>Total line length (km)</th>
<th>Max. length (m)</th>
<th>Avg. length (m)</th>
<th>SD length (m)</th>
<th>Avg. axial connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeddah</td>
<td>45,697</td>
<td>9,932</td>
<td>9,985.0</td>
<td>217.3</td>
<td>352.8</td>
<td>4.52</td>
</tr>
<tr>
<td>Zahedan</td>
<td>4,639</td>
<td>1,093</td>
<td>6,423.1</td>
<td>235.6</td>
<td>315.1</td>
<td>4.55</td>
</tr>
</tbody>
</table>

Table 5.1 - Statistical summary of axial models for Jeddah and Zahedan.

As can be seen from the Table 5.1, the average line length in Jeddah is slightly less than Zahedan while the maximum line length is more in Jeddah that can be attributed to the city size.

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96 This is different from the high-resolution axial models that represent each walking route as a separate axial line. For example if there are two pavements on both sides of a street those are modeled as two separate lines.
The segment angular analysis of Jeddah and Zahedan

Because the focus of thesis is on topo-geometric definition of accessibly and its related analyses (i.e. segment angular) the conventional axial analysis is not addressed here. The software used to do the segment angular analysis is Depthmap (Turner, 2001) that is available for academic uses and can perform axial and segment angular analyses. Both of the axial models for Jeddah and Zahedan where transformed to segment maps first by the software and then was processed to calculate accessibility measures of ‘closeness’ (or integration) and ‘betweenness’ (or choice). The calculation for each measure was also done in different metric radii to capture the different urban scales from which each street segment is accessible from.

Through segmentation of the axial model, each respective axial maps of Jeddah and Zahedan was transformed to an axial-segment model for which the statistical summary follows in the below table (Table 5.2). As can be seen the number of segments is Jeddah is more than 12 times more than Zahedan with the later model having slightly longer segments in average. However, the last column in Table 5.2 indicates that Jeddah has a slightly more segmented axial lines compared to Zahedan.

<table>
<thead>
<tr>
<th>City</th>
<th>Segment count</th>
<th>Avg. segment length (m)</th>
<th>SD of length (m)</th>
<th>Average segments in axial line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeddah</td>
<td>226,864</td>
<td>48.46</td>
<td>88.65</td>
<td>4.96</td>
</tr>
<tr>
<td>Zahedan</td>
<td>18,185</td>
<td>54.78</td>
<td>53.16</td>
<td>3.92</td>
</tr>
</tbody>
</table>

Table 5.2- Statistical summary of the axial-segment models for Jeddah and Zahedan.
‘Average segments in axial line’ is resulted from dividing the total number of axial lines by total number of segments in each respective model.
Figure 5.3 - Axial segment maps for Jeddah (upper row) and Zahedan (below row) for measures of segments angular choice in Radius infinity (left column) and Radius 800 metres (right column). Spontaneous settlements are bounded by black outline. See Plates 1 to 4 at the end of the thesis for better graphics.
After processing the two axial segment maps with the application Depthmap, each segment was attributed with calculated values for the measures of angular choice and angular integration in different radii. The segments were then exported to GIS application of MapInfo for further integration with other layers of data (especially land use) and also visualizing the accessibility values assigned to the street segments. The visualisation of accessibility data can help with revealing the overall patterns that can be complemented with quantitative statistical summaries. Because the radii by which the accessibility analysis was done were numerous, just two radii (800 meters for local and ‘infinity’ for global’) will be visualized for the measure of choice. The maps are shown in Figure 5.3.

Before proceeding with the analysis of the segment maps a caveat should be made about the values of choice and integration. In addition to the mathematical distinction between choice and integration as measures of accessibility, a major difference between those should be highlighted that is reflected in the visualized thematic maps rooted in the statistical distribution of the values attributed to the segments. It should be noted that the measure of segment angular choice is too much positively skewed and should go under logarithmic transformation but even after this stage the histogram consists of a large number of very low values and the non-zero values are still slightly and positively skewed. This is quite different from integration that exhibits a close to normal distribution. In terms of visualization this difference in statistical distribution results in various features: while in the global radii, choice magnifies the super-grid (or the major set of highest accessibility routes) from its background with much lower values, the integration map has a much slighter grading from high value accessibility street segments to lower ones. In this regard it can be concluded that segment angular choice is more appropriate to capture the super-grid network while the integration measure is more efficient in investigating the variation amongst groups of streets such as a settlement or neighbourhood (i.e. the background network).
Having clarified the difference between integration and choice measures, one can be argue that segment angular integration analysis is a better means to evaluate the overall accessibility pattern of spontaneous settlements (as if these are patches or a background) while segment angular choice would be more useful to highlight the main arteries in a city wide scale or the internal spatial structure within the settlements.

**Interpreting the segment angular analysis of the two cities**

Looking at the global accessibility map of Jeddah one can understand that the two major spines of the city i.e. Mekkah and Medinah Roads are highlighted with high values (red and orange colours in the thematic map in Figures 3 and 4). The eastern highway also comes up as a strong route with high value of choice. The reason for such high values can be attributed to the very long length of these arteries that increases their connectivity to other routes as well as their straight alignment. The two highly accessible alignments of Mekkah Road and Medinah Road were introduced as the main spines of Jeddah in chapter 4 that radiate from the old core in two different directions along which the city expanded quickly in last few decades while there is a high concentration of commercial and public land use along these two spines are reported.

For Zahedan the routes with highest value of global accessibility (i.e. measure of angular-segment choice, radius infinity) are making a cross-shape pattern intersecting in the centre of the city. The two main alignments of this cross are University Street (north-south) and Imam Street (east-west) that were also highlighted as the main ‘spines’ of the city in chapter 3 due to the high concentration of commercial and other non-residential activities along those.
In both cities, the high accessibility routes (Choice Radius n) are not limited to the main spines and there are other routes going parallel with the mentioned ones: in Zahedan the east-west streets of ‘Mostafa’ and ‘Keshavarz’ are running parallel and close to Imam street and in Jeddah, King Fahad Road and King Majid Road are running parallel with the Medinah Road. Moreover, the series of parallel highly accessible routes are crossed perpendicularly by another series of high-accessibility routes that creates what Budiarto (2003) calls the super-grid where the official and public urban functions are concentrated due to being easily reachable in a city-wide scale.

The other observation on both cities in terms of global accessibility (Choice radius infinity) is that the spontaneous settlements are sharing some outward edge with the high accessibility routes. It is as if the settlements are ‘leaning’ to the super-grid whenever possible and while highly-accessible routes in global scale (i.e. high values of choice radius infinity) are not penetrating into the settlement, one might find mid-value accessibility streets (highlighted with yellowish colour) branching from the super-grid into the inner areas of a spontaneous settlements as shown in Figure 5.4.

The measure of segment angular integration can be used to look at the spontaneous settlements as patches or areas within the larger urban context in terms of their overall accessibility pattern with less concern for highlighting the super-grid. In this regard and looking at the global integration analysis (Figure 5.5) one can find out that these areas –especially their internal areas- are coming up as less accessible patches in a city-wide radius.

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97 Integration value for a segment (or the target segment for calculation) is gained by dividing the total angular-segment depth of that segment to other segments in the given radius by the total node-count of that segment in the same radius. The total node-count is simply defined as the number of other segments reachable in the defined radius of the target segment.
Figure 5.4 - The segment angular analysis of choice measure with radius infinity (R=n) for the two Zahedan spontaneous settlements of Babaeyan (right) and Shirabad (left). The map and colour ranges are the same scale while the commercial plots are highlighted as dark polygons.

This observation goes in line with the residential function of these areas. It should be noted that Hillier (2001) in a more general argument about cities points to the group of socio-cultural forces that shape mostly the residential urban fabric. These forces as Hillier (Ibid.) hypothesizes are reflecting variations in different cultures and social groups through generating differences in the geometry of urban layout mainly in the residential areas. Accordingly, it can be speculated that in spontaneous settlements due to their preference for territoriality and social isolation, the socio-cultural forces generate less accessible urban layout\(^8\).

\(^8\) However, answering how the geometry of urban layout and accessibility interact with each other is not a task of this chapter (see chapter 7 for the relevant discourse).
The accessibility analysis of spontaneous settlements

The spontaneous settlements’ topo-geometric accessibility indicates that these areas have cores of higher local accessibility within them. These cores are highlighted as cluster with high values of segment angular choice in local and medium radii (radii roughly ranging from 400 to 2000 meters). The below tile in Figure 5.6 illustrates such clusters within Rabwa spontaneous settlement (Jeddah) in local radius of 1200 metres that are highlighted with warmer colours like red and orange. Such high accessibility clusters of axial segments, on the other hand, are usually sparser on the edges of spontaneous settlements where most of the time the settlements is bounded with globally well-accessible route(s) as the upper tile of Figure 5.6 indicates it for Rabwa area. In other words, and especially for the case of Jeddah, the globally accessible
routes on the outward edges and the locally accessible routes within the settlements have a very low overlap. This pattern is also observable for Zahedan spontaneous settlements with slightly more overlap between the two levels of accessibility.

Figure 5.6 - Segment angular analysis of Rabwa spontaneous settlement in Jeddah. The segment colours reflect their choice value in radius infinity (above) and radius 1200 meters (below). The edge commercial land plots are highlighted by dark polygons.
Measuring the impact of accessibility on commercial land use distribution

The highly accessible routes (either globally on the edges or locally within the spontaneous settlement) generally attract commercial shops to themselves. However the confirmation of such observation (i.e. the concentration of commercial land use on more accessible routes) needs a concrete quantitative measurement and comparison with the other areas of the city. In a wider sense and through qualitative eyeballing of the accessibility thematic maps, it is understandable that commercial plots tend to be found around more accessible routes throughout both cities of Jeddah (Figure 5.6) and Zahedan. This is in a way opposite to a random distribution when commercial plots are placed regardless of their accessibility (measured as their accessibility rank amongst all plots in the city).

For example if a hypothetic settlement have just 9 plots out of which 3 are commercial, if the two plots are placed in the highest accessibility plots (i.e. first, second or third ranks in accessibility) or the opposite, happened to be in plots with ninth, eighth and seventh accessibility ranks, then it can be inferred that the distribution is affected by accessibility factor as a first-order effect and hence the distribution is non-random. On the contrary, if the commercial plots are occurred in the 8th, 5th and 2nd plots in accessibility rank, then it is approximate to a random distribution with regards to accessibility.

When the total number of plots increases, more advanced statistical methods can be applied to calculate the extent of non-randomness (or ‘inequality’) of the distribution of commercial land use called ‘Gini coefficient of inequality’. The basic idea is again to see if accessibility rank of plots has any impact on the occurrence of commercial land use in those, mainly the concentration of commerce on highly accessible plots. The first step is to produce a ‘Lorenz curve’ by using the cumulative distribution function (CDF). CDF or alternatively ‘cumulative frequency’ is defined as follow by Wolfram MathWorld (Weisstein, 2010):
“Let the absolute frequencies of occurrence of an event in a number of class intervals be denoted \( f_1, f_2, \ldots \). The cumulative frequency corresponding to the upper boundary of any class interval \( c_i \) in a frequency distribution is the total absolute frequency of all values less than that boundary...” [the source then mentions the following formula]:

\[
F_\leq \equiv \sum_{i \leq n} f_i
\]

(Source of formula: Ibid.)

Applying the above function to the commercial land use distribution, it means to ask what percentage of all commercial plots are occurring up to a certain rank of accessibility throughout all land plots. The trend can also be plotted that is called the Lorenz curve. An example of that Lorenz curve\(^99\) illustrated in Figure 5.7 below that is based on the actual global accessibility analysis for Zahedan (choice radius infinity). Referring back to the above formula the frequencies \( f_1, f_2, \ldots \) are translated to the occurrence of commercial buildings in a certain class interval of accessibility rank of buildings.

The vertical axis shows the percentage of all commercial buildings/plots in the whole city and the horizontal axis represents the percentage of all buildings/plots in terms of their accessibility rank. For example the number 90 on the horizontal axes represents the lowest 90 percentage of all plots in terms of their global accessibly rank and –according to Figure 5.7- about 70 percent of commercial buildings in terms of count are happening in lowest 90 percent plots or to put it another way, about 30 percent of all commercial buildings are

\(^{99}\) Lorenz curve is also used in poverty studies especially as a mean to measure inequality of wealth distribution amongst a population. The Gini coefficient of inequality is the measure applied to the Lorenz curve to quantify the
in top 10 percent buildings in terms of global choice. This is to be compared with a hypothetic situation in which the commercial buildings are located regardless of accessibly or ‘equally distributed’ that results more or less in the blue dotted line (Figure 5.7) that is the opposite way of having all commercial buildings in the highest accessibly locations (the red dotted line in the same figure) as the most ‘unequal’ way.

Figure 5.7 - The Lorenz curve of commercial building distribution amongst all the buildings in Zahedan based on the rank of global accessibility rank (Choice R=n).
The more the Lorenz curve gets close to the ‘unequal’ distribution, the more the effect of accessibility on the placement of commercial activities can be inferred. A mathematical question is then how to quantify the extent of inequality? This is done through calculation of Gini coefficient of inequality (or ‘Gini’) as illustrated in Figure 5.8 showing the same curve of Zahedan as an example with two surfaces marked with A and B for which Gini is calculated as $\frac{A}{A+B}$. Gini in this way ranges between 0 for minimum inequality (or random placement in the case of commercial land use) and 1 that is the maximum inequality (or structured placement of commercial land use in locations with highest accessibility).

![Figure 5.8](image)

Figure 5.8 - The calculation of Gini coefficient for the red curve illustrating the commercial distribution relative to the global accessibility of Zahedan buildings. Gini measure is equal to $\frac{A}{A+B}$. 
According to the aforementioned theory of ‘movement economy’ the commercial activities tend to happen on more accessible routes as efficient locations to benefit from higher movement ratios. The more concentration of commercial buildings/plots on highly accessible routes – measured through the above Gini calculation method- is then called ‘efficient’ distribution and the Gini value is therefore an indicator of commercial land use efficiency or the degree to which commercial land plots are structured regarding accessibility. The next section will then apply the Gini calculation method to the spontaneous settlements.

**The internal spatial structure of the case study spontaneous settlements**

Before carrying on with commercial land use efficiency measurement (or the Gini calculation) for the settlements, first a qualitative assessment of the accessibility pattern in these areas will be performed. The aim is to show that the internal spatial structure or the deformed wheel pattern do exist in these areas as was predicted by space syntax theories (Hillier, 2001) although to various degrees of distinction.

This can be understood from the accessibility pattern (angular-segment choice) of various spontaneous settlements in Zahedan and Jeddah. The suitable radii to highlight the internal structure can be described to be between 800 meters to 2000 meters –according to the author’s review of accessibility thematic maps- but radius 1200 meters is finally chosen. This radius can be regarded as ‘meso’ because it is not covering the city-wide scale nor it is very local (i.e. reflecting a short walking distance of 5 minutes that is 400 metres). For the matter of consistency between Jeddah and Zahedan the logarithmic scale of choice measure (scaled between 0 and1) is coloured in equal ranges for their respective axial segment models of the cities. As Figure 5.9 illustrates, each one of the two settlements of Babaeyan (Zahedan) and Rabwa (Jeddah)
exhibits an internal structure consisted of highly accessible street segments with concentration of commercial land use around those.

This internal structure along with its impact on the commercial land use distribution can be observed in different spontaneous settlements of both cities (see Figure 5.6). Although in some cases the structure is not very distinct from its surrounding, the more important observation is that the commercial land use seems to be attracted to this internal structure to various degrees. To see if this non-random (or efficient) distribution of commercial land use - as an indication of the internal structure existence - is present in the spontaneous settlements, there is a need for a concrete quantification method that will be done using the Gini coefficient calculation along with some complementary measure in the next section.

Figure 5.9 - Segment angular choice maps (radius 1200 meters) coloured in logarithmic scale with equal ranges for Babaeyan spontaneous settlement in Zahedan (left) and Rabwa spontaneous settlements (Jeddah). The commercial plots are coloured with black polygons.
Gini calculation for the internal areas of the case studies

Before doing the Gini calculation for the internal (or non-edge) areas of the case study spontaneous settlements, there is a need to define which land plots or buildings constitute the internal part and what constitute the outward edge: an edge street is a wide continuous and (very often) a planned street that bounds the settlement and if it goes through it, it should be fairly straight and extends beyond the settlement at least equal to the settlement length. With this definition whatever plot/building that faces such edge street will be excluded from the internal commercial land use Gini calculation. In this way the Gini is calculated for both groups of Jeddah and Zahedan spontaneous settlements and the results are reflected in Tables 2 and 3 below respectively. The accessibility rank of plots (needed for Gini calculation) for both tables is segment angular choice for radius 2000 meters.

<table>
<thead>
<tr>
<th>Area name</th>
<th>Age</th>
<th>Mean (ScDDRad200m)</th>
<th>Gini (CH2000) non-edge</th>
<th>Upper decile (CH2000m) com. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babaeyan</td>
<td>40</td>
<td>0.34</td>
<td>58.24</td>
<td>39.10</td>
</tr>
<tr>
<td>CHZ,DPZ, NUZ</td>
<td>12.5</td>
<td>0.13</td>
<td>53.78</td>
<td>42.50</td>
</tr>
<tr>
<td>KAZ,SIZ,MOZ</td>
<td>30</td>
<td>0.32</td>
<td>52.77</td>
<td>36.21</td>
</tr>
<tr>
<td>KNZ,PGZ</td>
<td>20</td>
<td>0.37</td>
<td>38.66</td>
<td>26.00</td>
</tr>
<tr>
<td>Qasemabad</td>
<td>5</td>
<td>0.05</td>
<td>18.93</td>
<td>12.50</td>
</tr>
<tr>
<td>Shirabad</td>
<td>20</td>
<td>0.23</td>
<td>51.99</td>
<td>27.65</td>
</tr>
</tbody>
</table>

Table 5.3 - Commercial land use distribution in the non-edge (inner) plots of Zahedan spontaneous settlements. Gini is based on Choice 2000m while the percentage of commercial plots in the upper decile of accessibility (Choice R=2000m) is reflected in the last column to the right.

100 It happens when a major planned transport artery traverses through a spontaneous settlement.

101 The abbreviated settlement names are explained in Table 3.2.
<table>
<thead>
<tr>
<th>Area Name</th>
<th>Age</th>
<th>Dist to Hist. Core (km)</th>
<th>Mean (ScDDRad200m)</th>
<th>Gini(CH2000) non-edge</th>
<th>Upper decile (CH2000m) com. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amariyah</td>
<td>54</td>
<td>0.9</td>
<td>0.42</td>
<td>34.34</td>
<td>23.57</td>
</tr>
<tr>
<td>Aziziyyah</td>
<td>25</td>
<td>7.0</td>
<td>0.37</td>
<td>28.12</td>
<td>26.50</td>
</tr>
<tr>
<td>Baghdadiyyah</td>
<td>44</td>
<td>1.2</td>
<td>0.36</td>
<td>26.11</td>
<td>22.82</td>
</tr>
<tr>
<td>Balad</td>
<td>64</td>
<td>0.6</td>
<td>0.54</td>
<td>26.54</td>
<td>18.91</td>
</tr>
<tr>
<td>Banimalik</td>
<td>44</td>
<td>4.8</td>
<td>0.39</td>
<td>38.96</td>
<td>30.68</td>
</tr>
<tr>
<td>Baryman</td>
<td>10</td>
<td>16.6</td>
<td>0.16</td>
<td>45.78</td>
<td>35.39</td>
</tr>
<tr>
<td>Betrumin</td>
<td>44</td>
<td>3.6</td>
<td>0.45</td>
<td>37.32</td>
<td>25.95</td>
</tr>
<tr>
<td>Ghalil</td>
<td>44</td>
<td>3.5</td>
<td>0.46</td>
<td>18.43</td>
<td>19.88</td>
</tr>
<tr>
<td>Hindawiyah</td>
<td>64</td>
<td>1.0</td>
<td>0.53</td>
<td>32.43</td>
<td>20.93</td>
</tr>
<tr>
<td>Jameah</td>
<td>44</td>
<td>6.6</td>
<td>0.49</td>
<td>45.81</td>
<td>28.25</td>
</tr>
<tr>
<td>Kandarah</td>
<td>54</td>
<td>1.6</td>
<td>0.48</td>
<td>30.75</td>
<td>21.79</td>
</tr>
<tr>
<td>Khomrah Sorur</td>
<td>10</td>
<td>11.0</td>
<td>0.18</td>
<td>52.97</td>
<td>23.08</td>
</tr>
<tr>
<td>Khomrah Thahalebah</td>
<td>10</td>
<td>12.9</td>
<td>0.12</td>
<td>54.64</td>
<td>47.37</td>
</tr>
<tr>
<td>Kilo14 North</td>
<td>10</td>
<td>13.3</td>
<td>0.23</td>
<td>47.54</td>
<td>40.93</td>
</tr>
<tr>
<td>Kilo14 South</td>
<td>10</td>
<td>13.6</td>
<td>0.26</td>
<td>39.89</td>
<td>27.88</td>
</tr>
<tr>
<td>Kilo15</td>
<td>10</td>
<td>14.9</td>
<td>0.15</td>
<td>NA.</td>
<td>NA.</td>
</tr>
<tr>
<td>Kilo16</td>
<td>10</td>
<td>15.3</td>
<td>0.18</td>
<td>39.45</td>
<td>18.18</td>
</tr>
<tr>
<td>Kilo18 North</td>
<td>10</td>
<td>16.9</td>
<td>0.09</td>
<td>NA.</td>
<td>NA.</td>
</tr>
<tr>
<td>Kilo 11</td>
<td>10</td>
<td>10.5</td>
<td>0.30</td>
<td>30.96</td>
<td>14.29</td>
</tr>
<tr>
<td>Madaen Alfahad</td>
<td>44</td>
<td>4.4</td>
<td>0.43</td>
<td>24.91</td>
<td>25.00</td>
</tr>
<tr>
<td>Montazohat</td>
<td>10</td>
<td>9.4</td>
<td>0.32</td>
<td>32.24</td>
<td>15.84</td>
</tr>
<tr>
<td>Moshrefah</td>
<td>32</td>
<td>5.7</td>
<td>0.42</td>
<td>15.38</td>
<td>9.68</td>
</tr>
<tr>
<td>Nozhah</td>
<td>10</td>
<td>14.7</td>
<td>0.23</td>
<td>32.55</td>
<td>33.70</td>
</tr>
<tr>
<td>Nuzlah</td>
<td>44</td>
<td>2.9</td>
<td>0.40</td>
<td>25.62</td>
<td>17.82</td>
</tr>
<tr>
<td>Quaizah</td>
<td>10</td>
<td>8.6</td>
<td>0.31</td>
<td>33.25</td>
<td>27.17</td>
</tr>
<tr>
<td>Qurriyah</td>
<td>44</td>
<td>2.3</td>
<td>0.41</td>
<td>29.29</td>
<td>18.44</td>
</tr>
<tr>
<td>Rabwa</td>
<td>10</td>
<td>12.1</td>
<td>0.40</td>
<td>32.36</td>
<td>28.21</td>
</tr>
<tr>
<td>Rawabi</td>
<td>25</td>
<td>8.7</td>
<td>0.36</td>
<td>24.38</td>
<td>16.43</td>
</tr>
<tr>
<td>Rohab</td>
<td>10</td>
<td>7.8</td>
<td>0.30</td>
<td>46.21</td>
<td>22.64</td>
</tr>
<tr>
<td>Ruwais</td>
<td>54</td>
<td>3.8</td>
<td>0.42</td>
<td>35.39</td>
<td>29.53</td>
</tr>
</tbody>
</table>
Table 5.4 - Commercial land use distribution in the non-edge (inner) plots of Jeddah spontaneous settlements. Gini is based on Choice 2000m while the percentage of commercial plots in the upper decile of accessibility (Choice R=2000m) is reflected in the last column to the right.

<table>
<thead>
<tr>
<th>Settlement</th>
<th>Size</th>
<th>Accessibility</th>
<th>Gini</th>
<th>Commercial Plots (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sabeel</td>
<td>54</td>
<td>1.2</td>
<td>0.47</td>
<td>33.04</td>
</tr>
<tr>
<td>Sahifah</td>
<td>54</td>
<td>0.8</td>
<td>0.50</td>
<td>29.65</td>
</tr>
<tr>
<td>Sahifah</td>
<td>54</td>
<td>0.8</td>
<td>0.50</td>
<td>23.48</td>
</tr>
<tr>
<td>Salamah</td>
<td>10</td>
<td>13.1</td>
<td>0.33</td>
<td>56.55</td>
</tr>
<tr>
<td>Salamah</td>
<td>10</td>
<td>13.1</td>
<td>0.33</td>
<td>33.33</td>
</tr>
<tr>
<td>Sheraiyah</td>
<td>44</td>
<td>2.2</td>
<td>0.44</td>
<td>26.07</td>
</tr>
<tr>
<td>Sheraiyah</td>
<td>44</td>
<td>2.2</td>
<td>0.44</td>
<td>13.64</td>
</tr>
<tr>
<td>Thaghar</td>
<td>54</td>
<td>3.0</td>
<td>0.40</td>
<td>40.29</td>
</tr>
<tr>
<td>Thaghar</td>
<td>54</td>
<td>3.0</td>
<td>0.40</td>
<td>25.23</td>
</tr>
<tr>
<td>Thahlbah</td>
<td>44</td>
<td>1.8</td>
<td>0.42</td>
<td>46.36</td>
</tr>
<tr>
<td>Thahlbah</td>
<td>44</td>
<td>1.8</td>
<td>0.42</td>
<td>33.33</td>
</tr>
</tbody>
</table>

The Gini values calculated for both groups of settlements in their respective cities indicate that the distribution of commercial land use is not random regarding the accessibility either if all the buildings are regarded -including the settlement outward edges- in global radius (choice R=n) or just the internal buildings are considered in medium radius (choice R=2000m). However, considering the importance of the settlements internal areas, only Gini values for medium radius accessibility is included in following tables (Table 5.3 for Zahedan and 5.4 for Jeddah).

Moreover, it can be observed that the more concentration of commerce is with regards to the higher accessibility in both global and local radii as it is reflected in tables (Table 5.3 and 5.4). This can be understood by looking at the percentage of all commercial buildings amongst the top 10 percent locations. The latter measure of the percentage of all shops in top decile of accessibility complements the Gini measure to understand the impact of accessibility. In other words, the ‘upper decile commercial percentage’ should be used because it appears that the Gini value is affected by the size of the settlement mainly the number of commercial plots in it.
To support this claim it suffices to illustrate that the local Gini for internal plots (Choice R=2000m) shows a significant correlation with polynomial second degree fit in Jeddah (Rsquare of 0.43 p = 0.0001) for 34 spontaneous settlements\(^\text{102}\) as Figure 5.10 shows. On the other hand, the measure of upper decile commercial ratio (choice 2000m) for the same spontaneous settlements of Jeddah show a very weak correlation with the number of commercial plots (Rsquare of 0.05) which suggests, unlike the Gini value, the upper decile ratio is independent of the settlements’ size.

\(\text{Figure 5.10 - Correlation between number of commercial plots and Gini (non-edge plots, choice 2000m) for the 34 spontaneous settlements of Jeddah.}\)

\(^{102}\) The two settlements of Kilo 18 north and Kilo 15 are omitted from the list of 36 case study spontaneous settlements as these do not have any commercial plot in them.
Using the measure of upper decile commercial percentage (using choice R2000m) in conjunction with the Gini is helpful in understanding the impact of accessibility. While the Gini value shows that the distribution of commercial land use is not random regarding accessibility, the upper decile measure indicates that higher accessibility has a positive impact on the commercial land use clustering. This leads to the conclusion that the internal spatial structure, detectable through visual inspection of accessibility maps of choice 2000 metres, has a measurable impact on the distribution of commercial plots as the main enforcer of local centres.

The previous claim—the impact of commercial land use on the strength of local centres—can be supported quantitatively at this point. The below figure show the ratio of commercial land plots (with regards to all plots in terms of count) in the non-edge areas of spontaneous settlements that are correlated with the consolidation ratio for the spontaneous settlement of Jeddah and Zahedan. As can be observed for Zahedan, consolidation (or the average density-diversity measure with band-width of 200 metres) has a strong and significance correlation with the ratio of commercial plots for the 6 main groups of settlements (Rsquare = 0.93 p = 0.0018). In Jeddah (Figure 5.11) for 36 spontaneous settlements the correlation with second degree polynomial fit results in Rsquare of 0.51 (p<0.0001) that suggests again that commercial ratio in the internal areas of the settlements plays a significance role in the measurement of consolidation.
Figure 5.11 - Correlation coefficient between commercial plot ratio in the non-edge areas (independent variable) against mean density-diversity value with band-width of 200 metres (dependent variable). The analysis is done for two groups of spontaneous settlements: Zahedan (above) and Jeddah (below).
The chapter has shown that the internal street structure of spontaneous settlements can be best detected through the accessibility measure of segment angular choice that exerts its impact on the commercial land use distribution. On the other hand, the commercial in the internal areas of spontaneous settlement was highlighted as the main contributor to the consolidation ratio measured as density-diversity in short band width. If the two observations are true, the local accessibility (or choice R=2000m) should have a positive impact on consolidation. This hypothesis is tested for the two groups of spontaneous settlements in the respective cities of Jeddah (Figure 5.12) and Zahedan (Figure 5.13) below.

![Regression analysis for 36 spontaneous settlements of Jeddah with consolidation ratio (density-diversity band-width 200 meters) as the dependent variable and average value of accessibility (choice radius 2000 metres in logarithmic scale) as the dependent variable.](image)

In other words the mentioned value of choice is averaged for all the plots in each spontaneous settlement.

103
Figure 5.13 - Regression analysis for 6 groups of spontaneous settlements in Zahedan. The consolidation ratio (density-diversity band-width 200 meters) is the dependent variable and average value of accessibility (choice radius 2000 metres in logarithmic scale) is the dependent variable.

The two above analyses suggests that in both cities, the local accessibility plays a significant role in the consolidation process of their spontaneous settlements. A caveat should be made here that commercial land use clustering is not the only component of density-diversity measure in local level and there are other factors of land use mix, built-up density and the density of other non-residential land uses that influence it. To see how accessibility influences consolidation, its impact on each one of these variables should be measured but taking the commercial land use on its own and as a major component would be enough in this regard: The upper decile commercial percentage of 34 Jeddah spontaneous settlements (choice 2000m) shows a correlation coefficient of
0.39 in Rsquare (p=0.0004) against the logarithm of density-diversity measure. By developing a methodology to include other components of density-diversity measure in a correlation against accessibility and using a multiple regression method, one might find a stronger correlation but that goes beyond the capacity of this thesis. Instead, this study has examined the direct association between local density-diversity measure (band-width 200m) and average accessibility (choice 2000m) in the next paragraphs which was shown to be significant.

Going back to the beginning of this chapter, the question was if accessibility plays a stronger role than the factor of time regarding the consolidation process. Selecting the 15 Jeddah spontaneous settlements highlighted in Figure 5.1 (that have the same age, see Table 5.4), and correlating their consolidation ratio with the three factors of settlement age, distance to the historic core and accessibility\textsuperscript{104} results in three Rsquares of 0.00, 0.42 (p=0.0088) and 0.45 (0.0058). This suggests that accessibility if not stronger than time, has an equal impact on consolidation\textsuperscript{105}.

The same question can be asked about the settlements of Zahedan: does accessibility play a stronger role than time in consolidation process? The correlation coefficient between the dependent variable of local diversity-density and independent variables of age and accessibility are measured in two separate regression analyses: while the former results in Rsquare of 0.66 (p=0.049) the latter gives a Rsquare of 0.86 (p=0.0073) both for 6 groups of Zahedan spontaneous settlements.

These analyses suggest that accessibility of the internal areas of spontaneous settlements, in parallel with the factor of time plays a major role in their

\textsuperscript{104}Accessibility is calculated as the logarithm of the value for choice 2000m averaged for the non-vacant plots.

\textsuperscript{105}Although it might be argued that accessibility and time might be related with each other but because there is no clear theoretical base for such argument, the two factors can be treated as independent. The only reason the two might be related is that the older areas, have –generally- a denser fabric around themselves in general that results in a higher density of road network and hence higher measure of accessibly in local and meso-levels.
consolidation. Although isolating the effect of time is not easy from the accessibility ratio, it can be said that the two might be related: as the older areas, have –generally- a denser fabric around themselves in general it results in a higher density of their surrounding road network and hence higher measure of accessibly in local and meso-levels. Even based on this assumption it can be speculated that the impact of time (or part of it) is mediated to the consolidation process through accessibility while accessibility (in its geometric definition) provides a stronger explanation on how the local centres are formed in the micro-level of urban fabric compared to the general impact of time. In both cases -dependence or independence of accessibility from time- the impact of accessibility has been established on consolidation for both groups of settlements in Jeddah and Zahedan.

<table>
<thead>
<tr>
<th>Area Name</th>
<th>Age</th>
<th>D&amp;D (BW=200m)</th>
<th>Dist. To Hist. Core (km)</th>
<th>Log (CH2000+2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baryman</td>
<td>10</td>
<td>0.16</td>
<td>16.6</td>
<td>4.97</td>
</tr>
<tr>
<td>Khomrah Sorur</td>
<td>10</td>
<td>0.18</td>
<td>11.0</td>
<td>3.95</td>
</tr>
<tr>
<td>Khomrah Thahakebah</td>
<td>10</td>
<td>0.12</td>
<td>12.9</td>
<td>4.43</td>
</tr>
<tr>
<td>Kilo14 North</td>
<td>10</td>
<td>0.23</td>
<td>13.3</td>
<td>5.02</td>
</tr>
<tr>
<td>Kilo14 South</td>
<td>10</td>
<td>0.26</td>
<td>13.6</td>
<td>5.06</td>
</tr>
<tr>
<td>Kilo15</td>
<td>10</td>
<td>0.15</td>
<td>14.9</td>
<td>3.37</td>
</tr>
<tr>
<td>Kilo16</td>
<td>10</td>
<td>0.18</td>
<td>15.3</td>
<td>4.11</td>
</tr>
<tr>
<td>Kilo18 North</td>
<td>10</td>
<td>0.09</td>
<td>16.9</td>
<td>4.18</td>
</tr>
<tr>
<td>Kilo 11</td>
<td>10</td>
<td>0.30</td>
<td>10.5</td>
<td>5.34</td>
</tr>
<tr>
<td>Montazohat</td>
<td>10</td>
<td>0.32</td>
<td>9.4</td>
<td>5.76</td>
</tr>
<tr>
<td>Nozhah</td>
<td>10</td>
<td>0.23</td>
<td>14.7</td>
<td>3.98</td>
</tr>
<tr>
<td>Quaizah</td>
<td>10</td>
<td>0.31</td>
<td>8.6</td>
<td>5.51</td>
</tr>
<tr>
<td>Rabwa</td>
<td>10</td>
<td>0.40</td>
<td>12.1</td>
<td>5.44</td>
</tr>
<tr>
<td>Rohab</td>
<td>10</td>
<td>0.30</td>
<td>7.8</td>
<td>4.56</td>
</tr>
<tr>
<td>Salmah</td>
<td>10</td>
<td>0.33</td>
<td>13.1</td>
<td>4.55</td>
</tr>
</tbody>
</table>

Table 5.5 - Density-diversity (BW=200m) of same age Jeddah spontaneous settlements compared with their distance to the historic core and their average meso-level accessibility.\textsuperscript{106}

\textsuperscript{106}Meso-level accessibility for a spontaneous settlement is gained by averaging the value of segment angular choice (radius 2000 metres) for all plots in that settlement.
Conclusion

The chapter first established that the geometric concept of accessibility mainly its consideration of the finer properties of urban fabric (such as street layout) is more suitable for the study of spontaneous settlements compared to the general concept of geographic accessibility. Other strengths of geometric accessibility – as a notion mostly developed in the field of space syntax – such as its theoretical and empirical accounts of movement flows, land use patterns and socio-economic issues are considered as its general strengths in urban studies.

The impact of meso-level accessibility mainly through the formation of an internal spatial structure has been illustrated on the dense placement (mainly the linear arrangement) of commercial land plots in the case study spontaneous settlements. The linear concentration of commercial land use with regards to higher-accessibility street segments (or the efficient placement) on the other hand was proven to be contributing to the formation of local centres while theoretically such efficiency should contribute to the economic gain of the dwellers and hence facilitate consolidation. At the end it was shown that the formation of local centres (measured through the mean diversity-density value in local level) is directly affected by how well the internal spatial structure of a spontaneous settlement is accessible from its surrounding urban context.

This empirical observation is in line with the economic and territorial preferences of spontaneous settlements’ dwellers – extracted from literature in the second chapter. It was observed that the settlements are constructed as close as possible to the globally accessible routes in the city and at the same time their internal areas are generally isolated from outside. While proximity to globally accessible routes can satisfy the economic preference of the dwellers

107 Also see the discussion by Hillier (2007) on the advantages of having a ‘well-defined’ variable for researches pertaining to built-environment.
the internal spatial isolation can respond to the territorial preference. In this context, what the internal spatial structure can do in the case of a non-small spontaneous settlement – where the commercial activity on the outward edges is not enough to benefit the internal areas – is to connect the inner areas to the surrounding urban fabric in a limited sense and as a medium: it brings the benefits of internal commercial activities to dwellers through higher accessibility in meso-level without undermining their territorial preference to remain globally isolated.

The empirical observation that the internal spatial structure along with the factor of time has a positive impact on the consolidation process leads to another question: what is the role of the so-called ‘irregular’ urban fabric of spontaneous settlements in the emergence of the internal spatial structure? Although space syntax theory of ‘city as an object’ (Hillier, 2001) predicts that the internal spatial structure emerges under any circumstances in spontaneous settlements the very particular accessibility pattern of these areas (city-wide spatial isolation) would still make it a dilemma. How come the two different properties (i.e. global isolation and meso-level structure) occur in the street network of spontaneous settlements? The clue should lie in the very particular aspect of their morphology i.e. irregularity but first it should be related to the notion of topo-geometric accessibility in the next chapter.
Chapter 6: Empirical examination of urban block fragmentation

Introduction

This chapter answers the questions raised at the end of the previous chapter regarding the role of the physical fabric irregularity in the observed accessibility pattern of the case study spontaneous settlements. The main aim of this chapter is to develop a definition of physical fabric irregularity –termed urban block fragmentation- that is related to the notion of geometric accessibility. This definition is founded on the geometric properties of urban blocks perimeter captured through innovative measurements of elongation and direction that treat the two aspects as integral aspects of a shape. With such a definition developed in this chapter then it will be possible to investigate -in the next chapter- how the internal spatial structure of the spontaneous settlements emerges while their overall city-wide accessibility remains low. The questions this chapter tries to answer are if the reported irregularity of spontaneous settlements can be quantified using the developed measure and how that measurement differentiates between these areas and the rest of the city.

As discussed in the second chapter, the physical morphology of spontaneous settlements shows distinct characteristics that could be attributed to the lack of formal planning control, their piecemeal growth process and illegal subdivision of land. These attributes could be qualitatively described as the lack of a geometrically regular layout for these spontaneous settlements along with a prevailing diversity in the size of built elements (mainly plots and buildings). These morphologic particularities are also in direct interaction with the street layout in the sense that streets are usually more meandering and sinuous in terms of their alignments with their junctions deviating from right angle while
the street width might vary along the same route. Moreover, the urban blocks seem to be smaller and show irregular geometries with some of those reaching very or indented perimeter outlines compared to the formal areas (For example, see the right tile in Figure 4.9).

One explanation on how internal spatial structure emerges in such irregular fabric is that the aggregation process of built elements might follow specific local rules that give rise to their global accessibility properties. This hypothesis will be investigated in the next chapter that reviews generative simulation models but a more fundamental question to answer before proceeding is that what attributes of urban built fabric might be related to these spatial attributes especially the observed pattern of geometric accessibility.

Thinking of the perimeter of urban blocks where the streets are defined in terms of direction and geometry suggests a clue. The relation between urban block size and shape with the configuration of streets was addressed by Hillier (2001) and will be reviewed again in this chapter but as could be understood from the previous chapters the phenomenon of live centres—the existence of small and convex urban blocks where local and global accessibility are simultaneously high—was not evident in the case study spontaneous settlement. So, the question is what other attribute of urban blocks is contributing to the emergence of a distinctively integrated structure of streets in a local level while decreasing the overall accessibility of a settlement from outside.

The answer—as the thesis conjectures—should be sought in the diversity of urban blocks’ direction (and elongation) in spontaneous settlements compared to the formal urban fabric. Although there are informal settlements that are following regular layouts such as grid-iron pattern (as chapter two referred to

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108 This was mainly because the local centers of the spontaneous settlements appear within the settlement and away from its highly accessible outward facing edges while the live centers—by Hillier’s definition (Ibid.)—are where the highest global and local accessibility overlap.
De Soto, 1989), the case spontaneous settlements in Jeddah and Zahedan show more dynamism and irregularity in their urban blocks that can contribute to the mentioned accessibility patterns.

The hypothesis

It was observed that the case study spontaneous settlements exhibit distinct accessibility patterns compared to their formal urban context. The main hypothesis of this chapter is then that the case study spontaneous settlements should be different from the rest of the city when the accessibility-related measurement of shape and direction is applied to them. In other words, using such measure of urban block shape direction to analyze and then statistically summarize the properties of urban blocks should allow for quantification of the so-called irregularity of spontaneous settlements against their otherwise formally planned urban surrounding. Such investigation has to take into account the particular issues related to the analyses of directional data that will be discussed in further detail here.

Outline

This chapter consists of two main parts. The first part sets the theoretical foundation for the application of shape direction measurement to quantify fragmentation of urban built-fabric and then develop the required mathematical definition for such measurements. The second part will apply the developed measure of directionality to sampled areas including both spontaneous settlements and the formally planned areas in the cities of Jeddah and Zahedan. The second part aims to show that the hypothesized fragmentation is observable in spontaneous settlements.
The first part will start with a brief review of fragmentation notion in different fields. This review indicates that fragmentation refers to the diversity in the properties of elements belonging to a larger whole. Considering the necessity of defining fragmentation with regards to accessibility then fragmentation of built fabric—the chapter suggests—should be defined with regards to the geometric attributed of urban blocks. To this end, a brief review of literature related to two-dimensional shape and direction measurement in different fields such as geography and built-environment studies will be presented. The review will show that general shape and direction measures fail to capture syntactic properties of streets that bound the shape of urban blocks. This shortcoming—the chapter argues—is mainly because these measures can not take into account the impact of the urban block’s boundary on its overall linear elongation and the direction to which this elongation happens. An innovative mathematical definition of shape linear elongation will then be developed to capture the magnitude and direction of its stretching with regards to the detailed geometry of its perimeter.

The second part of the chapter will apply the developed measure of shape direction to the urban blocks of the sampled urban areas in Jeddah and Zahedan. To eliminate the difficulties of representing the directional data when providing the statistical summary of each zone, special circular histograms called ‘double radar diagram’ would be used. Comparing the resulted plots for spontaneous settlements and formal urban areas show that fragmentation (i.e. the higher diversity in urban block direction) happens in the former group while the latter exhibits a more predictable pattern. A further step will also be suggested to devise more advanced measures of urban block fragmentation through weighting the directional analysis with the shape elongation measure directly. The chapter will end with questions raised about the interaction between urban block fragmentation and accessibility pattern in spontaneous settlements.


Fragmentation from the point of view of accessibility

This section will provide a context to connect the notion of geometric accessibility to the fragmentation of physical fabric in spontaneous settlements. Because the relation between accessibility and consolidation (as a socio-economic matter) is already established in the previous chapter, this section will focus on sole matters pertaining to the physical fabric of spontaneous settlements and how it might be related to accessibility.

Chapters 3 and 4 already presented aspects of irregularity in the physical fabric of spontaneous settlements of Jeddah and Zahedan mainly the variation in the shape of urban blocks as well as more meandering street alignments. The previous chapter showed that the overall global accessibility of the spontaneous settlements (measured through segment angular integration R=n) is generally low. Also it was shown that while the global accessibility is low within the settlements they usually have higher local accessibility in their internal areas.

A key notion to interpret all these particularities in the accessibility pattern, as the thesis posits, is the linearity of the street segments and the impact of urban blocks’ properties (i.e. geometry, direction and size) on that. Going back to the mathematical formula for accessibility in chapter 5 especially in segment angular analysis, the linearity of street network plays an important role in determining how accessible a street segment is. In other words, the less change of direction on a route the more it approximates a long line and hence more decreases in the topo-geometric distance to the rest of the urban street network is. This was subtly illustrated by Hillier (2001) that the few longer lines in the ‘deformed wheel pattern’ are contributing to the decrease of the global distance or more integration in an otherwise unintelligible background of many short lines. The increase of shorter lines in a system in is somehow equivalent to the breakage of longer lines where one has to change direction frequently for
travelling in the system the result of which is an increased (topologic) distance. Regarding this highlighted importance of linearity, space syntax research has rarely pointed to the impact of urban block directional and geometric properties on accessibility measures. This can be mainly attributed to a lack of measures of urban block shape and direction that can be related to the topo-geometric accessibility.

Having such measures of urban block shape and directionality would also be helpful in terms of quantifying the irregularity of physical fabric in spontaneous settlements. As Kemper and others (2008) argue, the building structures in spontaneous settlements show more diversity of directions compared to formal fabric but one cannot be sure about the effect of buildings on the accessibility of streets because the street limits are not defined by building footprints *per se* but by the limits of land plots that together make urban blocks. Can it be that urban blocks of spontaneous settlements also have diverse directions compared to the formal urban areas? This makes intuitive sense as the urban layout of spontaneous settlements tends to deviate from orderly pattern observed in formal areas and hence the meandering streets also leads to deviation from the orthogonal grid pattern that –generally- is oriented in two main directions that are perpendicular together.

This argument suggests that presumably such properties of urban block (i.e. elongation and direction) might be related to the accessibility of streets especially in topo-geometric terms where the direction of street segments is a major determinant of its distance from the rest of the network either in local or global radii. As a result the chapter will look at the frequency distribution of urban block directions as an indication of fragmentation in urban fabric but the exact mechanism through which topo-geometric accessibility and urban block fragmentation interacts will be explained in the next chapter.
The notion of fragmentation

Before proceeding further, a caveat should be made to explain why this property is called fragmentation. It is necessary to go back to the points made in chapter two and Gomes’ (2001) study where they argued that fragmentation is regarded as a statistically explainable diversity in the size of built-elements (i.e. the clusters of buildings). The weakness of such definition -similar to the aforementioned shortcoming in the work of Kempfer (2008)- is the difficulty in relating the geometrical properties of building or their clusters to the configuration of streets, accessibility and socio-economic matters. Nonetheless the idea of explainable diversity in statistical terms is a useful approach that can be applied to the urban blocks in order to relate their property to the measures of topo-geometric accessibility.

A brief review of the notion of fragmentation in different fields also suggests that fragmentation refers to the splitting of a larger entity into smaller pieces often in various sizes and characters that results in reduction of efficiency or integrity or lack of an overall orderly pattern. A familiar example is in IT where the larger entity is the memory storage the fragmentation of which leads to performance reduction; such interpretations can be observed in many other fields\textsuperscript{109}. The notion of fragmentation with the same connotations of subdivision of a whole to smaller entities is also used in other fields such as social studies (e.g. Allardyce et. al, 2005) that associate fragmentation with the singlehood in family status along with economic deprivation and lower mobility.

A closer definition of fragmentation (relevant to this thesis) can be found in the field of landscape ecology regarding the phenomenon of forest fragmentation:

\"Forest fragmentation results from patchwork conversion and development of

\textsuperscript{109} An advanced search in Britannica (2009) for the articles including the term ‘fragmentation’ results in 312 items belonging to the fields such as political studies, history (human and natural), geography, chemistry, behavioral sciences, communication, paleontology, biology, physics, economy, cultural and ethnic studies, astronomy, military, art, literature and so on.
most accessible and/or more productive sites, leaving the remaining forest in stands of varying size and degrees of isolation” (Harris, 1984). McGarigal and others (1995) also add to the previous definition by indicating that the above process also give rise to the forest islands of “smaller [size], geometrically more complex..., and more isolated”. This idea was also applied to the study of landscape fragmentation for which the application of FRAGSTAT (Ibid.) is developed to measure different properties of habitat patches such as size, density, edge and shape.

The reader is reminded that a definition of fragmentation applied to the spontaneous settlements by Sobreira and Gomes (2001) was also reviewed in chapter 2. Two useful points can be borrowed from their concept of fragmentation. One is that that fragmentation, although might appear as a chaotic amalgamation of entities at first sight, can be formulated in statistical terms. Secondly, and relevant to the previous point, such statistical description might, as in the case of complex systems in physics, be an indication of an emerging structure. As will be argued in the next chapter, fragmentation in urban blocks, while can be captured through statistical analysis, can also contribute to the emergence of a more distinct internal spatial structure within spontaneous settlements.

As a result of this discussion, the key issue to inspect regarding spontaneous settlements is the diversity in the direction of urban blocks. Such measurement while embedded in the concept of fragmentation can also be clearly related to the measures of topo-geometric accessibility. For doing so, there is a need to establish a measure of shape direction suitable for syntactic studies that is addressed in the next section.
**Shape measurement, shape direction and accessibility**

This section will put forward an innovative measure of shape (elongation) and direction applicable to physical urban fabric that can be related to the factor of topo-geometric accessibility as discussed before. This shape and direction measure is supposed to capture the overall direction of urban blocks and to quantify how elongated in a certain direction the urban block is; this is important because the urban block is influencing the overall direction of street -or axial- segments defined by its edge (Figure 6.1) so to calculate the overall urban block direction is like summarizing the overall direction of the street segments tangent (or ‘leaning’) to it. However, before carrying on with the development of such particular measure of shape, a background should be provided about the concepts of shape and direction measurements in the fields that are closely related to the urban morphological studies, i.e. geography and architecture. When it is necessary other fields such as computing will also be addressed.

**A brief background to the shape and direction measurement**

In the context of geographical analysis, O’Sullivan and Unwin (2003) give the following definition: “Aerial units all have two-dimensional shape, that is, a set of relationships of relative position between points on their perimeter, which is unaffected by changes in scale” (Page 177). MacEachren (1985) suggested that the aim of shape measurement$^{110}$–in the context of geographical studies- is to go beyond the verbal and qualitative descriptions to be able to come up with rigorous comparisons and analyses.

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$^{110}$ Also terms ‘shape analysis’ by Millier and Wentz (2003) as: “a body of techniques for analyzing geometric form” (Ibid.Page 585)
Adding to the above claim by MacEachren (1985), Wentz (1997) suggests that a shape measurement for geographical studies should follow some criteria according to literature. The qualities mentioned by Wentz (Ibid.) are as follow:

- Attributing different values to different shapes
- Applicability to both convex and non-convex shapes
- Being considerate of the existence of holes in a shape
- Independency of translation, scale changes and rotation
- Ease of applicability to geographic data
- The clarity of computing process
- Ease of data preparation and outcome interpretation
- Being intuitive regarding our shape cognition

However as Wentz (1997) reminds elsewhere the objective of shape measurement is different for various fields such as computing science and mathematics. Hence the above criteria might change slightly according to the particular objectives in each respective discipline. This is also the case for the objective of shape measurement in this thesis, i.e., to relate to the accessibility of street segments bounding the shape of urban blocks. Therefore, as the hole in urban block—as a private space— is not considered in geometric accessibility calculations, it is not a major issue in shape measurement here in this chapter.

Another point mentioned in the list by Wentz (1997)—reflecting a general approach to shape measurement— is its difference with issues pertaining to the overall direction or orientation. This can be inferred from the forth point indicating that the shape measurement should be independent of rotation. The distinction between shape and direction measurements as well as their relation is described as follow: “Shape is the spatial expression of an object, independent of its position, size, and orientation as a whole, but dependent on the position, size, orientation, and shape of each of its parts.” (Zhao and Stough, 2005). This study also accepts this distinction between shape and
direction measures. However, it argues that the two attributes are integral parts that should be considered and calculated simultaneously especially in enquiries relating to the top-geometric accessibility (see the reasons below).

In a wider sense of relating geometric accessibility (studied in the field of space syntax) to the shape measures, Shpuza (2006) points to a shortcoming: “Only a few measures proposed by space syntax research are aimed towards properties of shape per se, or can be modified and used to assess features of shape. The majority of studies in space syntax have aimed, on the contrary, towards analysis of space, often with a clear bias towards neglecting metrics.” (Ibid. Page 84). Because his research is confined to the architectural scale of office buildings and how the shape of boundary would affect the configuration of the internal space, he develops two measures of shape that address such problem. On the contrary, in the case of this thesis the shape of urban blocks are bounded by the spatial network of streets and the question is about the impact of shape on its surrounding spatial configuration.

An exception in space syntax research in relating the shape of urban blocks to the accessibility to their immediate street network is the work of Hillier (1999) on ‘live centres’ (see chapter 5) in which he reports the occurrence of smaller and more convex urban blocks around the city centres that happen along the globally more integrated streets that traverse through the same centre. The effect of smaller and more convex urban blocks is hypothesized by Hillier to increase permeability to facilitate further movement (Ibid.). However, because Hillier’s argument on accessibility was limited to geometric accessibility based on axial analysis (as opposed to the finer scale topo-geometrics accessibility using segment angular analysis), the finer aspects of directionality of both the streets and urban blocks are not fully taken into account.

The question of shape directionality or the overall orientation then should be dealt with as an outcome of summarizing the direction of its individual
outward edges because each edge of an urban block often defines and influences the axial line adjacent to it; more explanation in this regard will follow. As Turner and others (2005) propose, all possible axial lines can be drawn between each two inter-visible vertices (either convex or reflex) of an urban layout. It makes intuitive sense then that in an urban setting, where the street widths become narrow (Figure 6.1, left) the vertices are enclosed in areas that are parallel with the edges of the urban block and hence all the possible axial lines tend to be approximately orientated along the outward edges of urban blocks. This is to be contrasted with places like a plaza (Figure 6.1, right) where the vertices might be scattered and the direction of each possible axial line is not affected by the shape of the areas that encloses the vertices.

The more an overall direction of edges is towards a certain direction, the more elongated a shape in that direction is. It should be emphasized that a shape can deviate from an ideal compact shape (such as a circle) in two different ways: either by having a more jagged edges (or indentation) or by being stretched towards a certain direction as illustrated schematically in Figure 6.2.

While conventional shape measures of compactness such as the one proposed by Davis and Benedikt (1979) -that is the squared perimeter divided by area of the shape- can capture the overall deviation from convexity, these cannot indicate in which of the two ways the deviation is happening (elongation, indentation or both) while the overall direction of shape is not addressed by shape measures. This criticism is also applicable to more powerful compactness measures such as $\Psi_i$ that has been suggested by Batty (2001) in the context of visual field studies. He defines it: “as the ratio of the radius of an idealized circle associated with the actual area of the isovist [or the shape] to the radius of an idealized perimeter from the actual perimeter in question.” (Ibid. Page 129)
Lack of attention to the linearity is also evident in measures that pertain to the perimeter *per se* such as edge roughness (Wentz, 2000). Even the more advanced ‘trivariate’ method \(^{111}\) by Wentz (2000) treat elongation and indentation as separate aspects of the shape. In other words, the edge roughness and overall direction are calculated through two independent variables the interaction of which together is not considered. Because of this, even the trivariate measure mentioned before cannot capture how the overall shape elongation is affected by the finer geometry of its perimeter.

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\(^{111}\) The trivariate method is based on quantifying three separate mathematical properties of a shape that relate to its edge (perimeter smoothness or roughness), elongation (how stretched the shape is) and perforation (that has to do with the number and size of holes in that shape). For more detailed mathematical definition of each index see Wentz (2000).
On the other hand, measures focusing on the overall direction of shape tend to ignore the fine geometry of the perimeter and its impact on the overall direction. Instead, many of the shape direction measures use physical analogies such as the ‘moments of inertia’\(^{112}\) to calculate the direction of the shape that are irrespective of the fine geometry of the shape boundary. Instead, there methods are based on the overall area of the shape as mass. For example, in the work of Zunic and Rosin (2007) using a physical analogy the shape area is divided into pixels and assuming equal weight for each, the moments of inertia for those are calculated to gain the shape direction.

The only exception is the work of Zunic and Milos (2008) that highlights the weaknesses of orientation measures that treat the shape area as a homogeneous mass (they call it ‘area-based’ measures). They, then, develop a shape direction measure based on its boundary that is defined as the direction of the line that: “maximises the total sum of the squared lengths of the projections of all the shape edges” (Ibid. Page 1786) on itself. Although their measure, (applied in the field of pattern recognition) seems to make intuitive sense when applied to different shapes, it is problematic for geographical data sets such as urban blocks as the total sum maximizing function seems to be computationally laborious.

These are important shortcomings when dealing with the impact of shape of urban blocks on accessibility because the individual axial segments along the edges of each urban block are generally affected -as depicted in Figure 6.1- by the detailed geometry of the edges and the overall shape direction simultaneously. The thesis then develops a measure that captures the real elongation (i.e. considering the effect of all the perimeter edges on the shape boundary) and the direction to which this elongation is extended simultaneously and as integral aspects of the same entity.

\(^{112}\) See Ha and Moura (2003) for a critique of such measures although their own proposed measure is based on the same physical analogy.
Calculation of Normalized Summary Elongation Axis (NSEA)

The idea of treating the shape edges as vectors can be helpful in defining the measure of overall direction but this leads to the problem of directional data. As pointed out by O’Sullivan and Unwin (2003) the direction of lines are not ratios so one cannot compare those proportionally and the lines that reach both ends of the spectrum 0 and 180 are getting close in their direction (i.e. direction of 180 is the same as 0). The latter property as Mardia and Jupp (2000) discuss is an attribute of axial data\(^{113}\) the value of which is always between 0 and less than 180 degrees. For doing vector operations on axial data, Mardia and Jupp (Ibid.) suggest the values of directions to be multiplied by 2 that transform the axial data to ‘circular data’ that stands between 0 and 360 degrees. After transforming the lines with axial data to circular data it is possible to perform vector operations on those as each line has a length (or magnitude) and a direction between 0 and 360 degrees.

Compared to axial data, doing vector operations on circular data is easier to understand. For example having a set of observations, all with the same magnitude but with different directions (direction represented by \(\theta\) between 0 and 360 degrees), O’Sullivan and Unwin (2003) calculate their average direction by decomposing those into vertical and horizontal axes. Summing those up in each group of North-South (\(V_N\)) and East-West directions (\(V_E\)) is obtained from the following formulas:

\[
V_N = \sum \cos \theta \\
V_E = \sum \sin \theta
\]

Then the two resulted horizontal and vertical vectors are combined to get the overall mean vector represented by its length \(V_R\) and direction \(\theta_R\) as follow:

\(^{113}\) Not to be confused with ‘axial lines’ used to represent the streets in a geometric accessibility calculations.
\[ V_R = \sqrt{(V_N^2 + V_E^2)} \]

\[ \tan \theta_R = \frac{V_E}{V_N} \]

The shape boundary edges can be summarized in the same way through the above formula. The key is to transform each edge line on the perimeter of a polygon from axial data to circular vectors. Therefore, the direction of each segment \( \theta \) is multiplied by two as if that segment is transformed to a vector with the same length. This allows for the decomposition of all transformed vectors into horizontal and vertical axis to calculate the sum of their images on each main direction as was discussed above. Through adding the total horizontal and vertical vectors the summary elongation vector is obtained in directional format the direction of which can be transformed back to axial data by dividing its direction by two, resulting in a summary elongation axis in axial format (i.e. between 0 and 180). The length and direction of the summary elongation axis (SEA) can be calculated as follow:

\[ D_{SEA} = \sqrt{\left( \sum d_i \cos 2\theta_i \right)^2 + \left( \sum d_i \sin 2\theta_i \right)^2} \]

\[ \Theta_{SEA} = \left[ \arctan \left( \frac{\sum d_i \sin 2\theta_i}{\sum d_i \cos 2\theta_i} \right) \right] \times 0.5 \]

In the above formula \( \theta_i \) is the axial direction of edge line \( i \) on the shape edge, \( d_i \) is its length, \( D_{SEA} \) and \( \Theta_{SEA} \) are the length and the direction of the summary elongation axis (SEA). SEA in this sense is a single line entity -and not a vector- that represents how linear an object is stretched and to what direction.

The calculation is easy to perform in GIS applications as the urban blocks can be approximated to polygons comprised of edge lines on their perimeter for which the direction and length are easy to extract. The only problem is the size dependency of this measure as it is not dimensionless. This can be easily solved by dividing that to the perimeter of the polygon. This is resulted in the normalization of measure of \( D_{SEA} \) but has no effect on its direction:
\[ D_{NSEA} = \frac{D_{SEA}}{\sum d_i} \quad \text{and} \quad \Theta_{NSEA} = \Theta_{SEA} \]

In the above formulae \( D_{NSEA} \) and \( \Theta_{NSEA} \) are representing the length of the normalized summary elongation axis and its orientation.

To simplify the representation, henceforth, the two aforementioned normalized measures of \( D_{NSEA} \) and \( \Theta_{NSEA} \) are shown in turn with the Greek alphabets of \( \Xi \) and \( \Theta \):

\[
\Xi = \frac{\sqrt{\left(\sum d_i \times \cos(2\theta_i)\right)^2 + \left(\sum d_i \times \sin(2\theta_i)\right)^2}}{\sum d_i}
\]

\[
\Theta = 0.5 \times \tan^{-1}\left[\frac{\sum d_i \times \sin(2\theta_i)}{\sum d_i \times \cos(2\theta_i)}\right]
\]

In the above equations:

\( \Xi \) is shape elongation equal to the length of the normalized summary elongation axis,

\( \Theta \) is the shape overall direction between 0 and 180 degrees,

\( \theta_i \) is the direction of the \( i \)-th edge of the original shape (between 0 and 180 degrees),

And \( d_i \) is the length of the \( i \)-th edge of the original shape.

It should be emphasized that the calculation is based on the assumption that the perimeter of each two dimensional shape can be approximated to a continuous set of edge lines. In this way a circle can be represented as a polygon while the number of its vertices is dependent on the resolution by which the approximation is done. In actual GIS procedures the higher resolution results
in a closer approximation but also increases the data volume due to the higher number of vertices. This issue and reaching an optimized resolution is a matter of generalization parameters set in GIS applications.

**Initial observation on the developed measures**

According to these formulas, one can predict that the more even the perimeter of shape is broken into edges that are vertical to each other, the less the measure of Ξ. For all the symmetrical geometric shape such as circle (assuming that it can be approximated by a polygon with a large number of edges), square and other symmetric polygons such as hexagon, decagon and etc. the measure is zero. For a hypothetic linear shape like a rectangle with its smaller dimension reaching zero, the measure of Ξ tends to reach 1 but in actual situations it never does. Going back to Figure 6.2, this measure can represent the elongation of different shapes with sensitivity to the way that their perimeter is spread. In other words, the measure Ξ captures the edge roughness or otherwise linearity of a shape that is impossible to infer from compactness measures.

In terms of visualizing the measures of Ξ and Θ, because the two are different attributes of a single ‘summary elongation axis’ of a shape, the best way is to draw the axis itself on each urban block. An example of this representation is shown for a part of Aziziyah spontaneous settlements in Jeddah and its adjacent formal fabric in Figure 6.3 below. Although there is no specific location for the ‘normalized summary elongation axis’, to visually assign that to the shape of its urban block, its midpoint can be placed on the centroid of its reference shape as shown in the same Figure. Another point about the length of NSEA is that as the measure is dimensionless (see the formula for Ξ), it does not have any unit hence for its visualization a proper graphic scale should be selected.
Figure 6.3 - Visual representation of ‘Normalized Summary Elongation Axes’ for Aziziyah spontaneous area in Jeddah (left to the red dotted settlement boundary) and its adjacent formal urban fabric (right side). The NSEAs are represented by black lines.

Although Figure 6.3 is just a visualization example, a couple of important observation can be made on that. First, it can be seen that the measures of $\Xi$ and $\Theta$ assigned to NSEA makes intuitive sense: each shape gest an NSEA along its main direction to which it is stretched while the NSEAs’ lengths are relative to the overall elongation of each shape. For more convex shapes the NSEAs become shorter which also points to lower $\Xi$ value. The second observation is that NSEAs in the spontaneous fabric have a higher diversity of orientations while in the immediate formal area they seems to be in major two perpendicular directions influenced by the grid-iron street network. This
suggests that the term ‘fragmentation’ with its connotation of diversity can be used to describe the irregularity of urban blocks in spontaneous settlements. However, to see if such fragmentation prevails in other areas of Jeddah and Zahedan the same analysis along with its statistical summary will be done in next sections.

The difference between elongation and compactness

Before proceeding with the extensive analyses of both cities a point should be clarified about the distinction between the elongation measure of $\Xi$ developed in this chapter and the conventional classic measures used in the field of geographic analyses. Using a compactness measure such as $\Psi$ (Batty, 2001) in conjunction with $\Xi$ one would realize that they work in opposite ways considering an ideal convex shape of a circle. The former is 1.0 for the circle while the latter is 0. It can be shown that by keeping the compactness constant, the more indented the perimeter, the smaller the $\Xi$ will be (see Figure 6.4). This preliminary observation can be the base for developing measures of urban block porosity as keeping the compactness measure constant while increasing the elongation results in less porosity on the perimeter of shapes.

Figure 6.4 - A comparison of different non-convex shapes with almost the same measure of compactness $\Psi$ (illustrated with blue fonts) while their elongation $\Xi$ (red fonts) increases$^{114}$.

$^{114}$ The five shapes used in the illustration are actual urban blocks from Zahedan city.
The next section will examine the urban blocks of Zahedan and Jeddah in terms of some existing measures of shape and compare it to $\Xi$ and $\Theta$. The aim will be to compare the spontaneous settlements with the rest of the urban context in each city.

**Fragmentation analysis of the spontaneous settlements**

This section will apply the above measures of shape direction $\Theta$ to the urban blocks of studied cities of Jeddah and Zahedan. The measure of shape elongation $\Xi$ although is not statistically summarized for the analyzed areas, it would be discussed towards the end of the chapter to understand its impact in combination with directionality. This is to say that the calculation of $\Theta$ will be enough for statistical summary of the frequency of urban blocks’ direction for both respective groups of spontaneous settlements and formal urban areas.

The data used for the analysis for both cities are in GIS format. Urban blocks for both Jeddah and Zahedan are defined by the outward edge of contiguous defined land plots. Because the calculation of $\Xi$ and $\Theta$ is dependent on the number of edges on the shape boundary (or the vertices on the perimeter), both groups of urban blocks in Jeddah and Zahedan went through a GIS generalization process to merge the vertices closer than a minimum distance (i.e. 1.0m) while keeping the overall shape of the polygons more or less the same. This was done in order to reduce the computing cost of the next stages.

Since, for selecting the sampling areas, it was not affordable to run the analysis for the whole urban system of Jeddah, a few spontaneous settlements were chosen randomly along with the formal urban fabric around those blocks up to the limits bounded by major arteries or wide streets (the defined zone is called ‘mega-block’ here). As a result, the statistical analysis will aim at comparing the frequency distribution of urban blocks orientation between each
spontaneous settlement and its immediate formal urban fabric within the same mega block as a sampling zone.

For Zahedan because the urban system is smaller and it is possible to calculate the elongation and directional measures (Ξ and Θ) for all the urban blocks, all of the spontaneous settlements were processed. Moreover, because the settlements are all more or less on the periphery, almost in all cases there is no settlement that is completely surrounded by formal urban fabric (or a mega block). As a result the statistical comparison will be between the zone including all spontaneous settlements and major formal zones in the city that have more or less equal surface area.

The statistical method used for this analysis should be further explained here before applying it to the case studies. To summarize the frequency distribution of axial data the problem again is that the directions of 0 degree and 180 degrees are the same. If someone then ‘wraps’ the frequency distribution histogram around a circle to match 0 and 180 degrees the problem would be the visual comparison between histogram bars and the original axial data as each angular value of an observation is doubled in the histogram. The left radar diagram in Figure 6.5 illustrates this problem as it shows the sample green and blue lines representing the axial data observations are not parallel with their corresponding green and blue histogram bars.

A way to avoid the above problem is to keep a frequency histogram between 0 and 180 degrees and copy it with the same order between 180 and 360 degrees to make a complete circle. This method is used by Kempfer and others (2008) for statistical summary of buildings’ direction in urban studies. The resulted histogram is called ‘double radar diagram’ here and will be used to summarize the orientation of urban blocks throughout this chapter. The right histogram in Figure 6.5 illustrates such double radar diagram the bars of which and their related axial data observations are visually parallel.
Figure 6.5 - Two methods for summarizing axial data orientation are applied to a sample of two lines (each one of the blue and green lines in the above frame constitutes 50% of total observations). In the left radar diagram the histogram representing the axial directions between 0 and 180 degrees is wrapped around a circle. In the right diagram the histogram between 0 and 180 degrees is repeated to make a ‘double radar diagram’.

The urban block analysis for Zahedan

After calculating the measures of Ξ and Θ for all of the Zahedan urban blocks, three distinct sampling zones were defined that include more than half of all the urban blocks. These three zones are in turn ‘spontaneous settlements’ (990 urban blocks), ‘the old city’ defined by the city growth boundary until
1956 (386 blocks) and finally the ‘south-west formal’ zone mostly comprised of planned housing developments (1230 urban blocks). The three zones totally cover 2606 blocks out of 4030 urban blocks in Zahedan data set. The total area of urban blocks in each one of the three above zones is in turn 659.8 ha in the spontaneous zone, 272.5 ha in the old city and 897.3 ha in the south-west formal zone.

While the definition of ‘spontaneous’ zone is based on the very distinct morphologic characters as well as the available surveyed boundaries, I outlined the ‘old city’ by using the available aerial photos from different times. The ‘south-west formal’ zone was also selected based on both the growth history (areas mostly expanded after 1975) and morphologic features (mainly having orderly layout geometry and the least meandering boundary). The three aforementioned zones are presented in Figure 6.6 below.
The same figure also shows a few very large urban blocks with nearly no built-up structure in those that were excluded from the analysis because the focus of the research is mainly on the physical fabric irregularity.

After calculating the shape direction measure of $\Theta$ for all the sampled urban blocks, the results were summarized in a ‘double radar diagram’ to show the frequency distribution of urban blocks direction (Figure 6.7). To eliminate the effect of different sample sizes in the three zones in each radar diagram, every frequency distribution was standardized as if the total number of urban blocks was 100 in each zone and then the count on each direction is shown as the percentage of occurrence in each one of the 90 bands (in the double diagram it becomes 180 bands). The diagram is shown below in Figure 6.7.

![Figure 6.7 - The double radar diagram illustrating the percentage of occurrence of urban blocks’ directions ($\Theta$) in each one of the three sampling zones: The old city (green plot), spontaneous areas (orange plot) and the south-west formal development (blue plot).](image)
The above radar diagram suggests that the south-west formal zone (the blue graph) has the most predictable pattern in terms of urban block direction inferable with a skewed distribution happening close to the east-west axis. The old city has also a generally predictable pattern with its urban blocks mainly stretched in two direction perpendicular to each other that is inferable from the (cross-shape) star appearing in green colour. In contrast, the orange graph representing the spontaneous settlements shows less skewed distribution although still two slightly distinct spikes in east-west direction are evident. The more convex shape of the double radar graph for the spontaneous settlements can be interpreted as more diversity in the direction that was already termed ‘urban blocks fragmentation’ in this chapter.

The urban block analysis for Jeddah

Doing the same measurement of urban block direction for Jeddah required a different sampling zone definition as has been introduced as mega-block. Therefore, four mega-blocks were selected each one including both spontaneous and formal urban fabric that are in turn Rabwa (zone 1), Aziziyah (zone 2), Ruwais (zone 3) and Eastern mega-block (zone 4). The central spontaneous settlements\textsuperscript{115} are also important in terms of age and location and the analysis of urban block fragmentation can be insightful if applied to those. However, because of the complexities of their immediate urban fabric\textsuperscript{116}, it seems difficult to define a mega-block boundary around those.

\textsuperscript{115} This group includes the eight central spontaneous settlements of Sahifah, Amariyah, Kandarah, Baghdadiyah, Sherafiyah, Sabeel, Hindawiyyah and Balad.

\textsuperscript{116} These complexities arise mainly from the contiguous arrangement of these settlements, the very sinuous shape of the coastal line in their vicinity, the adjacency with the city historic core (that resembles the spontaneous settlements in its morphology) and the existence of large transport/warehouse facilities in their close distance. These factors together make it difficult to define a homogenous buffer inclusive of the formal urban fabric around the central spontaneous settlements.
Therefore, and as an exception, the group of central spontaneous settlements will be analyzed without comparison to its immediate formal fabric as the fifth sampling zone. Still, such analysis can support the conjectures on the occurrence of urban block fragmentation in the spontaneous settlements. A summary of the number and area of the analyzed urban blocks is illustrated in Table 6.1 and their location is reflected in Figure 6.8. Again, the urban blocks with no built-up structure in those were excluded from the sampling zones.

Before proceeding with the analysis a point should be made about the sample sizes reflected in Table 6.1. The total number of sampled urban blocks in the formal fabric although is about one third of urban blocks in the spontaneous settlements, their total area is about three times the spontaneous settlements. This is mainly due to the smaller urban size of urban blocks in the spontaneous settlements. Overall the existence of one spontaneous settlement in zone 1, two in zone 2, one in zone 3, four in zone 5 and eight in zone 5 (overall 13 spontaneous settlements ranging from central to peripheral locations) make sure that a wide and diverse range of these areas are examined.

<table>
<thead>
<tr>
<th>Zone ID</th>
<th>Sampling zone</th>
<th>Total block count</th>
<th>Total block area (ha)</th>
<th>Formal block count</th>
<th>Formal block area (ha)</th>
<th>Spont. block count</th>
<th>Spont. block area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rabwa</td>
<td>2,570</td>
<td>800.7</td>
<td>993</td>
<td>707.7</td>
<td>1,577</td>
<td>93.0</td>
</tr>
<tr>
<td>2</td>
<td>Aziziyah</td>
<td>2,881</td>
<td>931.1</td>
<td>1,506</td>
<td>846.1</td>
<td>1,375</td>
<td>85.0</td>
</tr>
<tr>
<td>3</td>
<td>Ruwais</td>
<td>2,116</td>
<td>521.2</td>
<td>1,167</td>
<td>471.1</td>
<td>949</td>
<td>50.1</td>
</tr>
<tr>
<td>4</td>
<td>Eastern</td>
<td>4,494</td>
<td>634.5</td>
<td>690</td>
<td>355.7</td>
<td>3,804</td>
<td>278.8</td>
</tr>
<tr>
<td>5</td>
<td>Central</td>
<td>3,698</td>
<td>283.9</td>
<td>0</td>
<td>0</td>
<td>3,698</td>
<td>283.9</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td>*15,634</td>
<td>*3,130.5</td>
<td>*4,231</td>
<td>*2,339.7</td>
<td>11,403</td>
<td>791.8</td>
</tr>
</tbody>
</table>

* these totals are calculated without double counting of the formal urban blocks in the overlap of zones 2 and 3.

Table 6.1 - Comparison of urban block sampling zones of Jeddah.
Similar to Zahedan, the direction measure of $\Theta$ was calculated for each urban block and then these were statistically summarized for each sampling zone. The double radar diagram for each mega-block then illustrates the frequency of $\Theta$ values for spontaneous settlements and its immediate urban fabric in two respective but overlapping graphs. The result for Rabwa mega-block is shown in Figure 6.9 below in which the green plot represents the formal urban fabric and the cyan plot summarizes urban block directions for Rabwa spontaneous settlement itself.

Figure 6.8 - The location of major sampling zones in Jeddah. Spontaneous settlements included in the statistical summary of urban block direction have red colour while the other spontaneous settlements are shown as pink areas.
To illustrate how the statistical summary works, a block direction map illustrating the NSEAs for Rabwa mega-block is shown in parallel with the radar diagram in Figure 6.9 (the next radar diagrams will be shown without reference to their urban layout maps). As can be seen the spikes on the formal fabric plot (green star-shape outline) are stretched in the same two orthogonal directions that the formal urban blocks are orientated that are almost north-south and east-west axis with slight counter clock-wise rotation. Again to overcome the sample size variation in spontaneous and formal block sub-samples, the frequencies are expressed as the percentage of total counts in that respective sub-sample (there are 90 directional bands that are represented as 180 bands in the double diagram).

The double radar diagrams for the five sampled zones (Figures 6.8 to 6.10) indicate that the urban blocks in spontaneous settlements exhibit more change of direction reflected in the more convex outline of their plots compared to the -generally- spiky pattern of the formal area plots. However, this contrast has different degrees and in a sample like the eastern zone (zone 4) the two plots of formal and spontaneous blocks direction are closer to each other in terms of their shape. The other observable point in the presented radar diagrams is that despite the mentioned contrast in plot shapes of formal and spontaneous sub-samples in each zone, their overall peaks (or spikes) are parallel. In other words, although the plots reflecting spontaneous settlements have slight extensions as bumps, these bumps are in the same direction as the sharp spikes on the formal fabric graph for the same zone. According to this observation it can be speculated that the spontaneous settlements are adopting the overall predominant urban block direction of their surrounding formal fabric but at the same time weaken this predominant pattern through their own urban block fragmentation.
Figure 6.9 - The double radar diagram for Rabwa mega-block (left) and the NSEA map for the same zone (right). In the graph the spontaneous settlement blocks are summarized by a cyan plot and the formal fabric is represented with a green plot.

Figure 6.10 - The diagram summarizing sampling zone 2 (Ruwais mega-block, purple plot for spontaneous and blue plot for formal urban blocks). Right diagram does the same for zone 3 (Aziziyah mega-block, blue plot for spontaneous and cyan plot for formal urban blocks).
Figure 6.11 - The left diagram summarizes the sampling zone 4 (Eastern mega-block, brown plot for spontaneous and orange plot for formal urban blocks). Right diagram does the same for zone 5 (central spontaneous settlements)

The hypothetical impact of urban block elongation

The reader might wonder why I have not addressed the length of NSEAs or Ξ as the measure of shape elongation when discussing the fragmentation. For example, this can be the case that the double radar diagram is simplifying the directionality issue by just counting the urban blocks in each direction regardless of their elongation (i.e. a thin linear shape and a convex shape slightly stretched in one direction are both counted as one entity in the radar diagram). The main purpose for this simplification is to facilitate the performance of shape and direction analyses for different samples. However, lack of attention to shape elongation can be easily solved by ‘weighting’ the double radar diagram with the elongation measure of Ξ for each direction band. The result is shown below for the settlement of Rabwa (both the simple count and the weighted radar diagrams). As can be seen, there is not much difference between the two. Further development of the weighted method and its
application to the case study areas goes beyond the limits of this study but suggests a potentially promising line of research enquiry in understanding the morphology of cities.

Figure 6.12 - The simple count double radar diagram for Rabwa mega-block and the same analysis weighted by the elongation measure (length of NSEA or Ξ) on the right. Spontaneous blocks are represented by the cyan plot on left and purple plot on the right diagram.

Another point should be reminded here regarding the statistical summary technique to detect urban block fragmentation. Although the thesis has used qualitative interpretation of the double radar diagrams to highlight the diversity of urban blocks’ direction, there are also well-defined measures of central tendency applicable to the axial and circular data that has been developed in the field of ‘directional statistics’ (Mardia and Jupp, 2000). Such measures could be applied to quantify the skewness or dispersion of values in the radar diagrams allowing for accurate comparison between different samples but because the observed patterns in the diagrams were clear enough for proving the fragmentation of spontaneous settlements comparing to the formal urban fabrics, such statistical measures have not been used here.
Conclusion

The chapter has developed a concrete mathematical method of measuring shape elongation and the direction to which its elongation happens. The two measures of elongation (Ξ) and direction (Θ) are both calculated simultaneously and as integral aspects of a single entity (i.e. the NSEA). Based on the calculation method -that concerns the shape overall elongation from the point of view of its perimeter edges- the developed measures were supposed to be related to topo-geometric accessibility. The aim of relating the measure of shape direction and accessibility was to show that spontaneous settlements are distinct as urban zones in exhibiting particular accessibility pattern as proved in the previous chapter for case study spontaneous settlements. As a result, the hypothesis in this chapter was that an accessibility-related measure of shape should be able to also make distinction between these areas and the rest of the city. Such distinction -generally termed as physical fabric irregularity – was marked for the spontaneous settlements through the higher diversity of the urban blocks’ direction that was specifically termed ‘urban block fragmentation’ in this chapter.

Considering the empirical observations of chapters 4 and 5 it can be summarized at this point that urban block fragmentation and particular accessibility pattern (especially the internal spatial structure) coincide in the case study spontaneous settlements. The question would now be about the mechanism through which the two properties might be related. The next chapter will be an attempt to answer this.
Chapter 7: A heuristic approach to fragmentation and accessibility

Introduction

This chapter is an attempt to understand the relation between empirically observed attributes of spontaneous settlements in the previous chapters. The two main attributes are urban block fragmentation and the internal street structure with high values of topo-geometric accessibility in intermediate urban level (or ‘meso-radius’). In addition to the internal spatial structure of the streets it was also observed that the overall accessibility of case study spontaneous settlements is low in the city-wide level (or when using the ‘global’ radius).

Relating accessibility and urban block fragmentation is a major task in line with the main aim of this thesis i.e. understanding the way through which physical fabric irregularity and consolidation interact in spontaneous settlements. On one hand, consolidation was shown to be influenced positively by higher topo-geometric accessibility in intermediate radius. The higher accessibility street alignments in this radius mainly manifested themselves as the internal spatial structure of the spontaneous settlement with measureable impact on the attraction of commercial land use. On the other hand, chapter 6 quantified the physical fabric irregularity of spontaneous settlements using the concept of urban block fragmentation. This meant that the diversity of urban blocks’ overall direction in the examined spontaneous settlements was more than the rest of otherwise formal fabric of the city. A caveat is necessary here that developing the measure of urban shape direction $\Theta$ in chapter 6 aimed at capturing the impact of urban block fragmentation on the topo-geometric
accessibility of its immediate streets. Because the exact mechanism (supported by empirical evidence) for this impact has not yet been clarified, this will be done as part of this chapter.

The main hypothesis of this chapter is that fragmentation while lowering the global accessibility of spontaneous settlements facilitates the emergence of a distinct internal spatial structure in the intermediate level. For testing this hypothesis the chapter takes a different approach from the previous chapters that is more of an experimental nature. In other words, while the previous chapters used statistical correlation between well-defined variables as the way to test their hypothesis, this chapter will perform experiments on heuristic urban layouts to understand the overall relation between fragmentation and accessibility. The main idea underpinning the experimental approach of this chapter is the idea of space syntax models as ‘tools to think with’ (Hillier and Hanson, 1984) which mainly refers to the exploratory power of space syntax models in addition to their real-world practicality. Based on this approach one can understand the hypothetic mechanisms through which accessibility patterns of urban space change under certain conditions (for example in the case of this chapter the affecting condition is the fragmentation of urban blocks)

**Outline**

Relating the two main concepts of fragmentation and accessibility the chapter starts with a basic discussion on the notion of emergent urban structures in space syntax research. A brief review will show that many aspects of space syntax reference to the deformed wheel pattern as an emerging phenomena would comply with the approach of complexity theory to cities. However, because there is not a well-established theoretical ground in urban studies to include both respective fields (i.e. complexity and space syntax), space syntax theoretical approach will be chosen as the basis for this chapter’s argument on
the emergence of internal spatial structure (or the deformed wheel pattern) in spontaneous settlements. As a result, the experimental methods developed in space syntax field (called ‘Basic Generative Process’ or BGP) will be reviewed which aim at exploring the local rules of urban development that give rise to the globally distinct structures in human settlements. The latest amendment by Hillier (2001) to the BGP model to generate the deformed wheel grid formation will also be reviewed which includes an introduction of ‘centrality law’ into the simulation process. However, because there is no examination of centrality law in actual computer applications, an experimental computer simulation done by the author on a simplified version of BGP will support Hillier’s hypothesis on the emergence of deformed wheel grid.

As a complement to the discussion on BGP and due to addressing the main issue (i.e. the effect of urban blocks orientation diversity on street network accessibility), the chapter uses a different experimental approach to carry on. In this stage, and after establishing that the internal spatial structure emerges in spontaneous settlements in the previous stage, the impact of fragmentation will be ‘designed’ into some heuristic layouts representing spontaneous settlements. This impact, based on a brief empirical observation done in this chapter, can be simply built into the axial models by ‘bending’ the street network. After running accessibility analysis on the bended axial models representing the spontaneous settlements, it will be observed that fragmentation while decreases the overall accessibility of a settlement in a city-wide level, can give rise to the emergence of a more distinct internal spatial structure in the intermediate urban level. The chapter concludes by summarizing the implications of fragmentation for the consolidation process.
The concept of emergence in space syntax urban studies

Although the issue of complexity was addressed in the second chapter it will be briefly readdressed here due to its relevance. On one hand and as was mentioned the term complex refers to the systems that their larger order is the result of interaction between its many constituent components in micro-level. Presuming cities as complex entities then, their global order in many cases can be conceived as the outcome of aggregated actions that happens by agents (such as citizens, households or developers) in a local level without being aware of or intention to create the emergent global order.

The mentioned emergence of deformed wheel pattern also is described by Hillier (2001) as to be without any large-scale plan and as a result of following local rules in aggregation of urban built-form (for further explanation see the Basic Generative Process below). This makes the deformed wheel pattern similar to the descriptions of complex urban phenomena. Moreover, many aspects of the emerging deformed wheel structure are also described with terms pertaining to complex systems (see the terms in apostrophes in the following quotation):

“However, the fact that most settlements evolve over long periods compels us to the view that the patterns arise from a largely ‘distributed’ or ‘bottom-up’ process, that is, from multiple interventions by many agents over time. Even if single agencies are involved, then even so the fact that settlements evolve over such long periods implies that the process of settlement generation must be regarded as an essentially distributed one.” (Hillier, 2002, Page 9)

The above similarities (between the attributes of deformed wheel structure and other complex urban phenomena) however have not led to the formation of a single theoretical framework to include both space syntax and complexity study fields. Because developing such overarching framework would go beyond the capacity of this thesis, the space syntax theories would be used
throughout this chapter as the theoretical and methodological base for the chapter although whenever possible the similarities between the two theoretical realms (especially when debating their generative modelling techniques) will be addressed. Taking space syntax theoretical approach as the basis for the debate the question is then how the deformed wheel pattern as a globally distinct structure is formed. Answering this question, space syntax research has developed experimental modelling techniques to explain this emerging phenomenon that will be discussed in the next section.

**The Basic Generative Process (BGP)**

The Basic Generative Process was first envisaged by Hillier and Hanson (1984). Their aim was to reproduce the piecemeal growth process at the end of which the resulted fabric (i.e. their studied south France villages) exhibited orderly patterns in the settlement-wide global level. Despite lack of large-scale planning, Hillier and Hanson (Ibid.) observed rules governing the local level aggregation of built elements and open spaces: all buildings are arranged evenly along ring-like routes each one directly connected through its façade to an open space. These ring routes (called ‘beady rings’) although looked various in their width were almost invariant between the settlements-like settlement-wide structures that ensured access to all dwellings while increasing the permeability and route choice.

Knowing that these beady rings came about without any *a priori* design and just resulted from the aggregation of buildings by following the observed local rules, Hillier and Hanson inferred, by application of such local rules to a simulated aggregation process, the same global pattern should be generated: the model to do so was called the Basic Generative Process (BGP) by the same authors (Ibid.)
Their early BGP model hence was a simplified version of the settlements based on an orthogonal tessellation of equal squares. It consisted of two basic elements that were coupled through a face-wise joint: closed and open cells representing building and open spaces respectively (the couple makes a ‘dyad’ together). The aggregation rule is simple and indicates each dyad is added providing that firstly its open cell is joint face-wise to another dyads’ open cell and secondly its closed cell should not joint another closed cell on its vertex (see Figure 7.1, the left side). The process is easy to perform manually using playing cards and a randomizer mean like dice or to run in simple computer applications as the author’s own experiments show in Figure 7.1 (the script for this simulation is included in appendix 2).

Figure 7.1 - Schematic illustration by the author showing the early BGP rules of aggregation devised by Hillier and Hanson (1984) to generate ‘beady rings’. Open spaces face-wise joint is circled by green oval while the refrained vertex-vertex joint has a red circle. The result of such process as generated by computer algorithm is shown on the right.

117 The computer simulation is done in StarLogo software (Resnick, 1994) by the author.
The early BGP model was further developed and altered by other researchers and Hillier in different contexts. For example Salah-Salah (1987) used BGP for a study of North African Islamic cities in her doctoral study. By adjusting the basic rules of dyads’ aggregation she then managed to replicate what she described as the dense and fragmented urban fabric of the case study settlements in terms of characteristics of built fabric (e.g. diversity in the size of plots) and street network topologic accessibility (i.e. the lack of integration core and an overall low accessibility).

Also Erickson and Lloyds-Jones (1997) created three derivates of the early BGP to generate different aspects of spontaneous settlements’ morphology that were in turn 1- the simultaneous formation of streets and buildings immediate to each other 2- the changes of land use in buildings along a fixed street network and 3- the process of land subdivision and built-up increase in a urban blocks already defined by streets. Although the three models incorporate more sophisticated rules and parameters (as well as having more geometric flexibility that allows deviating from orthogonal tessellations), neither of the three models aim at generating a well-defined global order in terms of accessibility pattern such as the deformed wheel structure.

The task of tinkering with BGP aggregation rules to achieve the deformed wheel structure was initiated by Hillier (2001). He based his approach on the observation that the deformed wheel structure is nearly an invariant amongst world cities while the local geometry of urban layout is adjusted to the cultural needs of each place and hence is variable. He concluded then that the two issues are the results of interplay between two forces of socio-cultural and micro-economic natures: while the former causes the differences by imposing restrictions on the local geometry of streets (mainly in residential areas) the later -due to its functional requirement to overcome cultural limitations for social mixture and interaction- tends to extend as central loci for markets and exchange in a city-wide global scale that creates the deformed wheel pattern.
Hillier (2001) then returns to the early BGP model to see what rules it requires in order to generate the observed invariant global structure of cities.

What conditions are overlooked by the early BGP to do so, answers Hillier (2001), is addressed by inferring and then application of two spatial laws of placing objects the in space. These two laws are the laws of ‘compactness’ and ‘centrality’. The law of compactness is relates to the way that closed built elements such as buildings are aggregated to form urban blocks and is more used by socio-cultural forces that try to put certain limits on local movement in favour of defining residential areas. The law of centrality is a mean through which the micro-economic forces are shaping the overall structure of a city. To follow the centrality law, when adding a dyad, one should try not to block the longer lines of sight and movement in the BGP iterations as Hillier (Ibid.) suggests.

What he achieves by the manual application\textsuperscript{118} of the above rules to the amended BGP version was very close to the deformed wheel structure (Figure 7.2). Moreover, the layout he generates using the semi-random process is exhibiting the same distribution of axial line length observed by Hillier in the actual cities that is comprised of many very short lines and a few very long lines.

\textsuperscript{118} What Hillier (2001) does not specify was if the amended experiment was done in any computer software or manually but because he does not point to the computing algorithms it is more likely that he used the first method. Because BGP models can be done using simple means (e.g. playing cards and dice) this does not mean his outcome is not valid but to run it in a computer simulation is a stronger proof that the aggregation rules are objective. This is why the author runs a simplified version of BGP to do so in this chapter.
As a result and to confirm that introducing the law of centrality to the BGP model leads to the formation of deformed wheel pattern the author runs an experiment with StarLogo software\textsuperscript{119}. To implement the centrality law (i.e. not blocking the longer lines of sight and movement when adding buildings) and instead of using dyads of open and close cells, the simulation uses the close cells only that are shown as yellow cells in Figure 7.3 (left); in other words the layout is just formed through the application of centrality law in building placement while no vertex-to-vertex joint allowed between those. The vacant space that is left between the buildings is considered as the public open spaces while the coverage ratio of the whole surface can be controlled by putting a limit on the number of total buildings\textsuperscript{120}.

\textsuperscript{119} See appendix 3 for further details and StarLogo scripts of this experiment.

\textsuperscript{120} Using dyads of open and closed cells ensures the continuity of streets in BGP but when conjoined with the centrality law makes the model very complicated to the degree of halting the growth process in StarLogo environment.
Although the open space loses its continuity at some parts during the simulation (i.e. non-accessible courtyards are made), all the generated layouts of which a sample is shown in Figure 7.3 (left) tends to have less building density in their central parts with extension of open space network -although in a deformed manner- along the central axes of the container space. This pattern might not seem as clear as the Hillier’s overarching cross-shapes street pattern in Figure 7.2 but looking more closely one can find out that in the sampled generated layout of Figure 7.3 (left) open spaces exhibits a kind of structure when compared to the layout with the same density that is solely generated with non-vertex joint rule shown in Figure 7.3 (right). Initial syntactic analysis comparing two groups of generated layouts (i.e. using centrality law and without) suggests that the former are more intelligible when simple axial analysis is performed on those\textsuperscript{121}.

It is a noteworthy point to consider that some of the similarities between BGP as a heuristic modelling technique developed in space syntax field and other modelling techniques routes in complexity theories of cities. Erickson and Lloyds-Jones (1997) points to the fact that the early BGP model used by Hillier and Hanson (1984) has similarities with Cellular Automata that are widely used in simulations of complex systems\textsuperscript{122} mainly in terms of the two-dimensional tessellation and the application of local rules. Even StarLogo application used by the author to implement the centrality law in a simplified BGP model is basically a multi-agent platform developed for the study of complex systems. As was mentioned before an overarching theoretical

\textsuperscript{121} For the purpose of comparison two groups of layouts were generated, each including 10 separate layouts. The same tessellation of 48 by 48 cells was used as the empty base for all the layouts and 600 buildings were placed in that empty base to generate each respective layout following the no-vertex-joint rule. For the first group of 10 layouts the centrality law was also applied using 20 moving agents (see appendix 3 for detail) while for the second group only the no-vertex-joint rule was applied. The intelligibility measure for the first group (calculated as the correlation coefficient between axial connectivity and axial integration) was averaged around 0.85 while for the second group it was 0.54.

\textsuperscript{122} Some aspects of complexity theory and its reliance on computer to simulate the myriad of local interactions in a complex system were addressed in chapter 2. Cellular Automata (CA) and Multi Agent Simulation (MAS) are some of the computing methods used to do so. The reader is referred to Batty (2005) for a comprehensive review of these methods.
framework to include space syntax and complexity urban studies does not exist but the resemblances and compatibility in their experimental modeling methods would suggest that the approaches share many common grounds.

Figure 7.3 – The left tile shows the simplified BGP simulation outcome with buildings coloured as yellow. There are 608 buildings placed in a 47 by 47 cells container space. The placement of 608 buildings with no application of centrality law is shown on the right (the rule of no-vertex-to-vertex-joint is still applied in the right tile).

Because the aim of this chapter is not to show how the deformed wheel pattern is shaped in human settlements, the above review of BGP models is considered sufficient to support the next steps. A basis can be established here though and that is the formation of deformed wheel pattern as an emergent structure in cities can happen through their piecemeal growth process and just by following local rules of built-fabric aggregation. Hillier’s empirical observation (2001) and the above experiment with BGP model show that there is a key rule ensuring the emergence of deformed wheel that is the centrality law. The argument can also be extended to spontaneous settlements, in that the gradual and not globally planned formation process of these areas is not a barrier to the emergence of the deformed wheel pattern as the empirical observations of
chapter 5 would support this claim by proving the existence of an internal spatial structure in those.

However, BGP model has limitations with regards to the questions of this chapter (especially urban block orientation). This is mainly due to its underlying two-dimensional tessellation that gives it some degrees of geometric rigidity. Although there has been attempts to overcome this such as in the reviewed work of Erickson and Lloyds-Jones (1997) but even using such techniques for diversifying the urban blocks orientation requires more parameters that adds to the models’ sophistication.

To deal with this problem and as a shortcut solution, the chapter incorporates the aspects of fragmentation into experimental urban layouts that are made of axial lines only (so the urban blocks are schematically defined as bounded islands between the axial lines). This will allow for isolating the impact of fragmentation on street network accessibility in an exploratory manner that will be done in the next section.

**The design of the heuristic experiments**

Before carrying on with the experimental stage a clear relation should be made to the empirical observations in the previous chapter: what is the impact of urban block fragmentation on the street network to be reflected in the experimental layouts? An intuitive answer would be more orientation diversity of the street (axial) segments but such assumptions should be validated first.

For doing so, the mega block of Rabwa is selected here (this mega-block was previously used for sampling urban blocks in chapter 6). Because Rabwa mega block includes both spontaneous and formal fabrics, the axial segments of both categories can be compared in terms of orientation. It is recalled here that the
urban blocks of Rabwa spontaneous settlement were proven to be more diverse in orientation comparing to their immediate formal urban blocks (previous chapter -Figure 6.9). Would the axial segments of this spontaneous settlement be more diverse in their orientation similar to its urban blocks?

![Figure 7.4 - Double radar diagram summarizing the orientation of axial segments in Rabwa mega-block. The orientations for both categories of spontaneous axial segments (orange plot) and the formal axial segments (blue plot) are represented as the percentage of total axial segment length for that category in one of the 90 directional bands.](image)

This is shown in Figure 7.4 below were the axial segments of each category of streets (i.e. spontaneous and formal) are summarized in terms of their orientation. The double radar diagram in this Figure show what percentage of total street segments length in each respective categories of spontaneous and formal areas are directed towards. Those are 90 directional band (each one covering an interval of 2 degrees) that are represented as 180 bands in the double-diagram and as can be observed the formal axial segments have a more
skewed distribution that is similar to the urban blocks orientation pattern (compare to Figure 6.9, previous chapter). On the contrary, the axial segments in the spontaneous settlement have a more even distribution in all directions that is again parallel to the observed urban block fragmentation in the same area (Figure 6.9, previous chapter). This suggests that urban block fragmentation –as agreeing with intuition- can result in higher diversity in axial-segments’ direction while in formal areas the streets tend to keep their linear continuity in one of the two orthogonal directions. The diversity of axial segments direction in spontaneous settlements can then be interpreted as interruption to their linear continuity (or linearity).

The implication of the above empirical observation for the following experiments can then be stated here. The designed layouts representing spontaneous settlements should reflect the urban block fragmentation as interruption to linearity. The reader is reminded that in topo-geometric accessibility calculation, linear continuity (or a straight connection) between axial-segments means less change of direction and hence less angular depth. In opposite way, the more deviation from linearity (for example as a result of diversity in axial-segments’ direction) can increase the overall depth in street network of a settlement. This suggests that to simulate the impact of urban blocks fragmentation on streets’ accessibility it is enough to interrupt the linearity of their adjacent street network in a way that the overall change of direction increases. The designed experimental urban layouts then will have to incorporate such interruption or ‘breakage’ of linearity to resemble the actual fragmented fabric of spontaneous settlements. The geometrical solution to include such breakage will be explained shortly but first the basic axial models should be provided.

\[123\] See the accessibility mathematical formulations by Hillier and Iida (2005) and Appendix 1.
The experimental axial layouts

To start the accessibility analysis of a hypothetic spontaneous settlement the section starts with a simple orthogonal grid (also called ‘Manhattan’ or ‘grid iron’) with 64 urban blocks of 40 meters by 40 meters. The block size is just for illustration purpose and inclusion of metric aspects in the analysis\textsuperscript{124}. The grid representing the street network is also designed to make an overall symmetric square outline of 320 meters by 320 meters (overall area of 10.24 hectares) while the total street network length running between the urban blocks is 5,760 meters\textsuperscript{125} that can be divided to 144 axial line segments of 40 meters. Because the above grid is to be used as the base for generating other layouts in the next stages of this chapter, it will be referred to as the ‘basic layout’ from now on. The layout is shown in the below figure representing a hypothetic urban settlement (Figure 7.5).

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{basic_layout.png}
\caption{The basic layout representing the street network of a hypothetic settlement.}
\end{figure}

\textsuperscript{124} The metric size of the blocks is larger than the average urban block size of Jeddah spontaneous settlements but smaller than the average size in Zahedan spontaneous urban blocks.

\textsuperscript{125} Because this is a schematic urban layout, there is no consideration of street widths in it.
Alterations and accessibility analysis of the experimental layouts

Before carrying on with the analyses a point should be made about the software used for these. Because of the need for very precise measurement of symmetric layouts, the application SEGMEN version 0.64 Beta (2009) was used that also has different segment angular measurements of accessibility. The version used for the analyses (version 0.64, year 2009) although is slow for processing large urban systems but insures high scientific accuracy especially for symmetric layouts with small size devised in this section.

Analysis of the basic layout

Running the simple angular segment measures of accessibility on the basic layouts in SEGMEN (Iida, 2006; 2009) can only be done in five metric radii of 100, 200, 300, 400 meters and radius infinity. Amongst these radii the study will focus on two radii of infinity as the global radius and 300 meters as the intermediate radius (when helpful, radius 100m is also used as the local level)\(^{126}\). Using GIS software it is also possible to visualize the accessibility values assigned to the axial segments as illustrated in Figure 7.6 that is done for the measure of angular-segment choice in intermediate and global radii.

\(^{126}\) The basis for this definition is partly derived from the system size on which the analyses are run that is slightly different from the definitions in the empirical chapter 5 in which 400m and 2000m were in turn local and intermediate radii.
Figure 7.6 - Segment angular choice analysis for the basic layout using two respective radii of infinity (left) and intermediate (right). The logarithmic values for each layout are scaled between 0 and 1 and then visualized with equal range scheme.

As agreeing with intuition one can find in the above figure that the spot with high value of choice in intermediate radius (300m) is confined to the central urban blocks with decreasing grades when reaching the peripheries. Moving along each street, the axial segments closer to the middle have a higher values comparing to the street ends. For the global measure of choice (radius infinity) the spatial pattern is similar to the intermediate radius except for a considerable increase of values for the segments around the middle of axial lines.

The integration value is slightly different in that its magnitude for the street segments is directly affected by proximity to the geometric centre of the layout (Figure 7.7). The intermediate radius (300m) for integration measure is less concentrated on the geometric centre and more distributed but follows a clear concentric grading that decreases toward the settlement outward edges (Radius infinity analysis not shown here)
Bending the basic layout

The above observations on the basic layout indicate that the symmetric layout also leads to symmetry in the accessibility values while show slightly different patterns when comparing betweenness (or choice) versus closeness (i.e. integration). The reader might argue that the analyzed basic layout is more similar to the formal urban areas in that the urban blocks and streets are oriented in two major orthogonal directions. To makes the layout similar to the fragmented fabric of spontaneous settlements (and study its effect on the emergence of internal spatial structure) it is then required to interrupt the linearity of streets as was discussed above. The breakage of linearity can be done by bending the respective axial segments along each urban block from its midpoint as shown in Figure 7.8.
Figure 7.8 - The bended axial segments are shown in red while the original layout is represented by thick black lines. The amount of bending in this illustration is 30 degrees. Note the urban blocks transformation from square to a butterfly shape.

Although the bending increases the total network length slightly, in topological sense it doubles the number of axial segments (and hence doubles the node-count in the graph calculation) that is the more important effect as it makes it difficult to compare the accessibility values of segments from the original and bended layouts because of various system sizes\textsuperscript{127}. Apart from this, it is still possible to compare the relative distribution of values in both respective systems through visualizing those for the axial segments. Regardless of the above concerns, it is still possible to compare the bended layouts with each other to see if interrupting the linearity of streets would influence the accessibility and if the answer is positive, how this would happen relative to the bending ratios.

\textsuperscript{127} Also the axial segment lengths are halved as each segment is divided to two by bending.
The effect of bending on accessibility

For testing the effect of linearity interruption, first five layouts extracted from the basic layout are created for which the bending angles include 5, 10, 15, 30 and 42.5 degrees (Figure 7.9). After running the accessibility analysis using SEGMEN application, the average integration value (Radius infinity) for all axial segments in each layout were calculated separately. The significant and strong correlation between mean integration for each layout and the bending ratio (Figure 7.10) agrees with the qualitative observation in Figure 7.9 that there is an inverse relation between the two: the more bending, the deeper the layout will become (Figure 7.10).

Figure 7.9 - Bending ratios of 5, 10, 15, 30 and 42.5 degrees applied to the basic layout. The same scale is used for visualizing segment angular integration values for all the layouts so the more integrated layout comes up with warmer colours.
The significance of the above observation should be emphasized here. The reader is reminded of the lower accessibility of spontaneous settlements in their wider context that was highlighted as generally low segment angular integration in radius infinity (Figure 5.5, chapter 5). Accordingly, the overall lower integration of actual spontaneous settlements –that makes them appear like segregated patches in global analysis- can then be attributed to the fragmentation of their urban blocks.

**Figure 7.10 - Regression analysis between the bending ratios in degree and mean integration (radius infinity) for the five layouts shown in Figure 7.9.**

To illustrate this, as shown in Figure 7.11, a bended layout (30 degrees) with overall 360m by 360m dimension is wrapped with a simple orthogonal network representing the formal fabric following the observation in Jeddah. While the larger urban blocks of the hypothetic formal street network (1600

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128 A critical area to model is the outward edges of the settlement or where formal and spontaneous fabric meet; because in most of the observed cases (especially in Jeddah) the bounding alignments are of planned nature, the axial lines around the settlement boundary are not bended to resemble the formal arterial roads that go tangent to the settlements.
sqm as opposed to average 400 sqm for the spontaneous fabric) means to resemble the studied cases, maximum possible streets from formal fabric are connected to the alignments from the spontaneous settlement. Despite this connectivity, and running the segment angular integration analysis, it is observed that the streets from the schematic spontaneous area come up as a low accessibility patch similar to the empirical cases (Figure 5.5, chapter 5). Although the urban blocks sizes are for illustration purpose in this layout but it can shed light on the way that fragmentation isolates spontaneous settlements from the wider city. This kind of layout (and its other derivatives) that has two network patterns of spontaneous settlement (as the core) and surrounding formal street network (as the periphery) will be called ‘wrapped’ layout from now on as opposed to the basic layout that has just one pattern of street network.

Figure 7.11- Segment angular integration analysis of a wrapped layout with the bended network (30 degrees) representing a spontaneous settlement in its core. A buffer of simple Manhattan network representing the formal urban fabric surrounds the hypothetic spontaneous settlement.
The wrapped layout and its emerging internal structure

This might be argued that the spontaneous settlements are not simply inaccessible in all radii and as was predicted by the amended BGP model (Hillier, 2001) and also observed in chapter 5, there is an internal spatial structure that emerges in those. How would fragmentation relate to that? To answer this, and knowing that the emergence of deformed wheel pattern within spontaneous settlements is a plausible scenario, a designed layout should reflect such condition.

Pursuing this idea does not require a drastic measure such as superimposing a set of longer lines (or the ‘spines’ of the deformed wheel) on top of the bended layout; on the contrary, a very slight decrease of bending (or inclining back towards linearity) would be enough to form the spine(s). This is shown in Figure 7.12 in which just 20 connected axial segments in the spontaneous area of the ‘wrapped’ layout (analyzes in Figure 7.11) are selected in a cross-shape arrangement with a lower bending ratio of 16 degrees while the rest of the segments maintain a bending ratio of 30 degrees. The cross-shape arrangement is just a schematic configuration to resemble the deformed wheel and its location with regards to the whole layout is also indicated in Figure 7.12.

After running the segment angular analyses of accessibility for the above layout the results are noticeable. The set of 20 segments with less bending angle gains more values both in intermediate radius (300m) and regarding both measures of choice and integration appearing as an internal spine (integration thematic image is shown in Figure 7.13). In both measures the spine is distinct as it seems like it drags the higher accessibility value towards itself\textsuperscript{129}.

\textsuperscript{129} The resulted pattern in the basic layout illustrated in Figure 7.7 in which the integration measure was more distributed (comparing to choice) is also observable in the later experiment in which the integration values tend to keep an overall increasing grading towards the geometric centre of the layout although the asymmetric placement of the spine would affect the overall asymmetry of the accessibility value distribution. To allow comparison, the bended layout without the spine is also included on the left side.
Figure 7.12 - The straightening of 20 axial segments (red colour) in the bended network representing the internal structure of a spontaneous settlement. The spontaneous settlement is wrapped in a simple orthogonal network similar to Figure 7.11.

Figure 7.13 - The schematic spontaneous area from the core of the wrapped layout is visualized for segment angular integration values in intermediate radii (300m) once with homogenous 30 degrees bending (left) and once with the straightening of 20 segments (right).
The significance of the above experiment is that it can emphasize the role of directionality in the emergence of deformed wheel pattern. The superimposition of longer axial lines over a set of shorter lines by Hillier (2001) was addressed before in chapter 5 as part of his attempts to explain the role of deformed wheel pattern to maintain the intelligibility of settlements through its expanded linearity. As a complement to Hillier’s argument, and regarding the irregular fabric of spontaneous settlements, the later experiment (Figure 7.13) shows that linearity is still the key notion that give rise to the spatial structure in such areas. However, because the urban block fragmentation makes it difficult to find long straight alignments in spontaneous settlements, linearity can even be achieved by less bending (or straightening) of routes comparing to the more fractured network in their vicinity.

It should be reminded that using the ‘wrapped layout’ in the analysis of Figure 7.13 has advantages in that it resembles the empirical cases with no cutting of the street network on the settlements’ outward edges that can create an edge effect in the accessibility analysis (i.e. lowering the values on the edges as a result of not being surrounded evenly from different directions by other streets). Therefore the analysis in Figure 7.13 the settlement outward edge has even a high value due to its relation with the wider network both on the spontaneous side and the formal side that is not shown in the figure.

The whole wrapped layout with its in-built internal spine is also presented in Figures 7.14, 7.15 and 7.16 using the angular-choice measure in global, intermediate and local levels respectively (R= n, R=300m and R= 100m). As can be observed the overall distribution of accessibility values have a considerable resemblance with the analysis of the actual settlements especially from Jeddah that were presented before (see Figure 5.6 – the fifth chapter, the positive impact of street network linearity on the ease of navigation and way finding was also shown by Conroy (2001) in her PhD study. She showed through experiments in immersive virtual environments that breaking the linearity of street network in an urban layout would result in longer time for finding a certain destination. The more linear urban layouts, on the other hand, were shown to be more intelligible and easier to navigate by the participants.
spontaneous settlement of Rabwa as an example). Based on such similarity, further interpretation of the analyses done on the wrapped layout with its internal spine can help with understanding the accessibility patterns observed in the empirical cases and hypothesizing the impact of fragmentation on those patterns. The interpretations follow in the next paragraphs.

In the global level of choice measure (Figure 7.14), there are some important points that can be inferred from the analysis. Firstly, the internal structure (or the straightened spines) is not very distinct and just a slight increase of choice value can be observed around it while the overall global accessibility is low within the spontaneous settlement’s street network. Instead, the strongest alignment in choice radius infinity analysis, are the outward edges of the settlement. The strength of edges can be partly attributed to their central location in this particular layout but the adjacency of settlements with high
value choice routes (as the settlement ‘leans’ to such alignments) was also reported in both groups of case studies in Jeddah and Zahedan where the edge-oriented commercial activities were happening.

![Image of segment angular choice analysis](image)

**Figure 7.15** - Segment angular choice analysis (R= 300m) of the wrapped layout with an internal structure designed into the spontaneous areas.

In the intermediate level choice analysis (R=300m), the distribution of high accessibility values amongst the street is slightly different. While still the spontaneous settlement’s outward edges are still have strong betweenness accessibility, its internal network seems to be more accessible in intermediate level comparing to the formal street network outside the settlement. Moreover, the internal structure is very distinct with its preset and schematic cross-shape through high values of choice that is as strong as the outward edges in their accessibility values. This distribution of choice values in intermediate level also has strong resemblance with the analyses of real spontaneous settlements where their internal spatial structure was picked by choice measure (see Figure 7.15).
5.4, chapter 5) where generally higher concentration of commercial activities was found.

In the local level of choice analysis, the image is nearly the inverse of the global radius analysis and while the settlement is highly accessible in radius 100 meters, the surrounding formal context is much lower in comparison. Also the outward edges are not highly accessible in level and the inner parts of the spontaneous settlement seems to have their high values due to the smaller size of urban blocks, the internal spine is the dominating alignment due to its stronger linearity that dominates the rest of the inner settlement axial segments in terms of high local choice value.

Going through the above choice analyses and their similarities with the actual situation around the case study spontaneous settlements, it can be understood that fragmentation is a key factor with strong impact on the accessibility pattern in different urban scales. While in global level fragmentation isolates the settlement from outside, in intermediate and local levels it compensates indirectly by preparing the condition for the emergence of a distinct internal structure. Although the smaller urban block size can be considered as the main reason for high local accessibility in spontaneous settlements, fragmentation creates inequalities in linearity that differentiates the structuring spines from its background. Finding that the internal structure is as accessible as the outward edges of the settlement in intermediate level also suggests that it can accommodate commercial and public activities necessary for sustaining local centres without increasing the overall global or intermediate accessibility of a settlement (such increase might happen theoretically if the internal structure is aligned with a highly accessible route in global level such as the ones that run tangent to the spontaneous settlement’s outward edges).
Figure 7.16 - Segment angular choice analysis (R=100m) of the wrapped layout with an internal structure designed into the spontaneous areas.

To sum up, urban block fragmentation while decreasing the overall global accessibility of a spontaneous settlement makes the local street network sensitive to slight increases of linearity in the streets so an alignment little less meandering than the rest can play the role of the internal spatial structure through its increased local accessibility (mainly highlighted by analysis of segment angular choice).
Conclusion

The chapter showed that urban block fragmentation in spontaneous settlements can influence the accessibility pattern of their street network. The mechanism through which this happens is mainly through increased diversity of the axial segments’ orientation that in turn interrupts the linear continuity of street alignments. This breakage of linearity was built-in the schematic layouts representing spontaneous settlements through bending their street network to simply replicate the observed increased angular depth due to fragmentation. The bending of street network (as an abstract representation of fragmentation) was shown to decrease the overall accessibility of the schematic spontaneous settlements.

Beforehand an in this chapter it was also shown that the emergence of deformed wheel pattern is theoretically possible and empirically observable in spontaneous settlements. What happened to the deformed wheel when appeared as the internal spatial structure of a fragmented spontaneous settlement was also illustrated here: fragmentation would make it possible for the local spine to remain meandering similar to the generally irregular geometry of a spontaneous settlement and yet it gains more meso-level through slight increase of its linearity relative to its surrounding street fractured alignments. It should be reminded that the addressed ‘distinctiveness’ of the internal structure is not exactly the same as the higher meso-level accessibility which was hypothesized to have a positive impact on consolidation in chapter 5. However, it is reasonable to assume that the more distinct the internal spatial structure from its surrounding fragmented street network, the higher the accessibility measures assigned to its street segments should be. Moreover, it can be concluded from the experiment that fragmentation has two different aspects: while it segregate the settlement globally, it does not impede (if it doesn’t help with) the chances of having a meso-level internal structure.
Having a meso-level structure then it is possible to connect the highly accessible street network to the global level (in a limited sense) without undermining the global isolation of a spontaneous settlement.

The heuristic experiments of the chapter and their results can now be seen in the light of the thesis theoretical framework (developed in chapter 2). In other words, it is now possible to see the fragmentation of spontaneous settlements in relation with the preferences of dwellers in spontaneous settlements and the consolidation process. This will be done in the concluding chapter that comes next.
Chapter 8: Conclusion

Here the contributions made by the thesis in different areas, limitations of the study, the future works to overcome those limitations are highlighted. Before going through the above issues, there is a need to synthesize the finding from different chapters to gain an overarching statement about the studied spontaneous settlements.

Overview

The thesis illustrated an approach to spontaneous settlements in which their fragmentation and consolidation are related to each others through the notion of accessibility. On one hand fragmentation influences the accessibility pattern of spontaneous settlements (i.e. lowering global integration and making distinct internal structure in intermediate level). On the other hand, accessibility (along with other factors such as the city-wide settlement’s location and age) was shown to be influencing the socio-economic issues underlying the consolidation process. As a result, and regarding the core hypothesis of this dissertation set in the first chapter- it can be claimed that fragmentation can have a positive impact on consolidation process. Even if according to the reviewed conventional views of physical irregularities, fragmentation does not help with consolidation directly, the thesis showed that in long term the two issues of consolidation and fragmentation are not contradictory.

For example the conventional views claim that irregular features such as the variety and narrowness of road widths would decrease the accessibility of spontaneous settlements leading to its deprivation. The thesis does not deny
this but using the developed notion of fragmentation, it was shown that such low access is more evident in city-wide level where movement to a settlement is from the wider formal city. While such high global accessibility can undermine the dwellers’ territorial preference at the same time such it might increase the land value and chances for redevelopment. As a result the lower global accessibility due to the observed fragmentation has advantages for the dwellers in securing their position over time.

In local and intermediate levels, it was also observed that fragmentation does not create barrier for the emergence of an internal spatial structure while the accessibility levels are higher than the global accessibility in these none global levels. This means that the street network would carry higher levels of movement mostly generated from the spontaneous settlement itself and its immediate areas which might also be amplified by the generally higher population density of these areas. The internal spatial structure would then organize this high level of local traffic, activities and social interactions through accommodating public and commercial land uses. The intensity and concentration of these land uses manifests itself as strong local centres that are indicative of an ongoing consolidation process (as opposed to a declining neighbourhood).

Overall it can be said that fragmentation as one of the major aspects of morphologic irregularity with socio-economic implications, can influence the course of consolidation positively. The internal spatial structure -while not impeded by fragmentation- can help with the fulfilment of the economic preferences through supporting well-integrated local centres that simultaneously benefit from their local accessibility to the cheap labour131 and higher accessibility in an intermediate level to urban customers. On the other hand, fragmentation can keep the city-wide accessibility of the settlement low.

131 This low cost of labor is due to the cheap property and low land values that are partly resulted from the generally lower global accessibility of the spontaneous settlements.
that can be in favour of the territorial preference of the dwellers to benefit from cheap and secure dwelling. The difficulty in accessing the settlement from city-wide level would also render it unfavourable by the formal transport means such municipality service cars that further mount to the unpopularity of these areas for formal investment in housing and commercial development. There might be cases that too much global inaccessibility of a settlement coincides with the weak internal spatial structure the result of which is very likely be a degrading condition but highlighting such negative impact of fragmentation requires solid quantification of fragmentation through application of directional statistic dispersal measures that goes beyond the capacity of this thesis (see proposals for future work below). This and other limitation will be summarized later on in this chapter but before that a discussion to complement the above hypothesis will follow.

A complementary synthesis

Regarding the mentioned hypothetic process of consolidation put forward by the thesis, an alternative view can be provided here. The aim of presenting this different view is to discuss the scientific genuineness of the hypothesis in the next section. The hypothesis indicates that consolidation process of spontaneous settlements is affected by the two major factors of time and (geometric) accessibility. The accessibility factor in turn was hypothesized to be influenced by the fragmented morphology of spontaneous settlements. In other words, for the same age settlements, consolidation, accessibility and fragmentation make a one-way casual chain influencing each other (i.e. fragmentation influences consolidation).

Moreover, it was discussed in chapters 2 and 7 that spontaneous settlements show properties of urban complex systems. One distinct property of such urban
complex systems is the existence of positive feed-back loops that sustain self-organization (Allen, 1997). In this relation, one might think of the above mentioned casual chain of consolidation-accessibility-fragmentation in a different way consisting of a feed-back loop that is usually observed in self-organizing systems. This requires finding a mechanism through which fragmentation is directly or indirectly influenced by consolidation. In other words in such hypothetic process the increase of local centres’ strength (i.e. consolidation) should increase the diversity of urban blocks orientation (or fragmentation). Detecting such process in an empirical sense was not in the capacity of this thesis but a theoretical relation can be established by using the medium of geometric accessibility in the following paragraph.

Accordingly, it can be suggested that in spontaneous settlements the increase of local centres’ strength leads to an increase of the local movement ratios as these centres act as movement generators due to their higher intensity of urban activities. The generated movement flows then lead to further demand for the expansion of road network that leads to its development in different directions in a spontaneous manner (termed ‘street orientation diversification’ here). The street orientation diversification—to some degrees—is similar to ‘Siksna process’ (Hillier, 1999) in which the splitting of larger urban blocks into smaller and more convex shapes happens to facilitate more intensified local movement around urban centres. The difference between Siksna process and the hypothetic orientation diversification of spontaneous settlements should be noted here: while the former manifest itself in the size and shape of urban blocks around major urban centres the latter is related to the orientation of street segments and urban blocks around local neighbourhood centres. Nonetheless, detecting the process of ‘street orientation diversification’ in an

132 It should be emphasized that feed-back in a complex system is not performed in a top-down manner by a centralized entity (such as command centre) but is a global self-adjustment mechanism that is resulted from the distributed interactions amongst the numerous system components (Resnick, 1997).
empirical sense requires time series data including maps or aerial photos of spontaneous settlements that was not available to this study.

**How scientific is the hypothesis?**

The above argument on an alternative or rival hypothesis brings the chapter to a wider discussion addressed by the philosophy of science. The question is how genuinely scientific the hypothesis of this study is in relating consolidation and fragmentation.

A characteristic of a scientific theory -as Popper (1968) argues- is its falsifiability that is its acceptance in a tentative way and after being examined against other rival theories; the advantage of that theory over others –according to Popper- does not imply that it will constantly survive as the only explanation; instead it will be repeatedly tested in different contexts through further research until anomalies are found which necessitates alternative hypotheses. From a methodological point of view there are many ways through which the hypothesis of this study can be falsified to meet the Popper’s criterion. Being falsifiable in this regard, does not mean that a theory is wrong but indicates that it can be replaced by more ‘fit’ theories through future research or critical revisions.

Having the falsifiability agenda in mind, the first idea to re-examine the hypothesis of this study with is the issue of fragmentation itself. There might be spontaneous settlements that despite their incremental and unplanned growth process, does not show the irregularities observed in the cases of this thesis (i.e. settlement in Jeddah and Zahedan). For example, the street network in a spontaneous settlement might follow very orderly grid-iron pattern which can result in less diversity of the orientation of urban blocks (i.e. less fragmentation). There might also be cases in which a spontaneous settlement reaches a consolidated stage without developing strong local centres (such as
the case of Poshteh Garage area in Zahedan, see chapter 3). In such cases instead of having local centres within the settlements as the economic contributors to the neighbourhood, the economic advantage comes from proximity to job-providing areas such as workshops and industries.

There are other similar points to reject the hypothesis relate to the geometric concept of accessibility due to the limitations with space syntax theories and techniques. Although space syntax approaches make use of dynamic simulation techniques like BGP, they do not pay due attention to the dynamic interaction between built elements (e.g. urban blocks and building) with space in an empirical sense. This shortcoming is mainly due to the major focus of this field on the spatial configuration which implies the treatment of road network as a fixed entity when analysing it. Even in the analyses done in this thesis in which urban built elements are considered in conjunction with the road network, there is not enough attention to the gradual interaction of land use with the road network; this was partly because of the absence of chronologic data (such as time series settlement maps) and partly due to the above shortcoming of the space syntax theoretical framework. Instead the thesis assumes that the process of commercial land use clustering has been influenced by a property of the road network (i.e. its accessibility) but not the other way around. This shortcoming can lead to weaknesses in explaining why the accessibility in the internal area of a spontaneous settlement might have changed as the result of feed-back effect from the buildings and their land use.

Overall, in cases where fragmentation or strong local centres are not observed in a consolidated spontaneous settlement other hypotheses might be developed mainly based on the factors of time and accessibility to amenities outside the settlement. In such cases and providing the availability of extensive chronological data (such as snapshots of settlements physical condition and the socio-economic status of households in a consistent format) more extensive use of complexity simulation techniques can be deployed to develop dynamic
models of consolidation. In such simulation models the dwellers’ status can interact with a variety of physical factors in a two-way manner where feedback loops reflect the impact of socio-economic improvements on urban built-form, land use and road network. The main concern with such model should be the inclusion of various factors and the resulted level of sophistication. Nonetheless, such model –based on extensive empirical evidences- will be able to explain how consolidation as an emerging order would result in a community and their environment.

The contributions

The thesis based its approach on finding gaps in the existing literature in one main field and some other fields of secondary importance. The core area of contribution was the developed theoretical framework to include consolidation and urban block fragmentation. Although consolidation was measured through its physical features as a proxy (i.e. density and diversity of land use) but it was an indicative of a process including non-physical factors of socio-economic nature. The key idea to relate consolidation and fragmentation was to use the notion of geometric accessibility as a medium that can be considered as one of the main contributions of the thesis.

There have been other fields in which the thesis has genuine findings and innovations or alternatively tried to fill the gap in some specific fields:

- The study of Middle Eastern cities and their overall spatial structure along with features observable in other Third World countries. Although the Ford and Griffin model used for the two studied cities was adopted from the context of the Latin American cities but that was, as the thesis showed, has the ability to explain most of the general characters of
Middle Eastern cities in macro-level using its underlying notion of geographic accessibility.

- Quantifying consolidation by using a modified definition of morphologic density-diversity to measure the strength of local centres. Comparison with other socio-economic and physical data showed that local centre strength is a fair proxy for consolidation.
- The usage of statistical methods (such as Gini measurement) to detect the internal spatial structure of spontaneous settlements. This was mainly done through measuring the impact of street network accessibility on commercial land use distribution.
- Proposing a new definition for morphologic fragmentation based on the directional diversity of urban blocks. The definition of each urban block’s overall direction is also founded on a unique mathematical formulation that was developed in this thesis for the first time.
- The application of centrality law for the first time in a computer environment although using a simplified version of BGP to observe the emergence of deformed wheel pattern in a simulation.
- Presenting some new experiments on heuristic layouts indicating the emerging properties of topo-geometric accessibility under fragmentation.

The limitations

Some limitations of the thesis have already been discussed in the above section about the scientific genuineness of the hypothesis. However, a more comprehensive view of the constraints that this study has to accept should be given here. Accepting these limitations was mainly in favour of having a practical and manageable scope within the time and resource budgets available to the author. It is noteworthy that some of the issues are either put forward in
the thesis for the first time (such as the fragmentation measurement) or are one of the few examples in their field (e.g. space syntax study of Middle Eastern spontaneous settlements) but more extensive investigation of each topic could not be done. In other words, many of the raised issues are meant to encourage further research activity but are limited to just showing initial prospects of exploring those topics. These limitations can mainly be put in four major groups as follow:

- **Empirical data limitations:** The lack of extensive data for the case studies and the lack of a unique format of data for the two different cities of Jeddah and Zahedan. Amongst the most important data categories that are unavailable to the author, the thesis could have benefited from socio-economic and infrastructural, movement flows and also time series settlement growth maps in short time intervals;

- **Technical limitations:** The application of some of the analyses to limited samples. Some of the analysis and modelling have been completed knowing that either doing those for large samples either needs much more computing power (such as Jeddah urban block directional analysis);

- **Analytical limitations:** Some of the analyses are done in a simplified manner enough to gain initial results. More sophisticated methods (such as directional statistic formulae or more advanced BGP simulations along with full accessibility analysis of their generated layouts) are not used due to increased levels of sophistication.

- **Theoretical limitations:** Space syntax theoretical framework although helped with gaining insight to the morphologic characteristics of the case study settlements but at the same time led to some shortcomings due to the inherent lack of attention to the dynamic interaction between road network, dwellers and built-form (discussed earlier in this chapter under the section ‘How scientific is the hypothesis?’)
It should be also mentioned that although the notion of dweller’s preferences is not quantified itself – while it was extracted from literature - it is strongly parallel with the dual forces shaping human settlements (see chapter 7 on Hillier, 2002): the ‘territorial preference’ is an equivalent of Hillier’s ‘socio-cultural force’ that shapes the layout of residential areas in local level while the ‘economic preference’ is the translation of the ‘micro-economic forces’ coined by him (Ibid.). Although the limitation to investigate this preference in an empirical sense (for example through direct interaction with dwellers) was partly overcome by looking through the land use distribution but further works can be done to eliminate this shortcoming.

**The future work**

To overcome the above limitations the following tasks are proposed below:

- Inclusion of more extensive set of factors (especially based on gathering further socio-economic data) on the evaluation of spontaneous settlements’ consolidation ratios\(^{133}\). Also in measuring the dwellers’ preferences and how fulfilled they are – resulting in further consolidation - more field surveys can be done to gain the dwellers’ point of view more directly by using questionnaire or focused groups.

- In measuring the impact of internal spatial structure, there can be other categories of non-residential land uses in addition to the commercial category to be tested in terms of their distribution with regards to accessibility of streets. Also having movement flow data (vehicular and pedestrian) would be more helpful in measuring the impact of accessibility on land use. This is because the movement flows according to space syntax theories are influenced by topo-geometric accessibility while the land use distribution is affected by movement flows.

\(^{133}\) Interestingly the original measurement of urban centredness in London proposed by Batty and others (1998) and reviewed in chapter 3 includes economic factors such as sail turnover.
The urban block fragmentation can be extended to all areas of the second case study city of Jeddah; Moreover, advanced directional statistics suggest measures of dispersion that can be used to gain a solid measurement of fragmentation of sampled groups of urban blocks and then compare their fragmentation ratios to each other or to other variables especially the overall accessibility of an area.

- Although the experiments on chapter 7 showed that there is a relation between fragmentation and accessibility, further empirical tests need to be done to test this hypothesis in the actual spontaneous settlements. Such comparison requires the application of the solid fragmentation ratios suggested in the previous paragraph.

- The simplified BGP simulations also suggest a promising base for further development. In theory if even there is the possibility of automating the accessibility analysis of the generated layouts using applications such as Depthmap (for the time analysis of the generated layouts is a laborious process), then it is possible to quickly investigate the impact of different rules and variables governing the BGP simulation on the syntactic characters of the generated open space network. This would make a helpful heuristic tool regarding the impact of centrality and compactness laws in placing objects that is hypothesized to underlie the emergence of deformed wheel grid in real cities.

The practical significance

Although the original aim of this thesis was not to come up with operational conclusions for its case studies (such as action plans or intervention scenarios) but it has created some strong tools for the official and planning institutions that aim to do so. One of this tools that can be further developed for more
operational purposes is the consolidation measurement technique based on local centres’ strength. Using such techniques while giving a quick view to the decision makers in order to prioritize amongst settlements during their urban upgrading plans can be further complemented by incorporation of other socio-economic and physical data.

Also how internal spatial structure of a spontaneous settlement is performing on a local level (measured through its impact on the distribution of commercial or other land use categories) can inform the upgrading plans. Such examination while indicating how sufficient the street network of a settlement functions in its current status and before doing any intervention, would help with the level of intervention required to improve it. Such assessments can become more accurate if assisted with on-site observation on movement patterns (both vehicular and pedestrian) to see how and to what degree the accessibility is shaping land use through its impact on movement flows.

Overall, the thesis would suggests, that GIS techniques such as poverty mapping when applied to spontaneous settlements can be integrated with other physical fabric data (such as urban block fragmentation), accessibility data of different radii and land use data to come up with comprehensive indices of potential for upgrading.
Appendices

Appendix 1: Measures of segment angular analysis

The segment angular analyses of accessibility presented throughout the thesis (mainly in chapters 5 and 7) have been performed in Depthmap or SEGMEN applications both of which use the standard mathematical definitions of accessibility measure. The two main definitions of accessibility used throughout the thesis are the measures of choice and integration as known in space syntax research. Before quoting the formulae for the two accessibility measures first the basic notion of geodesic should be explained in the context of segment angular analysis.

As Iida (2006) explains, when moving from one axial segment to another, the cost of trip can be quantified by using an aspect of the connection between the two segments that is called the ‘weight’. In angular analysis the weight is set as the angel of intersection between the two connected segments although there are other weight definitions such as the ‘metric’ which is based on the trip length for going from one segment to another. When several routes are possible between two segments in a system, the routes with the minimum sum of weights are called the geodesics or the shortest path based on the weighting criteria (e.g. shortest metric distance or shortest angle). As a convention of segment angular analysis in Depthmap and SEGMEN, directional change of 90 degrees is weighted as 1, 180 degrees is weighted as 2 and so on. In this way the sequence of connected segments between an origin segment and a destination segment with the minimum summation of weights constitutes a geodesic in segment angular analysis.

The measure of Mean Depth is calculated by dividing the Total Depth value of each segment by its Node Count; the definition of each respective measure is given in the following paragraphs. Total (Angular) Depth is calculated as the graph distance of a segment from all the other axial segments in the system using the angular weighting
criteria mentioned above\textsuperscript{134}. This is equal to the summation of the lengths of the geodesics that connect a segment to all other segments. In this definition -pertaining to the angular analysis- the ‘length’ is the angular cost of the travel i.e. how much change of direction is assigned to each respective geodesic in total. Iida (2006) gives the following mathematical definition for Total Depth:

$$TD_{\mu_p} = \sum_{q \neq p}^{n} d_{p \rightarrow q}$$

(Source: Iida, 2006)

$TD_{\mu_p}$ represents total depth for the $p$-th axial segment; $d_{p \rightarrow q}$ is the geodesic that connects the $p$-th segment (or $m_p$) to the $q$-th segment (or $m_q$) and $n$ is the measure of Node Count that is the number of nodes in the graph that equals the total number of axial segments.

If the whole system is connected then Node Count ($n$) is the same for all segments in the global radius. However, it is possible to define metric radii that are shorter than the global radius which generally results in various Node Count values assigned to different segments. Overall, to calculate the Total Depth for a segment in $R$ meters radius, only the destination segments that are reached by geodesics of $R$ meters length are included in the calculation. The same is true for Node Count in radius $R$ meters: only segments that are reached by geodesics of $R$ meters length from the target segment are considered for its Node Count measure. Global radius or $R_n$ is then a special case when $R$ is the maximum geodesic metric length possible in the system.

It should be reminded that all of the segment angular analyses in the thesis have been performed by metric radii the reason for which has been explained in the fifth chapter. Dividing Total Depth of each segment by its (Node Count -1) then produces the measure of Mean (Angular) Depth for that segment:

\textsuperscript{134} While each two intersecting axial segments constitute two connected nodes in the graph, the intersections between those segments are transformed to graph edges that are weighted by the angle of incidence of the two axial segments.
\[ MD_{\mu_p} = \frac{TD_{\mu_p}}{n - 1} \]

(Source: Iida, 2006)

\( MD_{\mu_p} \) is the angular mean depth for segment \( \mu_p \) and \( n \) is the Node Count in the defined radius for that segment. Segment (Angular) Integration is then (Node Count - 1) divided by Mean Depth.

The Choice measure in segment angular analysis for each segment is the proportion of trips that pass through that segment out of all possible shortest journeys between every couple of origin and destination segments. To calculate Choice the first step is then to count all the geodesics between each two couple of segments in the axial segment map. The geodesics for angular analysis should be the shortest angular paths i.e. the routes that connect the segments with minimum change of directional cost. If the number of all the geodesics that connect \( i \)-th and \( j \)-th segments together are shown by \( g_{i \rightarrow j} \) then the ‘betweenness’ accessibility or Choice for the \( k \)-th segment (or \( m_k \)) is calculated as follow:

\[ C_B(\mu_k) = \sum_i \sum_j \frac{g_{i \rightarrow j}(\mu_k)}{g_{i \rightarrow j}} \]

(Source: Iida, 2006)

In the above formula \( g_{i \rightarrow j} (m_k) \) is the number of geodesics between \( i \)-th and \( j \)-th segments that passes through the \( k \)-th segment. Similar to the calculation of Total Depth, it is possible to introduce metric radii to the Choice analysis that is to limit the metric length of the geodesics that are included in the calculation. It should be reminder that both above formulas for Total Depth and Choice can be applied to other weighting criteria such as metric or topological for which the reader is referred to the paper by Hillier and Iida (2005).
Appendix 2: The Beady Ring simulation in StarLogo environment

The early BGP model also known as the ‘beady ring’ model (Hillier and Hanson, 1984) can be generated by using agent-based applications. One of such applications is StarLogo that is a programmable platform developed at MIT Media Lab and used to simulate the behaviour of decentralized or complex systems (Resnick, 1997). StarLogo environment is essentially made of three separate parts. Firstly a fixed grid comprised of cells or ‘patches’ that can change their state based on defined rules. Second part is a layer of moving agents or ‘turtles’ that are mobile entities with changeable status. The third part is the observer that can define rules or set procedures for the interaction of patches together, turtles together or turtles and patches (Batty and Jiang, 1999).

Appendix Figure 2.1- The structure of the three main parts comprising StarLogo environment: observer, turtles and patches (Source: Batty and Jiang, 1999).
The beady ring simulation process then can be done using the above three parts of StarLogo application working in relation to each other. The dyad (i.e. coupled building and its adjacent open-space) can be defined as states of two contiguous patches while the placement of each dyad and checking whether the local condition for adding that dyad holds true can be done by a turtle or turtles. The turtle, in other words, search for an empty patch to check if a dyad can be added with its open space facing the existing open spaces. In next stage the same turtle check if the building part of the dyad can be added following the ‘no vertex to vertex’ rule. Satisfying this condition will lead to the addition of a dyad and otherwise the turtle move to another spot to go through the same procedure. The StarLogo script (version 2.22 and newer) to do so will follow in the next paragraphs:

**Observer procedures:**

to clear
cr
end

to setup
cr
cr 1
ask-turtles [stamp grey fd 1 stamp blue]
ask-turtles [setc red setshape arrow-shape]

loop
[
ask-turtles [search]
ask-turtles [conditional-grow]
ask-turtles [fill]
]
end

**Turtle procedures:**

to fill
fd 1
ifelse
((pc-at 1 1)= blue and [(pc-at 1 0)= black or grey] and [(pc-at 0 1)= black or grey])
or
((pc-at 1 -1)= blue and [(pc-at 1 0)= black or grey] and [(pc-at 0 -1)= black or grey])
or
((pc-at -1 -1)= blue and [(pc-at -1 0)= black or grey] and [(pc-at 0 -1)= black or grey])
or
((pc-at -1 1)= blue and [(pc-at -1 0)= black or grey] and [(pc-at 0 1)= black or grey])
[search]
[stamp blue fd -1 stamp grey]
end

to search
seth ((pick [1 2 3 4]) * 90) fd 1
if (pc = black) and  (((pc-at 0 1) = grey) or ((pc-at 0 -1) = grey) or ((pc-at 1 0) = grey)
or ((pc-at -1 0) = grey)) [stop]
search
end

to conditional-grow
seth ((pick [1 2 3 4]) * 90)
if pc-ahead-one-patch = black [stop]
lt 90
if pc-ahead-one-patch = black [stop]
lt 90
if pc-ahead-one-patch = black [stop]
lt 90
if pc-ahead-one-patch = black [stop]
lt 90
if pc-ahead-one-patch = black [stop]
search
end
Appendix 3: Application of the ‘centrality’ law to a simplified BGP simulation

The core idea to generate the deformed wheel pattern through aggregating buildings is expressed here:

“Suppose then we apply the centrality law in the simplest and most localised way by setting up a rule that says that wherever you are adding a built form to the aggregate you have to choose a local location which preserves the locally longer line, but at the cost of continually creating shorter lines…” (Hillier, 2001, Page)

As was mentioned in Chapter 6, to apply the above rule in the BGP simulation process, the dyads are simplified to have just the closed cell (i.e. building). In this way, the turtles (in StarLogo environment) will place buildings on the fixed patch grid when the condition of ‘preserving the locally longer line’ holds true. To ‘choose’ amongst different locations, a number of turtles can be used simultaneously as explained below.

The process is illustrated in the image below in Appendix Figure 3.1. In the StarLogo interface window, 20 agents (red colour turtles) are released and locate themselves on empty cells (black colour) in a 48 by 48 square base. At first place they are all prepared to locate yellow blocks with the ‘non-vertex’ rule at the same time. However and beforehand they start to measure their visual field along the four main directions and find the longest line either in their x or y directions. At the next stage and amongst the 20 agents just the one (s) that has the shortest range of view will create the yellow solid cell. It means that the 20 agents choose not to ‘block the longest lines of sight’ that is the implementation of the centrality law. For example in the provided figure Agent1 and 2 has maximum view field of X1 and Y2 respectively. Because Y2 > X1 then it will be agent 1 (with smaller maximum view range) that agent creates a yellow cell.
The StarLogo script for the very sample simulation represented in Appendix Figure 3.1 follows below. There is a threshold after which the addition of yellow patches or buildings will be stopped while the number of turtles is set to be 20 in the script.

**Observer procedures:**

```starlogoscript
 turtles-own [X1 Y1 Ncnt Scnt Ecnt Wcnt EWsum NSsum NEWSsum Limits]
to setup
caspatches [if (ycor > 23) or (xcor > 23) or (xcor < -23) or (ycor < -23) [setpc yellow]]

loop
[
  ct
crt 20
ask-turtles [set Limits count-pc yellow]
ask-turtles [if (Limits > 1100) [stopall]]
ask-turtles [setxy 0 0]
ask-turtles [setc red]
ask-turtles [set Ncnt 0 set Scnt 0 set Ecnt 0 set Wcnt 0]
ask-turtles [locate1]
ask-turtles [ExploreN ExploreS ExploreE ExploreW]
ask-turtles [set EWsum Ecnt - Wcnt]
ask-turtles [set NSsum (Ncnt - Scnt)]
ask-turtles [ifelse EWsum > NSsum [setNEWSsum EWsum] [setNEWSsum NSsum]]
ask-list-of-turtles who-min-of-turtles [NEWSsum] [stamp yellow]
]
end
```
Turtle procedures

to ExploreN
seth 0
ifelse ((pc-at X1 Ncnt) = black) [setNcnt Ncnt + 1 ExploreN] [stop] end

to ExploreS
seth 180
ifelse (pc-at X1 Scnt) = black [setScnt Scnt - 1 ExploreS] [stop] end

to ExploreE
seth 90
ifelse (pc-at Ecnt Y1) = black [setEcnt Ecnt + 1 ExploreE] [stop] end

to ExploreW
seth 270
ifelse (pc-at Wcnt Y1) = black [setWcnt Wcnt - 1 ExploreW] [stop] end

to locate1
let [:x1 random 100 :y1 random 100]
setxy :x1 :y1
ifelse
((pc-at 0 0) = yellow)
or
((pc-at 1 1) = yellow and (pc-at 1 0) = black and (pc-at 0 1) = black)
or
((pc-at 1 -1) = yellow and (pc-at 1 0) = black and (pc-at 0 -1) = black)
or
((pc-at -1 -1) = yellow and (pc-at -1 0) = black and (pc-at 0 -1) = black)
or

((pc-at -1 1)= yellow and (pc-at -1 0)= black and (pc-at 0 1)= black)
[locate1]
[setX1 :x1 setY1 :y1 stop]
end

Appendix Figure 3.1- Illustration of the simplified BGP process by the application of the centrality law. The moving agents appear as red turtles while the buildings are yellow patches.¹³⁵

¹³⁵ Note the continuous yellow band that bounds the edge of the system (without this boundary StarLogo connects the edges of the system to make a doughnut shape space).
Bibliography


Hackenbroch, Kirsten, and Oliver Gruebner. 2008. “Land Use and Land Cover Mapping in Informal Settlements, The Case of Dhaka, Bangladesh” presented at the ITC expert meeting on slum mapping, Faculty of Geo-Information Science and Earth Observation of the University of Twente (ITC), Enschede, the Netherlands.


Henninger, Norbert, Mathilde Snel, World Resources Institute, and Global Resource Information Database. 2002. Where Are the Poor?: Experiences with the


Iida, Shinichi. 2009. SEGMENT 0.64.0 (Beta).


Iran Ministry of Housing and Urban Development (IMHUD), and World Bank. 2003. The Feasibility Study of a Citywide Upgrading and Community Enabling Programs in the City of Zahedan. Tehran: Iran Ministry of Housing and Urban Development (IMHUD).


Kemper, Thomas, Martino Pesaresi, and J. R. C. Italy. 2008. “Examples of Robust and Replicable Feature Extraction for the Study of Built-Up Surface, Using VHR Data” presented at the ITC expert meeting on slum mapping, Faculty of Geo-Information Science and Earth Observation of the University of Twente (ITC), Enschede, the Netherlands.


Sliuzas, Richard, Gora Mboup, and Alex de Sherbinin. 2008. *Expert Group Meeting on Slum Identification and Mapping*. Enschede, the Netherlands: Faculty of Geo-Information Science and Earth Observation of the University of Twente (ITC).


Plate 1 - Axial segment map of Jeddah that illustrates the measure of segments angular choice in Radius 800 metres. Spontaneous settlements are bounded by black dashed outlines.
Plate 2 - Axial segment map of Jeddah that depicts the measure of segments angular choice in Radius Infinity (Rn). Spontaneous settlements are bounded by black dashed outlines.
Plate 3 - Axial segment map of Zahedan representing the measure of segments angular choice in Radius 800 metres. Spontaneous settlements are bounded by black dashed outlines.
Plate 4 - Axial segment map of Zahedan illustrating the measure of segments angular choice in Radius Infinity (Rn). Spontaneous settlements are bounded by black dashed outlines.