To my parents

and

Catherine

Photogrammetric Mapping for Cadastral and Land Information ~~Management~~ Systems

by

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ABSTRACT.

The creation of a "clean" digital database is a most important and complex task, upon which the usefulness of a Parcel-Based Land Information System depends.

Capturing data by photogrammetric methods for cadastral purposes necessitates the transformation of data into a computer compatible form. Such input requires the encoding, editing and structuring of data.

The research is carried out in two phases, the first is concerned with defining the data modelling schemes and the classification of basic data for a parcel-based land information system together with the photogrammetric methods to be adopted to collect these data. The second deals with data editing and data structuring processes in order to produce "clean" information relevant to such a system.

Implementation of the proposed system at both the data collection stage and within the data processing stage itself demands a number of flexible criteria to be defined within the methodology.

Development of these criteria will include consideration of the cadastral characteristics peculiar to Greece.

"... It is the mark of an instructed mind to rest satisfied with the degree of precision which the nature of the subject permits and not to seek of exactness where only the approximation of the truth is possible..."

Aristotle

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Chapter 1

INTRODUCTION

1.1 Definitions

1.1.1 Cadastre

All societies, from the earliest civilisations to modern times have recognised the great value of land in relation to man and have attempted to protect man's rights upon it. The main means for this purpose was the collation of data about the spatial distribution of significant properties, and a public awareness of them. The cadastre was the answer to society's demand.

The origin of the word 'cadastre' may come from the Greek (Byzantine Times) 'καταστιχον' (katastihon). This term today reflects a system which describes the current situation of parcel-based ownership within an area together with subsequent changes to their status.

It is obvious that any physical and city planning, as well as a great number of urgently needed development and technical studies, can not be based, on the compilation of maps and tables which are constituted occasionally, incompletely and without any predictions for systematic monitoring of data changes and their relationships during the time. In this manner, basic problems such as those in modern cities of industrial development, rural development and even more, problems of environment can only be solved relying on the information a cadastre can provide.

J. L. G. Henssen states that the term "cadastre" means, a methodically arranged public inventory of the properties within a country or district, based on a survey of their boundaries. The delimitation of a cadastral parcel consists of a description of its geographic location together with its size and shape.

1.1.2 Components of a Cadastral System.

According to the previous paragraph, it can be stated that a cadastral system forms a very important basic instrument for government policy, helping to stimulate the economic and social development both of urban and rural areas. Subsequently it forms the base for an effective administration of the country. In this connection, it is obvious that a cadastral system depends on what a government or authority wants it to be and/or do and becomes what it or its customers want it to become.

The cadastre is primarily a public record which also maintains a record of private interests in land within its area of jurisdiction. Therefore the basic elements of a cadastral system generally are :

1. a brief, simple, unambiguous identification of the land units, which is shown on a large-scale (cadastral) map.

2. a descriptive part in which the actual data associated with legal or use status are represented, as well as thoseconcerning the nature of the real estate (Henssen, 1981)[33].

Even though a cadastre should be tailored to meet very specific demands for information there are nevertheless several general aspects which need to be discussed when formulating the policy for a cadastral system. The first concerns whether is going to be a multipurpose system. Such a system is a multidimensional structure bringing together within one system all the information and administrative support needed to record and describe land rights, land use, land development, land economics, land quality.

It should be noticed that such a cadastral system does not necessarily have to contain all the data required by its users. It can perhaps be confined to forming a framework for other systems. Thus, these separate components together build a large integrated land information system.

A second general point concerns whether the system should be computerised immediately. Although the automation of cadastre is the one and only way to proceed to a comprehensive land information system, many countries, for reasons of cost, or lack of required technology and manpower, still manage a large part of their cadastral system in a manual way. The problem of creation of a computerised system arises especially for countries like Greece which now try to establish a cadastral system.

1.1.3 Photogrammetry.

Much information is required at a number of levels to meet the needs of constituting a cadastral system. However, since the core unit for such a system is to be the parcel (para. 1.1.2), the potential for capturing and manipulating it and its associated attributes is seen as high priority. Any means which offers the way to make this task easy and less expensive, is of obvious interest.

Photogrammetry, as it has defined by the ASPRS, is the art, science and technology of obtaining reliable information about physical objects and the environment by recording, measuring and interpreting photographic images. Hence, it can be applied in capturing land-related information relevant to a cadastral system.

Photogrammetry has been principally applied for the production of topographic maps. This application has in many countries, led to the establishment of a fast, economic and efficient system for topographic mapping. However, the use of photogrammetry in cadastral surveys has had many economical advantages in countries such as Switzerland, The Netherlands, Italy and Germany (O. O. Ayeni, 1985)[6].

1.2 The Project.

1.2.1 Objectives of the research.

The creation of a cadastral system involves the creation of a map which can be stored either in an analogue or digitized format. There are four combined properties used in photography that offer the user tremendous capabilities (Ackermann, 1978). Firstly, it is an image storage device, features, objects and details can be identified. Secondly, these objects and other details can be related structured. Third, these objects and features can be both absolutely and relatively positioned through geometric measurements. Fourth, the information can be displayed on any reference system graphically or numerically. These all entail the use of photogrammetry for the cadastral surveys.

Data that are to be collected, analysed and maintained are the major part of the investment to be made. Therefore, photogrammetric methods for data capturing and the development of data structures required for corporate use of information for a cadastre may be two areas in which Greece is interested, because a cadastral system is to be established in an attempt to solve a variety of problems related to ownership, planning and management of the land.

Although land data are available (para. 3.4.1), the information which they provide is not sufficient. Thus, it becomes apparent that even current land management problems can not be solved efficiently. Subsequently, there is a need for faster and more comprehensive data collection and data processing activities, resulting in improvement of the accuracy and reliability of information. Additionally, it has to be considered that in the beginning the cadastral surveying and recording procedures will be neither sufficiently developed nor integrated to constitute a cadastre. This may be described as a pre-cadastral period, during which the state/authority does not effectively maintain a land information.

From the all above it becomes evident that an examination of data collection, editing and structuring procedures will lead to a better understanding and estimation of the operating strategy. Thus, problems of these activities as well as of their inter-dependency will be consider, helping to identify areas where further analysis and research are required. It will also address preliminary estimates of costs and benefits for the whole strategy of cadastral surveys as well as it will improve the basis of assessing, configuring and promoting future developments. Moreover, as an immediate result, it will provide the means of access to the land-related information, resulting in more effective solutions of current land management problems.

To summarise, this project is intended to develop and demonstrate a limited mapping and associated land-related information system. This system is to provide a working model of an automated procedure which could be implemented in Greece, so that it could:

1. provide land-related data essential to Greek cadastral
2. improve the accuracy and reliability of information
3. promote the basic (first) level of incorporation of land information and database.

1.2.2 Structure of the report.

This thesis addresses the above mentioned issues in eight chapters following this introduction.

In chapter 2 the evolution from cadastre to Land Information Management Systems is discussed followed by the use of photogrammetry in the cadastral systems. A variety of Land Information Management Systems from several countries are also reviewed.

Chapter 3 reviews the existing situation in Greece, emphasising problems involved in the management of land-related data. The spatial referencing for mapping is evaluated.

Chapter 4 describes the test area of the project and details the organisation of data for storage and management.

Chapter 5 describes the data, explains the methods used and highlights the problems arising during data collection. The merits of photogrammetry for primary data capture are also evaluated.

Chapter 6 describes the procedures adopted to "clean" the input data. Again evaluation of the procedure and problems are made.

Chapter 7 concerns the further structuring of data for processing and analysis.

Chapter 8 concerns the data base. The types of data that are to be incorporated into the data base are identified, together with the relationships between different entities and their attributes.

The conclusions in chapter 9 summarise the work and the results achieved. Recommendations for future work are made.

Chapter 2

Review of current Cadastral and Land Information Management Systems - Photogrammetry

2.1 Evolution from cadastre to L.I.M.S

The earliest cadastres were developed for taxation purposes. It is obvious that the primary requirement in implementing a **Fiscal cadastre** is the identification and mapping of all properties which are to be taxed and valued according to their productivity. Therefore it was usually associated with small scale mapping suitable to ensure that all parcels are identified.

Since personal rights and consequently personal property are considered a particular importance, the protection of property was the main demand of the society. The **Legal cadastre** was the answer to this demand. A detailed description of the parcel, in the form of either large-scale maps or survey measurement was necessary. In addition, the monumentation of the boundaries has been widely adopted. Information regarding land use and value has been also supported.

Land productivity, land use, and value were from the start of the above mentioned systems common information so the demand for additional data could in many cases be met by the improved land records. The new cadastral system could serve several purposes and thus the **Multipurpose cadastre** came into being.

While the particular function of the previous cadastral systems is to support the values associated with land or the recording of rights in it, a multipurpose cadastre may defined as a large, community-oriented land information system designed to serve both public and private agencies and individual users citizens by :

1. maintaining a complete inventory of the parcels and their spatial relations,

2. relating a series of land information records to these parcels,

3. providing an efficient access to the data in these records.

The components of such a system may be as follows (ACSM-ASPRS, Joint Cadastre Task Force, 1985) :

1. a reference frame consisting of a geodetic network.

2. a series of current, large -scale maps,

3. a cadastral overlay delineating all cadastral parcels,

4. a unique identifying number assigned to each parcel that is used as a common index of all land records in information systems,

5. a series of land data files, each including a parcel identifier for purposes of information retrieval and linking with information in other data files.

Soon, such systems face a new problem. The amount of data acquired soon creates management and processing difficulties, so that the traditional handling of these data becomes no longer economic. The parallel development of computer methods for data management gives further opportunities for storing, analysing, and displaying spatial data. The new approach of modern automation facilities produced a number of advantages over previous systems, one of which was the creation of integrated **Land Information Management Systems**, in which the cadastre forms an important part, since a L. I. M. S is a tool which contains land-related information for legal, administrative and economic decision making and an aid for planning and development.

2.1.1 Issues which should be considered in creating a satisfactory Cadastral system.

At its simplest level, the function of a land-related information system is to answer two questions: "what is where?" and "where is what?" (P. Dale, J. Mclaughlin,1988)[21].

The "where" can be defined by the location of the land feature expressed either by geographic coordinates of latitude and longitude or by their transformations into various plane coordinate systems. The latter is commonly used in mapping because of the simplicity with which geometric computations can be carried out and because graphic media are planar.

The reference system has a crucial impact, not only on the different data for a single user but also for a group of users and for any discussion on integration. It is needed so that the relative positions of different features can be established or compared. For a land-related information system on the national basis the national coordinate system is usually adopted.

The detailed land information are rendered into pictorial form creating maps which are a source of useful information for development, resource exploitation and management.

A variety of maps exist and it is possible to distinguished between those which form the basic topographic framework of a country and those which are designed for special purposes. On the top of this base mapping cadastral information layers can be overlain displaying land ownership and administrative boundaries. Other layers of information such as land use or value can be held within the system and they also reference the same features. The relevant records of each parcel are cross-referenced through a unique parcel identifier.

Summarizing, the above mentioned components of a (Multipurpose) cadastral system are considered as the main ones. Thus, it is obvious that a study of them should be made first, because if they are properly established and maintained they should provide the common framework for a more integrated Land Information Management System.

2.2 Photogrammetry and Cadastral systems.

Although the principal use of photogrammetry at present is still in map-making, particularly in topographic mapping (ASPRS)[3], other applications have been well developed. Probably one of its wider applications is the preparation of large-scale cadastral plans.

2.2.1 Use of Photogrammetry.

Many changes of the products and methods of map production have been created by the introduction of digital techniques. Users may now choose to store and handle spatial data in the form of traditional line maps or in any one of various digital forms (cartographic data bases, D.T.M, etc).

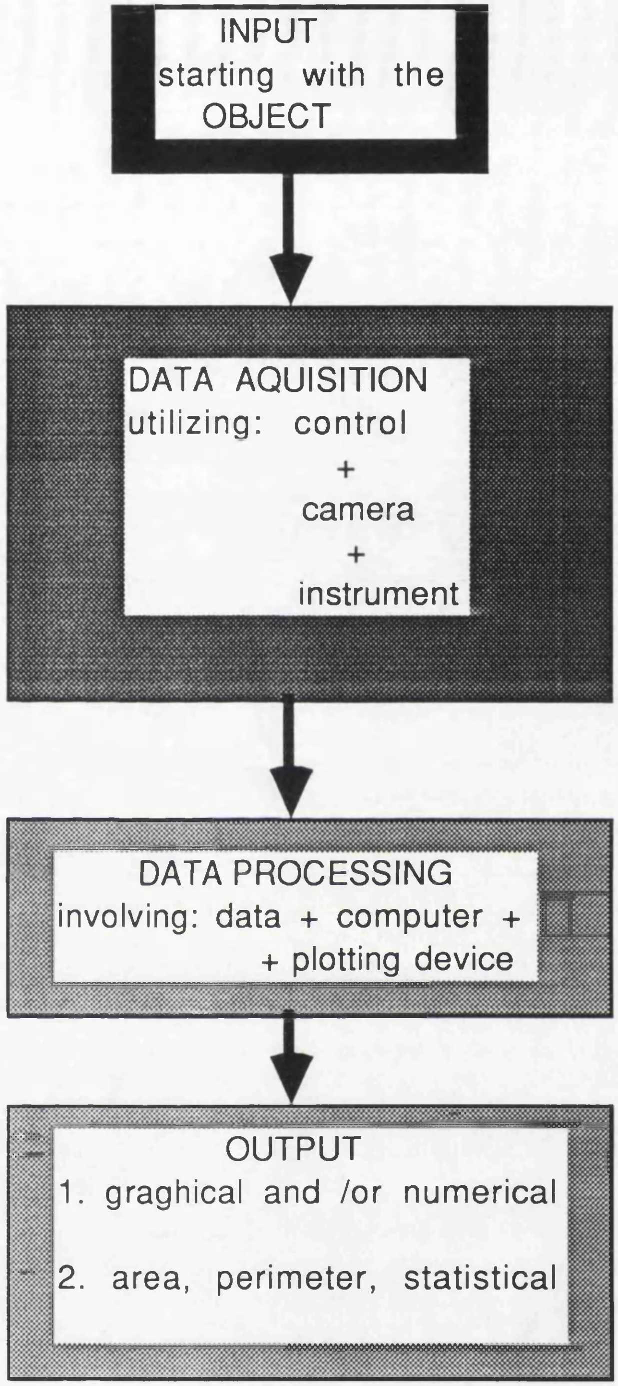
Photographs, hold a large amount of land-related data. To convert such data from an analogue to a digital form requires digitization. Photographs are digitized using a variety of photogrammetric instruments including stereoplotters and stereocomparators. In addition current developments have led to more versatile systems which can afford both:

- comprehensive processing of land-related data to digital and/or analogue output.

- data interchange with other information systems (e.g database).

Such systems include the P-series of Zeiss with PHOCUS cartographic package, Wild AP-9 which is integrated with a land information system (S-9), Kern DSRs 12-14-15 connected with a land information system (INFOCAM).

These devices, systems and methods developed to solve the above mentioned problem are generally well-known and need no further discussion here. However, the general photogrammetric working system (S. K. Ghosh, 1988)[28] should be referred in order to have a broad view of such a system.



On the other hand cadastral survey is distinguished by six operations :

1. the initial gathering of information necessary for delimiting the cadastral parcel bounds,

2. the analysis of this information,

3. the demarcation of the bounds,

4. the registration of the boundaries,

5. the maintenance of the boundary information,

6. the dissemination of this information.

A cadastral survey may be carried out both for the initial creation of the parcel and for any subsequent changes in the bounds of the parcel. A cadastral survey may also be executed to re-establish boundaries missing on the ground.

Photogrammetric mapping is obviously a data collection technique which addresses the first operation of the cadastral survey (item 1, above).

To properly carry out the survey of cadastral parcels by photogrammetry a set of issues must be considered, which are illustrated in Table 2.1.

Table 2.1 Set of issues must be considered for a cadastral survey

* terrain and vegetative cover of the area to be mapped
* available control in the area
* aerial photography available or to be acquired
* other resources available (personnel, old maps, etc)

All of these considerations have been addressed by many and there is not need for further discussion here (see chap. 5). On the other hand another issue considered, perhaps the most important which is the mapping scale, should be little discussed.

Information provided to solve problems in regional planing is displayed in different scales than those in urban planing(see Table 2.2-After Badelas and Savvaidis, 1985).

Table 2.2 Regional and urban planing scales

Rural areas	Sub-urban areas	Urban areas
1: 10000	1: 5000	1: 2000
1: 5000	1: 2000	1: 1000

As mentioned earlier the collection of thematic information is a next task which may interface a cadastral system (Multipurpose) to photogrammetry. The simple (sometimes single) aerial photographs and their photo-interpretation are those products of photogrammetry which are related with thematic information. In order to interpret aerial photographs, all maps, documents and literature relating to the study area have to be used. A classification scheme is then designed with the purpose of a specific application in mind (Appendix A.1). Such information is also displayed in different scales according to the area represented (see Table 2.3. Ref. [38] & [46]).

Using photogrammetry methods to capture the data, it is necessary to see the relationship between mapping and photographic scales (see Table 2.4. Ref. [38] &[46])

VIEW OF	SCALE REQUIREMENT
Area where land is devided in very small parts : eg : land use of each field OR more specific inform. is required	**1 : 10,000**
Objects which are of large areal extent (some fields, forests, lakes, rivers,...) and information in details is required.	**1 : 25,000**
Objects in which more general information is required in a particular area (shape of roads, railways, rivers, intersections of them, etc)	**1 : 50,000**

Table 2.3 Thematic information and scales.

Table 2.4 Mapping and photographic scales.

SCALE MAPPING	PHOTOGRAPHIC SCALE
1:500 1:1,000 1:2,000 1:5,000	From 1:3,000 to 1:15,000- 1:20,000
1:10,000 1:20,000	From 1:20,000 to 1:40,000
1:50,000 1:100,000 and smaller.	From 1:50,000 t0 1:80,000 and smaller.

2.2.2 Limitations of Photogrammetry

There are many advantages and benefits of the photogrammetric methods for cadastral surveys which are very well known. However, the disadvantage of photogrammetry is the great quantity of detail which can not been seen from the air. This is either because a ground mark (para. 2.1.1-item 3) is too small, or because the marks/details are obscured by overhanging buildings or vegetation. Due to this limitation in aerial photography, cadastral maps have to be completely digitized.

Often they must be reviewed and completed by those points visible in the aerial photographs. During the data acquisition process, features not readily visible may be flagged to indicate that they require further attention. Such a solution requires more time and cost for the overall mapping process. However, photogrammetric survey may still be the most economic way of survey, but in combination with a subsequent ground survey (Dale, Mclaughlin, 1988)[21].

2.3 Examples of Land Information Management Systems.

As mentioned earlier the core unit of a cadastral system is the land parcel. Therefore, in the establishment of cadastre the major concern has been the definition of the parcel. Indeed, the management, acquisition, presentation and manipulation of parcels and their associated attributes was, and remains, the keystone of any cadastral system.

However, over the last five years attention has been increasingly focussed on the construction of integrated Land Information Management Systems (L. I. M. S.). Such tools contain land-related information for legal, administrative and economic decision making and aid planning and development - in which the cadastre forms an important part. Efforts have been made to find optimum solutions on problems relating to the integration of cadastre within L.I.M.S. As a result many countries have introduced technological reformation of their current land-related information systems.

Several countries have different types of land information systems and are trying to establish an integrated Land Information Management System, others have a cadastral system and are trying to convert it into a L. I. M. S. The efforts of these two groups depend on their existing technology and upon technological change.

The examples below may provide a preliminary knowledge which could enable a better understanding of the technological and organizational aspects of the proposed Greek cadastre, since the long term goal (of Greece) is the creation of a L.I.M.S. (see para. 3.3).

2.3.1 Case Studies.

Maritime Provinces of Canada.

The Land Registration and Information Service (LRIS) of Maritime Provinces (Nova Scotia, New Brunswick, Prince Edward Island) of Canada is one of the earliest and best-known efforts to develop an integrated L.I.M.S. The programme of development has consisted of four component phases (fig. 2.1), (Dale and McLaughlin, 1988)[21]:

Phase I : the extension and densification of a second-order survey system.

Phase II : the development of a large-scale planimetric and topographic mapping programme throughout the Maritime provinces, and the introduction of a large-scale cadastral mapping series.

Phase III : the gradual replacement of the existing rudimentary deed registry system in each province with a computer-based land titles system.

Phase IV : the creation of a series of integrated land records.

The major benefits from the control survey phase have been greater cadastral and engineering survey efficiency. In phase II the cadastral mapping programme met with widespread public support and quickly became a necessary product. Despite the fact that an initial proposal for guarantee titles (and guarantee boundaries) was considered unfeasible it was finally adopted. this provided the state guarantee register of ownership rights, based on accurate survey of each parcel. Although the initial concept for the creation of a series of integrated land records (phase IV) was the establishment and maintenance of a large, centralized land data bank, it was not implemented for a variety of economic and institutional reasons (see Dale and Mclaughlin, 1988)[21].

Thus, in recent years, efforts have been directed towards the development of distributed land information networks, in which each organisation will maintain responsibility for its own data with a coordinated approach (fig. 2.2) to the exchange and use of the data, (Dale and McLaughlin, 1988)[21]. Thus, part of the system can be up-graded without disrupting the rest of network. Furthermore, the system can be easily expanded, thus allowing for a better response to technological improvements.

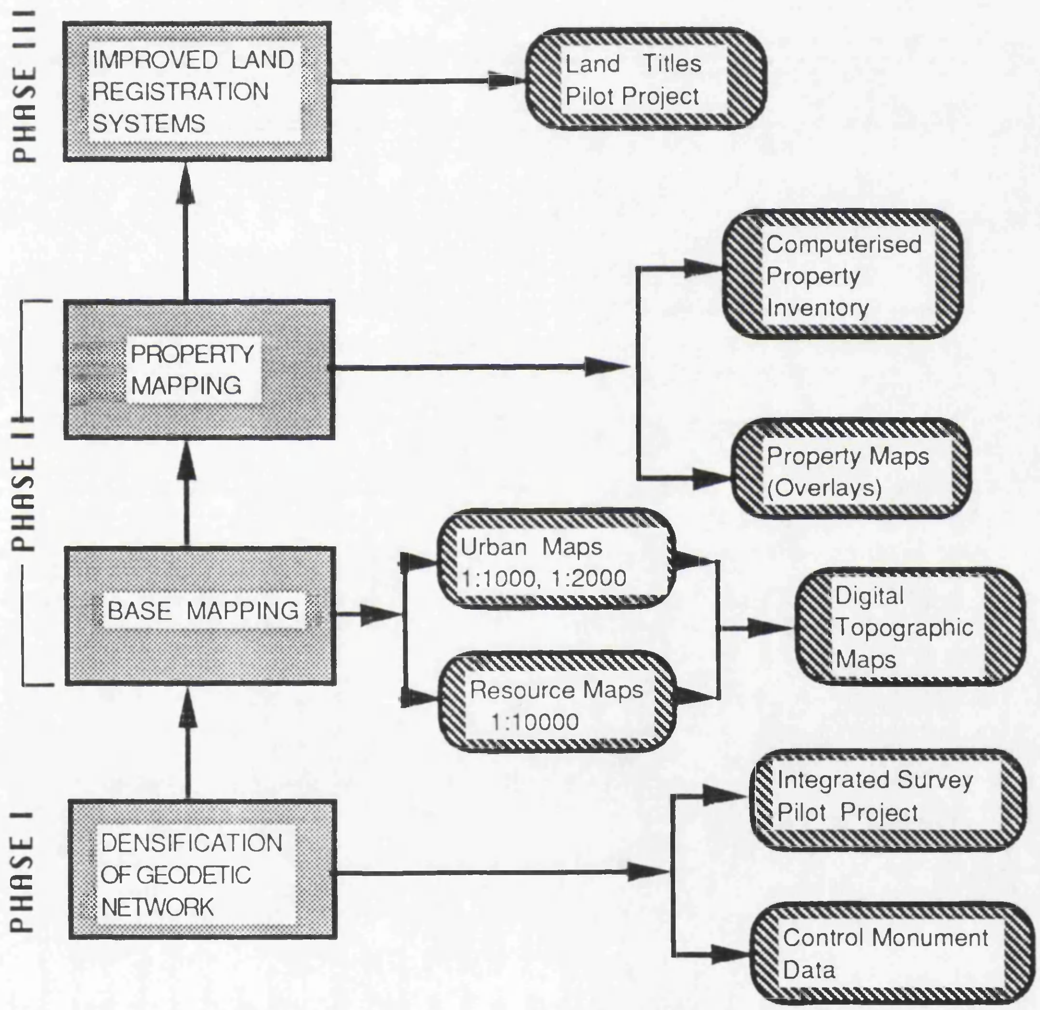


Figure 2.1. Development of LRIS - Maritime provinces, Canada. (after Dale and Mclaughlin,1988).

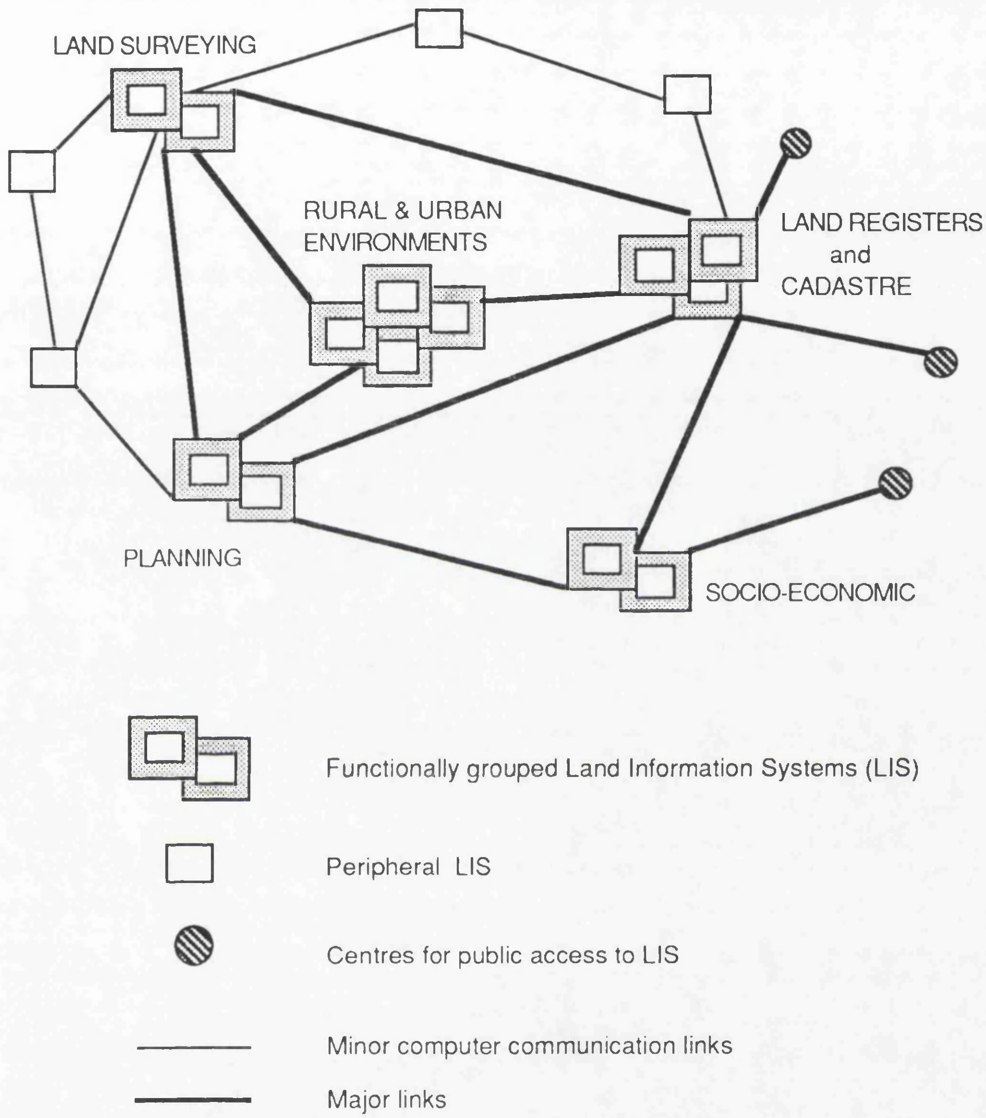


Figure 2.2. A design for a L. I. S. network.
(after Dale and Mclaughlin, 1988).

State of South Australia.

In Australia the Land Registry system is the Torrens Title system, which provides an up-to-date, state guarantied register of ownership based on an accurate survey of each parcel. Research has focussed on Land Parcel Identification and on Digital Cadastral Mapping, resulting in various approaches to parcel identification and the form of parcel reference used in different states (Appendix A.2).

The development of an integrated L.I.M.S. in the state of South Australia (S.A.) is possibly the most interesting case. In 1974 the S.A. government implemented a L.I.M.S. study to investigate the possibility of coordinating existing land related systems with systems being proposed by government departments. It was recommended that, because of the costs involved, a total L.I.M.S. be regarded as a long-term staged development. The first stage was to be a central system holding details of ownership, tenure, value, constraints, land use and other information for every parcel in the state. This system is called Land Ownership and Tenure System (LOTS) which makes information available on-line at numerous enquiry locations.

A further report (1977) outlined possible future stages of a total L.I.M.S. subsequent to LOTS. These included a computerised title system, a planning information system, an underground services system, a data bank of survey data and a data bank of soil tests. These systems were seen as being peripheral to, but greatly dependent on the central parcel system. This approach formed the basis for the development of a network of distributed systems.

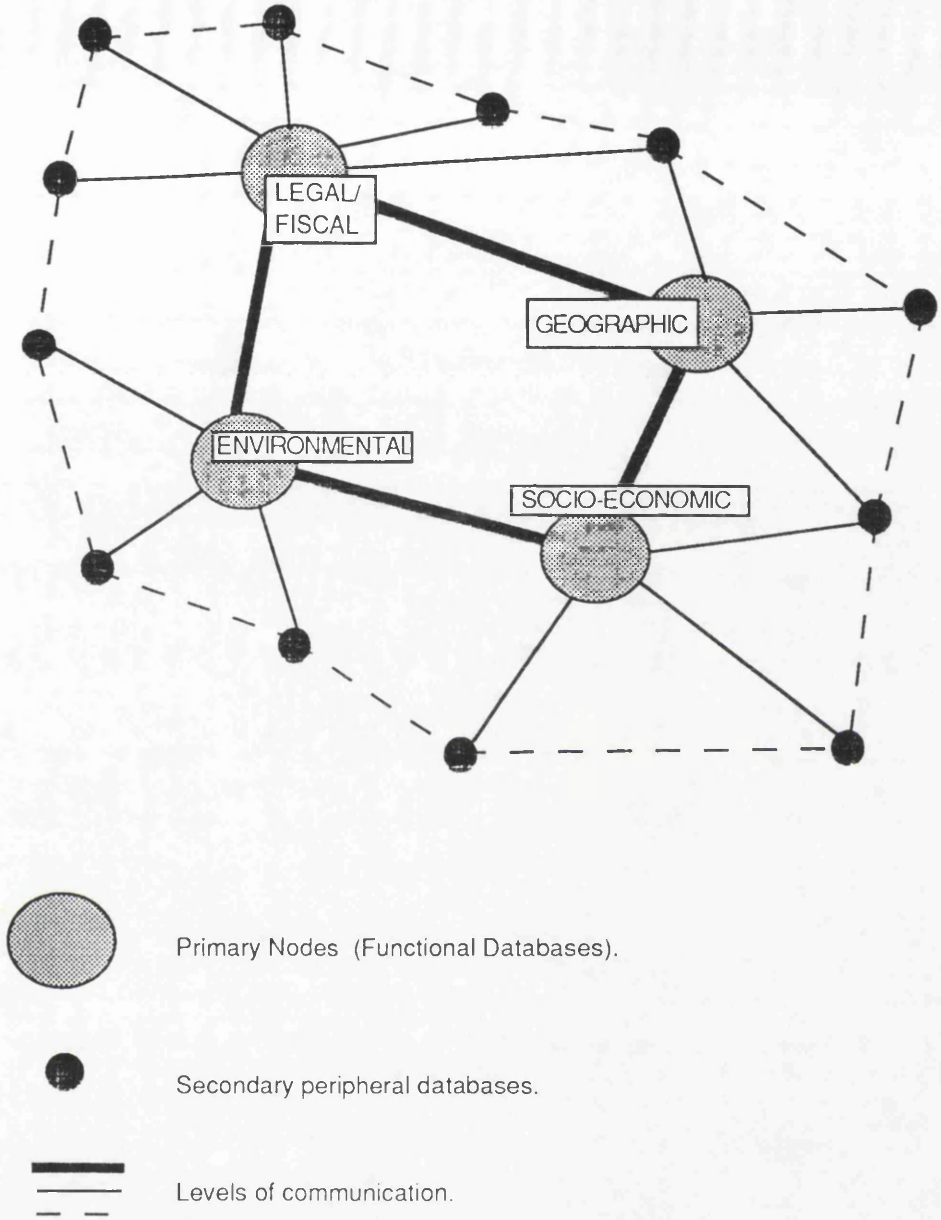


Figure 2.3 "Nodal Approach" of the South Australian L.I.M.S. (after Toms, Williamson and Grant, 1987).

Consequently, the L.I.M.S. is viewed as a series of procedures and standards that allow for the integration of land related data from a variety of individual systems (whether digital, manual or graphic) that form the state's corporate data resource. Conceptually the total L.I.M.S. is viewed as four major databases and many peripheral systems. These primary databases are: *legal/fiscal, geographic, environmental, socioeconomic*, (Figure 2.3).

In S.A. this “nodal approach” is seen as an effective balance between centralised and decentralised concepts and the most practical and cost effective method of achieving an integrated system. The administration of this system (fig. 2.3) is the major problem, since its functions fall outside the administrative control of the Department of Lands (which is responsible for it).

Sweden.

In Sweden there have historically been two cadastral systems: the *Urban* and *Rural* . The registration of properties was made with different way in the two systems, relying on the use of register books. Two further systems were also in use: the *Registration of Rights*, with information related to ownership, encumbrances and other legal aspects and the *Registration of Population and Taxation* with taxation information for each parcel.

A very long investigation and research programme has been introduced to solve problems in :

- technical and administrative planning,
- data storage process, due to the existence of many systems,
- duplication of effort in data management,

- integration of data.

After these long processes (investigation and research) for the modernization and integration of the existing registry systems, it was decided that the new system had to be divided in two subsystems :

1. The Registration of properties,
2. The Registration of real estate rights.

Thus, flexibility of the whole system is obtained in long term basis.

The data in the Register of Properties, (item 1 - above), which forms the *Swedish Land Data Bank System* (S. L. D. B. S.), are structured within six databases, resulting (as in previous examples) in a distributed approach to the system. Each database consists of information that similar services needs. These six databases are :

Database 1: contains the identification numbers of all parcels.

Database 2: divided in three sections. The first section contains information that determines a parcel (ID numbers, names of owners, boundaries and area in which the parcel is located). The second section contains historic information (previous ID numbers, encumbrances, etc). The last section contains the area (in sq metres) and the land-use of parcels.

Database 3: contains information about the description of town plans, regulations in town planning and finally land use information.

Database 4: the addresses of parcels.

Database 5: contains the coordinates of a centroid for each parcel.

Database 6: an intermediate database used for updating purposes.

Information contained in the *Registry of real estate rights* subsystem may be distinguished in the following sections :

* verification of titles,
* mortgages,
* encumbrances,
* origin of the parcel,
* lease of parcel.

Finally, as far as the identification of parcel is concerned, it is made with two ways :

1. Geometric (Geographic) identification, which is made with the centroid coordinates of a parcel.

2. Administrative identification, where the name of municipality/local authority, name of section (in the municipality), number of block (of parcels) and the parcel number, form the identification code.

Subsequently, these identifications result in a greater interconnection of database systems.

Denmark.

In Denmark important steps have been taken towards to an automated Cadastre. A review of the current situation is presented.

Denmark keeps three registers of properties:

1. the Cadastre,
2. the Land Register,
3. the Municipal Register of Real Property.

The Cadastre is the basic register with main tasks of maintaining and continually updating basic land data and managing of agricultural policies (size of farms, abolition of farms, etc). Today the Cadastre consists of four elements :

1. the parcel register (parcel numbers, area, number of plots, etc).
2. the cadastral maps (most at a scale of 1:4000).
3. measurements related to boundaries.

4. the register of control points used for cadastral surveys.

The Land Register is a decentralized register containing data on titles, land owners, mortgages, easements, etc.

The Municipal Register of Real Property is a computerised system containing data on valuation of land, and buildings. Two other computerized central registers are established, one for valuation and taxation and one for data concerning buildings and dwellings.

The cadastral parcel number provides the link between the three registers of real properties. Figure 2.4, shows the connections between the property registers and the connection between the land owner and the Cadastre, in case of alterations.

Efforts are made to modernize and adjust the cadastral activities to increasing user needs for information concerning properties, land, building, etc.

The parcel register is now being computerised. Thus, parcel numbers are transferred from the books to a database. The whole process is estimated to be in the range of forty (40) working years. The transfer of parcel data is also a time-consuming process since hither to undetected defects have been uncovered.

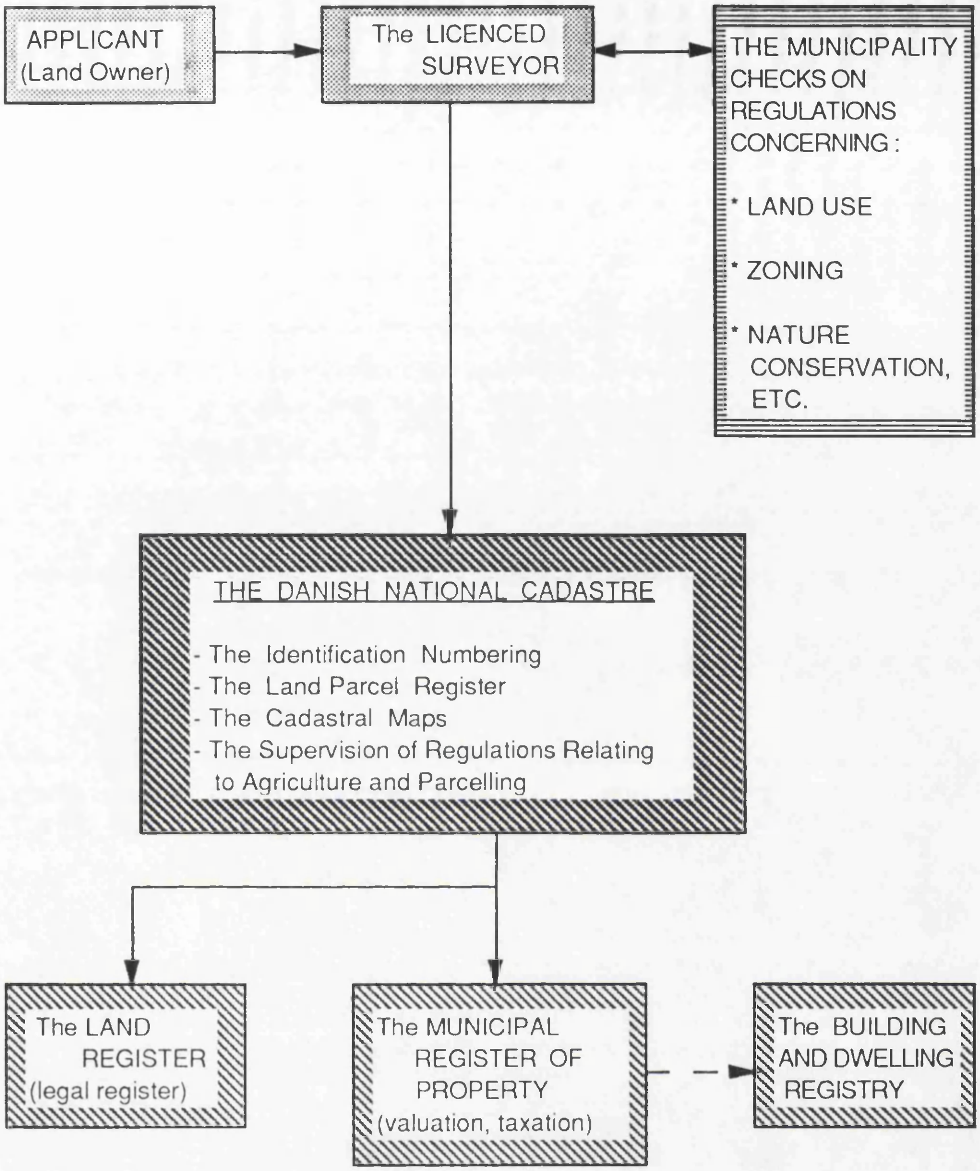


Figure 2.4. General flow diagram, in case of alternations, of Cadastre in Denmark (after H. H. Larsen and K. V. Hansen, 1986).

For the cadastral maps, it was considered insufficient to digitize the basic maps since most of them are not related to the national grid and are distorted (due to shrinkage, redrawings and sporadic updating). It was not also possible to rely on measurements in the archive because the whole process would very time-consuming. To this end, investigations and research have been made for some years now. Some sufficient solutions can be found in Larsen and Hansen (Larsen and Hansen,1986).

England.

A fundamentally different approach from the above examples is presented in England.

Registration, is compulsory on the sale of land only. The accuracy of Land Registry plan is made possible by the use of Ordnance Survey maps which are the basis of all registered description of land. The registration is based upon the general boundaries (Appendix A.2). Thus, the physical boundaries identify property which form the basis of all descriptions of registered land and the exact line of the actual property boundary is left undetermined. Pryer (1986) [67] gives the rule (278) what is registration with "general boundaries ".

On the contrary to the previous mentioned systems, the contents of the register are private and normally no details about the ownership of a registered property, even the name of the owner, may be revealed by the Land Registry without the consent of the proprietor or his solicitor.

Other examples.

Research on L. I. M. S. has been increasing during the last few years in Finland. The most significant information systems on the national level are: geological, forestry, water, cadastral, real estate.

Most of them have been created in order to serve only one application. These systems also need information from some other sources. Furthermore, there is redundant data collection and data maintenance because there is no generic spatial data exchange (A. Rainio, 1986) [70]. Therefore Finland is also trying to create an integrated L. I. M. S. based upon the decentralization of individual information systems, identifying the location of data (Appendix A.2) and possible links between various data sets together with national standards for data exchange (Appendix A.2).

On the other hand, Italy has a Cadastral system which is going to be converted into a integrated Land Information System (as for instance happens in Denmark). All cadastral information is gathered together in four documents with specific technical links (Appendix A.2).

The conversion of Cadastre into L. I. M. S. independent decentralized structures have been achieved through Digital Cadastre Centres. It is obvious that in Italy, as well as in the above mentioned countries, a distributed approach to system has been introduced. In the beginning they had the duty of defining the standards and procedures for the formation of the digital cadastre, both from existing maps and from new surveys, now they have been entrusted with production and management (Dequall and Maraffi, 1986) [24] .

Discussion.

Concluding it is realized that all of the above examples have either various land-related information systems or a cadastre and they try to structure these as the basis of a modern integrated L. I. M. S. There are many similarities in the approaches of these countries towards to L. I. M. S. development (e.g. in most of them land surveys are accurate to satisfy registration).The use of the main technical aspects (e.g. Appendix A.2) depends on the technology of each country as well as on the requirements of users.

A major deficiency of existing Land Registries was (e.g. South Australia) and in some countries still is (e.g. Finland), the duplication of effort in the maintenance and searching of land records, due to the incompatibility and insularity of the various state agencies, collecting land related information. Probably, this is one of the most difficult problems which will be confronted during the design and creation of the Greek parcel-based land information system. Furthermore, disputes may arise, between the various state agencies, due to either the changing role of their activities or the reduction of them (as actually happened between the Ministry of Physical Planning, Housing and Environment and the Ministry of Agriculture, over which agency should have the control of rural mapping activities, in October-November 1989).

However, all the above countries are opposed to creating a centralized system of data collection and maintenance, but favour a modular design, in which existing systems and information process will be rationalized and improved prior to automation and then integrated into a total system over several stages. This concept is also adopted in Greece, where institutions and state agencies are addressing their research towards to it. In fact, a preliminary study was carried out by Y. Maniatis (in Ph.D form-see [53]). Nevertheless, the problem is still substantial since the activities and needs of state agencies and society are not well determined (see chapter 3).

Perhaps one of the principal issues, in the above examples, is the transfer of data from register books to databases and the design of data structures, or manner in which all information contained in the system will be organized and stored for manipulation. Furthermore, the data exchange problem between databases is troublesome task.

Considering the above and the position of Greece, where conversion of Land Registry system into digital form is not needed since such reliable system does not exist (see chapter 3), the time saved in creating an automated cadastre and furthermore, an integrated L. I. M. S. would probably be substantial.

However, thorough studies should be made in order to estimate the extent of work carried out for the creation of the Greek parcel-based land information system. Consequently, the financial impacts should assessed and financial resources should be obtained. Coordination of L. I. M. S. activities is primarily a government responsibility in the above countries, however, in Greece, due to financial shortages (i.e limited amount of money given by the government) the organization (responsible for the system-see para. 3.3) should be also self-financed.

Finally, the adoption by Greece of a computerized system may be economically beneficial, nevertheless, it may lead problems. Computer technology is rapidly changing, therefore long range planning may be difficult. It is always possible that resources become committed to one system, and a better system emerges after a short time. To this effect, the estimation of costs should be made for a determined time within where there will be overall financial return. Besides that, an impulse should be given to the development of relevant technology, inside the country.

Moreover, since the introduction of a computerized system will allow an easy access to the data, another very important problem also arises: "*To whom these data are accessible and for what purpose* ". In Sweden for instance, where the databases are greatly interconnected, there is a Board (of nine members), under SFS 1973-289 (11th May 1973) rule, for monitoring the whole system (from illegal use). On the contrary, in Greece there is not any relevant legislative aspect, and even more, people are not aware of the problem. Thus, it becomes apparent that studies should be addressed to this direction too.

Chapter 3

Greece

3.1 Necessity for a Greek cadastre.

In Greece there is a basic, much outdated and rarely used Land registration system. A system of mortgage registries exists but it does not operate effectively because it relies on land owners to declare their properties instead of relying on its own, independent, records. In some cases the state does not know which is privately owned land and which is state owned.

Another basic problem is the total lack of titles for some parcels. Currently a potential property-buyer has to rely on the owner's knowledge of his own property holdings rather than referring to the official records as they do not exist.

The problem of non-existence of a cadastral system has been addressed by many the last two decades in Greece and it is well known. Rokos (Rokos,1981) ([73] & [74]), after detailed research reported and analysed the effects of the lack of a national cadastral system.

Obviously Greece needs a cadastral system which will provide a geometrical and legal property record and will also ensure an objective evaluation. Even more with the introduction of modern data processing methods it will not only improve present decision making but it will support and control future planning and management decisions.

3.2 Users.

A parcel-based land information system being a composite technico-economic project, involving substantial legal, economic and administrative decisions as well as important social repercussion. It must be approached methodically (Figure 3.1) within the framework of the Law. Poor system design has been identified as a major contributor to under-utilization and associated system faults (ASPRS,1983)[4].

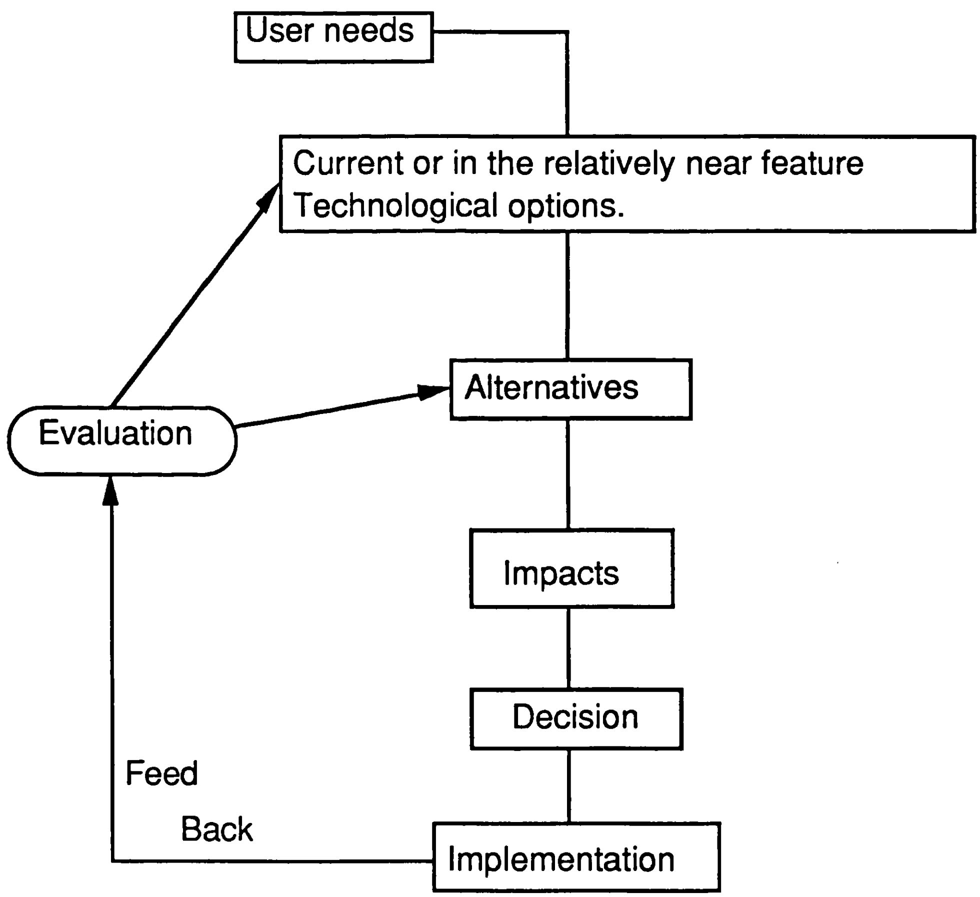


Figure 3.1 General flow diagram of the implementation cycle for a land information system

The most important part of the model design (Fig. 3.1) is to have a clear understanding of those who can benefit from the existence of such a system and their needs (not only maps or other tools of the trade) and the importance of the information is to them.

The main users of a parcel-based information system are found in the state government departments. In the case of Greece they include the following:

* **Ministry of Physical Planning, Housing and Environment**
* **Ministry of Agriculture**
* **Army Geographic Service**
* **Ministry of Finance**
* **Electricity Service**
* **Telecommunication Service**
* **Water Service**

The second user group is the private sector members of which are distinguished as below:

* **ordinary people**
* **construction companies**
* **notaries**

The third and last user is **municipalities/parishes** which need to make planning and development decisions for their area or to identify and protect their properties.

At present, a major lack of understanding of Greek user requirements and preferences is evident, along with problems in determining how preferences will change over a period of time as the use and significance of land changes. As a result, many state departments have now started to re-examine their needs. The main reason for this action arises from a government desire to use a cadastral system (see para. 1.2), hence it is vital to have a clearer picture of all user needs.

3.3 Greek attempts to establish a cadastral system.

In Greece from 1836 until 1961 different definitions about the cadastre have been given and therefore, many kinds of laws were established. Sometimes these contradicted each other, trying unsuccessfully to give an answer to the important cadastral survey problem. The most important were summarised by Rokos in 1981 [73].

In 1970, the dictatorship, under pressure of new techniques and human needs announced the beginning of the National Cadastral. However, even this initiative did not support any legislative infrastructure program or study. This attempt was stopped in 1974 by the new government. After 1974 the Technical Chamber of Greece (T.C.G), the Greek Association of Rural and Surveying Engineers (G.A.R.S.E) and the National Technical Universities tried to persuade the governments of the case for the creation of a cadastral system in national basis.

Finally in 1986 the government announced (rule 1647) the creation of **Organization of Cadastral and Mapping of Greece** which will be responsible for constituting, maintaining and updating of the uniform justificative cadastre of Greece. Furthermore, it will be responsible for geodetic network and mapping coverage of the all country, inventory and mapping the natural resources and finally the formation of an environmental and land data bank.

3.4 Cartographic Infrastructure in Greece.

Maps are the basic tool for planning, development and effective management of natural resources of a country particularly in rapidly developing countries.

In Greece the mapping data are insufficient, representing a variety of scales, projection systems, compilation times, and controlling organizations. Maps are made by various state departments and organizations without common standards in terms of projection systems, scales accuracy or coding of charts. For example the three projection systems are commonly used: Hatt, UTM, 3-degree UTM.

Cartographic applications are based on the triangulation network of a country which also relies on the ellipsoid suitable for this country. Greek cartographic applications rely on Hayford's ellipsoid.

As mentioned above there are various organizations which compile and keep cartographic data which may be used for the preparation of the Greek parcel-based land information system. Although such data must be evaluated it is out of the scope of this project (due to limited time) to proceed to this direction. However, the main state agencies are referred and their data are recorded (Appendix B).

3.4.1 Mapping data in state agencies.

The Army Geographic Service is the main state department which keeps a large volume of vital information about land. Its activities include triangulation, surveying of the entire land, compilation of charts and general purpose maps and finally aerial photographs (Appendix B) Maps in the range 1:1,000,000 to 1: 50,000 are compiled with sufficiency, some of them are updated and on a homogeneous system. Since 1960, the compilation of the maps in scale 1: 5,000 has been made, in the Hatt projection system, which has not completed yet. Thus, due to this delay, problems of cost and technological changes (e.g. accuracy) are caused.

The Ministry of Physical Planning, Housing and Environment comprises various departments which prepare and keep cartographic data to assist in problems of housing needs, land use, street planning and other developmental projects (Appendix B). Maps are without either uniform projection or coding system, and technical specifications vary in different projects. Mapping accuracy is depended on methods carried out and the current needs of the specific project.

The mapping work accomplished by Ministry of Agriculture may be distinguished to those plans prepared 1) for settlement programs, 2) for housing and settlement programs and 3) for reforesting programs (Appendix B). Taking into account overlaps in the work having been done, the total plans are estimated to cover an area of approximately 25,000,000 str [71].

Sea-shore regions, coast lines, beach boundaries and some state urban and rural property are mapped by the department of technical services of the Ministry of Finance. The work utilizes, but not consistently, the national trigonometric network. The regions where coast-line boundaries have been or are being, fixed are mapped by Hydrographic service in three different scales (Appendix B). The work involved in preparing these charts has infrequently used the national trigonometric network as a reference too.

As a result of the above is that within the same developmental program, the designing is made on maps with 1:50,000 scale in Hatt (1976) projection and the implementation is carried out either on 1:5,000 scale maps in Hatt (1967) projection or on 1: 1,000 scale maps in 3-degree UTM. It is obvious that problems like coordinate transformations, edge matching, data comparisons are confronted in every day work.

Concluding it should be referred that cartography in Greece is insufficient, specially in scales suitable for regional and urban planning (1: 10,000 - 1: 1,000).

3.5 Summary.

Reviewing the existing situation in Greece, which has been indicated above, and the examples of Land Information Management Systems currently in use in various countries it is realized that there is little comparison between them. In Greece there is not any description or registration based upon technical aspects, national standards and legislation. Greece can not, however compared with countries under development since their priority is to prepare small scale maps. Therefore, Greece occupies an unique position and the whole operation for the creation of the parcel-based land information system can be started from a "clean piece of paper".

Chapter 4

Land Information Modelling

4.1 Introduction.

The cost of developing a cadastral system is obviously high and the process is long term and incremental. To decrease the costs, it is necessary to use all of the available information and technology at hand.

An essential part of cadastral surveys is the production of appropriate maps to a usable scale. However, as stated before conventional mapping, as produced by most Greek state agencies can not deliver the maps needed in the rapidly changing situations. For most urban areas outdated maps are usually found. Thus, the problem of providing land-related data essential to the cadastral system has arisen. Furthermore, land information which could support other tasks within the same system like land use analysis, design and land valuation, is not provided.

Meeting such mapping needs, an efficient and flexible solution is urgently required to collect, edit and record data in order to be used in the very beginning stages of cadastral surveying as well as to provide land-related information for the solution of current land management problems.

4.2 Data Models.

The large amount of data that are to be collected during the mapping procedure must first be inventoried and classified appropriately. These data are intended to represent real world facts and to record real world events. If such data is to be capable of providing high level information , the data must be modelled in such a way as to reflect real world (real world reflected model). The elements of interest (entities), their relationship and their attributes must be described in a manner that is independent of any computer specifics. Thus, ideas on land-related data organization to be transportable and discussable among users of the limited land-related information and mapping proposed here system. Different implementations would change the performance of the system not the meaning of the information (Lodwick and Feuchwanger, 1987)[50].

One of the critical turning points in using the real world reflected model for the proposed system design lies in the setting its objectives. The objectives should offer direction for a first determination of data requirements for present and future activities of each user involved, specially of the Organization of Cadastral and Mapping of Greece.

In a real world reflected model, there are also two aspects to consider: one level of descriptive information understandable to users and another level of positional information (Fig. 4.1). These two levels of information are also well-known as geographic and geometric. Starting from the former, it is necessary to consider first the data investigation process which involves the identification of entities and the relationships types and the determination of attribute types.

4.3 Project Concept.

Land-related entities, considered for cadastral purposes are dependent on the scale of map. They are either point, linear or areal features. Point features might include street lights, telecommunication poles or valves. Linear features might include centre lines of roads, pipelines, or pavements. Areal features might include parcels, buildings, or blocks of parcels.

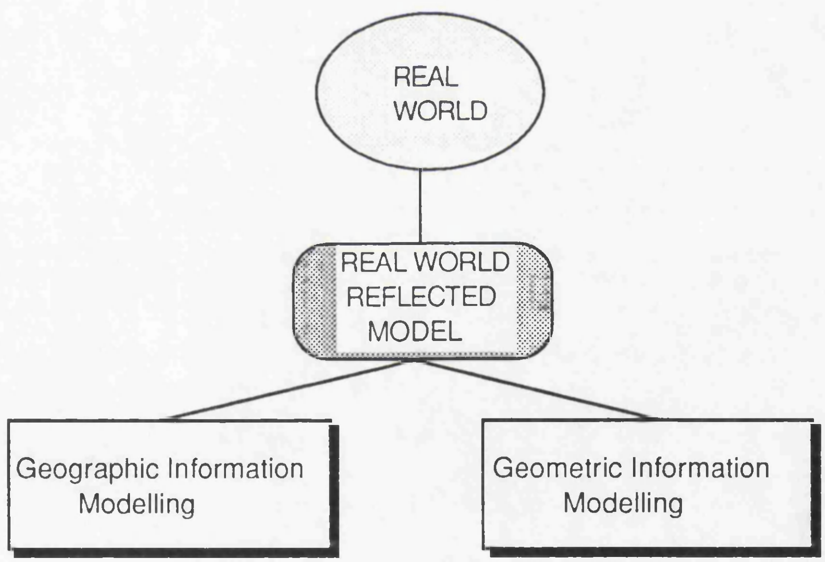


Figure 4.1 Data Modelling.

Land-related relationships are those relationships which describe the properties of sharing, connectivity and adjacency of land-related entities. The special form of these logical relationships is the topology and it is illustrated in Figure 4.2.

Sharing relates to the ability of land-related entities to belong to more than one higher level land-related entities. The line segment AE (Fig. 4.2) for instance, belongs to both polygon(1) and polygon(2).

By connectivity it is referred to the relations among land-related entities described by points and lines. The polygon(1) in Figure 4.2a, for instance, is formed from interconnected boundaries (: lines) AD-DE-EA.

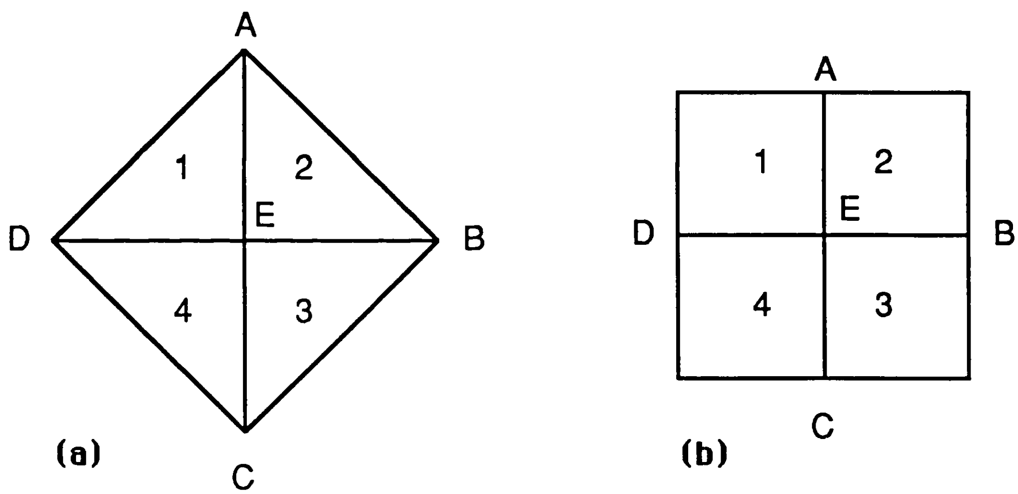


Figure 4.2 Topological equivalence (after Bogaerts, 1981).

By adjacency it is meant knowledge of the land-related entities next to the currently land-related entity of interest. For example in Figure 4.2b, polygon(1) is on the left side of polygon(2), or boundary EA has polygon (1) on its left side and polygon(2) on its right side.

Land-related attributes depend on whether they describe location or other characteristics. In this project only thematic attributes are considered.

In a parcel-based land information system the data are organized around the land parcel, and an objective of the system is to manage property ownership, boundary information and land use. Therefore, the system proposed is to be addressed to this direction, where two approaches are considered.

The development of the first approach lies on that the basic unit of the system is a feature. In this case it means that the data of interest is considered as an areal feature (Fig. 4.3). This comprises:

a) Land-related entities.

1- Block, having attributes: ID (identifier), percentage of defined parcels.

2- Parcel, having attributes: ID, land use, and type (see Appendix C.1).

3- Building, having attributes: ID, Type (see Appendix C.1).

b) Land-related relationships.

1- a block of composed of many parcels and a parcel is a part of a block.

2- a parcel may include many buildings and a building may be part of a parcel.

The second approach can be described in Figure 4.4. The basic unit of interest is the parcel boundary and then the parcel itself. This comprises:

a) Land-related entities.

1- Boundary, having attributes: ID, type (see Appendix C.2), length, left and right side parcel.

2- Parcel, having attributes: ID, area.

b) Land-related relationships.

1- a boundary may belong to more than one parcels.

2- Many parcels may share the same boundary.

Having defined the land-related features, their relationships and their attributes, it is also necessary to define their position. This can be done by geometric modelling (Fig. 4.1). Though, before proceeding to this step, it is also necessary to overview the test area.

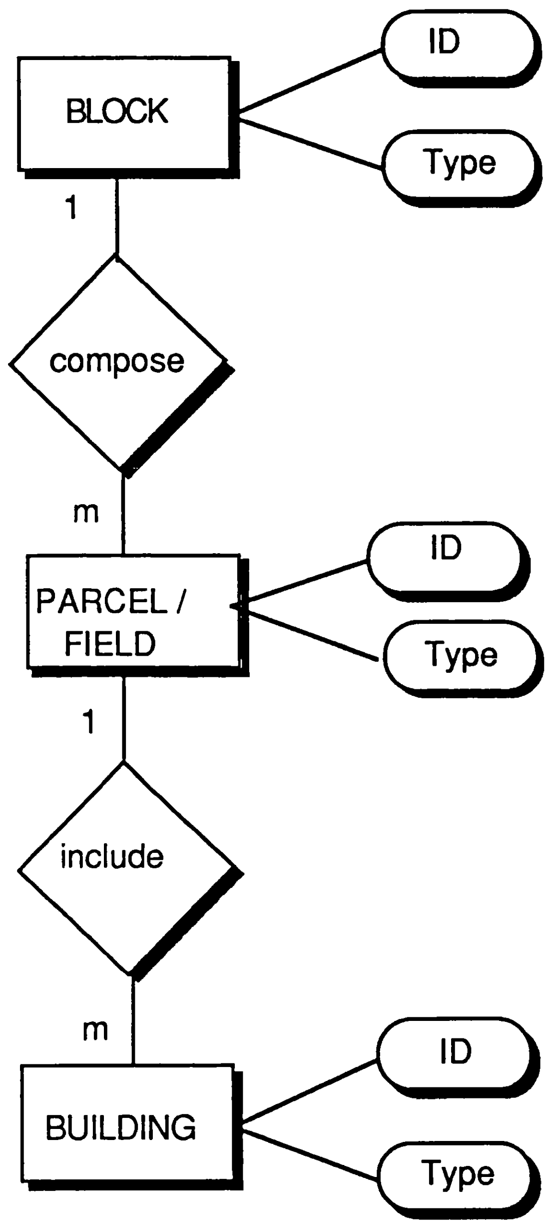


Figure 4.3 System first approach model.

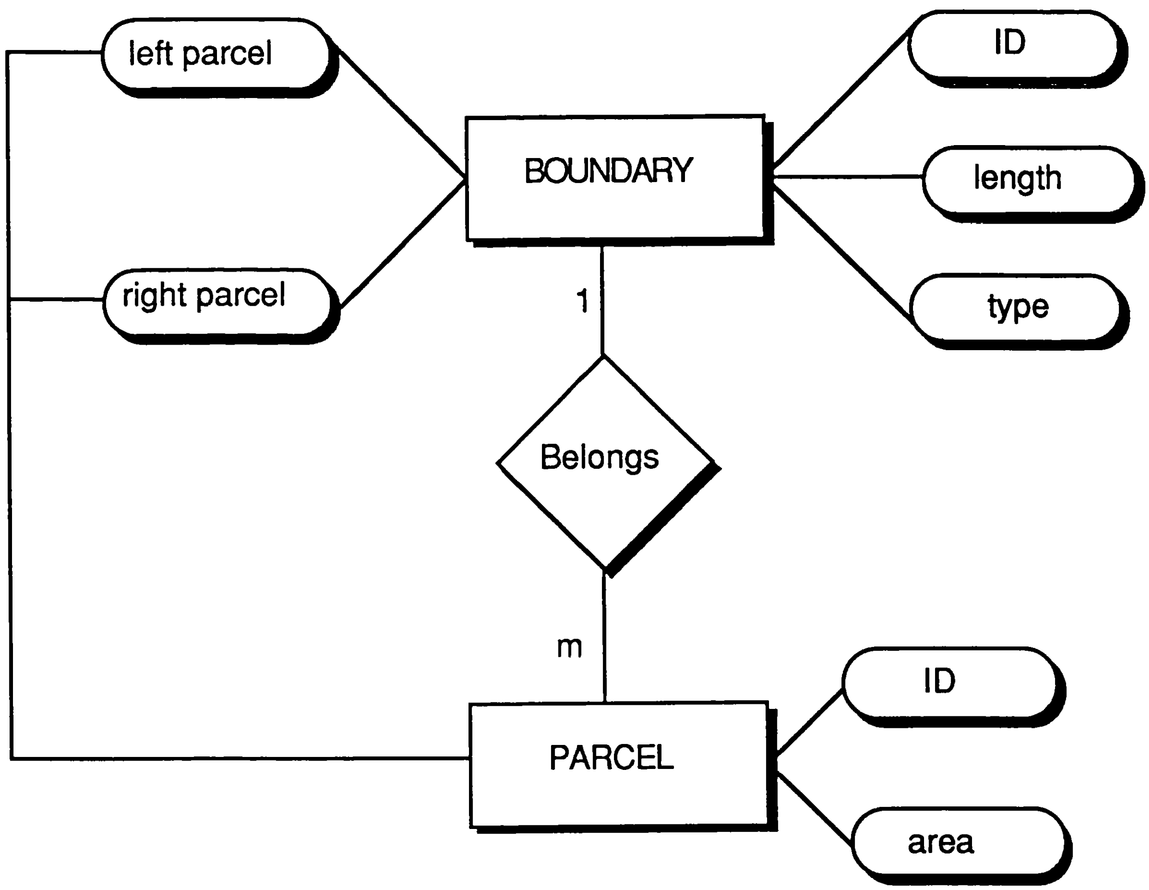


Figure 4.4 System second approach model.

4.3.1 The Test Area.

4.3.1.1 Location of Test Area.

The Greater Volos area is the site of the current project where the approaches presented above are tested. The test area is subdivided into two sections. A section (five blocks) of Volos city (urban site) has been chosen as suitable for the photogrammetric survey, because:

1- it is heavily build-up region.
2- there is a variety of buildings.
3- it is difficult to locate the boundaries of parcels.
4- there is a considerable amount of topographic details which should be captured.
5- Generally, all the above represent a common situation in most Greek cities and towns.

An urban-edge section of the same city, which combines urban and rural characteristics, is the second part of the test area. New buildings areas are located in this section and fields with different use are also included. A quick collection of these data is urgently required as the whole area rapidly changes. Furthermore, a data organization is also needed to maintain all this information for later use (cadastre).

4.3.1.2 Cartographic Material.

Photogrammetric plots at 1: 1,000 scale, provided by the department of photogrammetry of Ministry of Physical Planning, Housing and Environment, were the reference used for a better definition and interpretation of features. These plots derived in 1986 from 1: 7,000 scale aerial photographs taken in 1982, without any updating. The two test areas are within the rectangles defined by :

URBAN AREA

Nmin : 595,600m	Nmax : 595,900m
Emin : 134,100m	Emax : 134,300m

URBAN-EDGE AREA

Nmin : 595,200m	Nmax : 596,300m
Emin : 134,800m	Emax : 135,400m

4.3.1.3 Ground Control.

Five plan and five height control points were used for model formation of urban area, on the Kern analytical plotter DSR-1. These were provided by the same state agency. It should be noticed that a single incorrect control point was detected. Four plan and four height control points were used for model formation of the urban-edge area. In Appendix E the ground control points and their residuals are given.

4.3.1.4 Aerial Photographs.

The aerial photographs acquired to evaluate photogrammetric data capturing methods for use in initial steps of cadastral mapping in Greece, and the extraction of land-related information relevant to objectives of a cadastre, were also provided by the Ministry of Physical Planning, Housing and Environment. Details of photographs are given below:

AERIAL PHOTOGRAPHS covering part of Volos city.

	Date	Scale	Numbers of photographs.
Urban area:	2-11-82	1: 7,000	148770-148771
Urban-edge :	2-11-82	1: 7,000	148772-148773.

A disadvantage using the above photographs is that they are possibly at too small scale for cadastral mapping. Especially, for the Greek situation where land is divided in very small parts and its value is high. This is rather an important disadvantage, however, since photographs of larger scale (e.g 1: 4,000) could not be provided, this project was undertaken using the above mentioned photographs.

4.4 Spatial representation.

Having overviewed the test area, the positional extent of land-related features as stated before, should be also defined. There are two fundamental ways of representing geographic data which are the **vector** and **raster** representation. Raster representation is a set of cells having the same shape and size and they are located by coordinates, in the relevant system, of the column and row number. Linear and areal features are made by the sum of one or more cells (pixels). A point is represented by a single cell.

In vector representation areal features are described by a series of lines or points while linear features are described by a series of lines or points and point features are described by coordinates (Fig. 4.6). Using vector format the current project was carried out.

A comparison between raster and vector format can be found in Burrough, P. A. (1986)[15].

4.4.1 Vector Format.

Land-related entities considered for cadastral purposes are depending on the scale of the map and as mentioned above in vector format these are points, lines, areas. A point is representation of an entity that is adequately described by its position and descriptive attributes without having measurable length, at the scale that it is to be displayed.

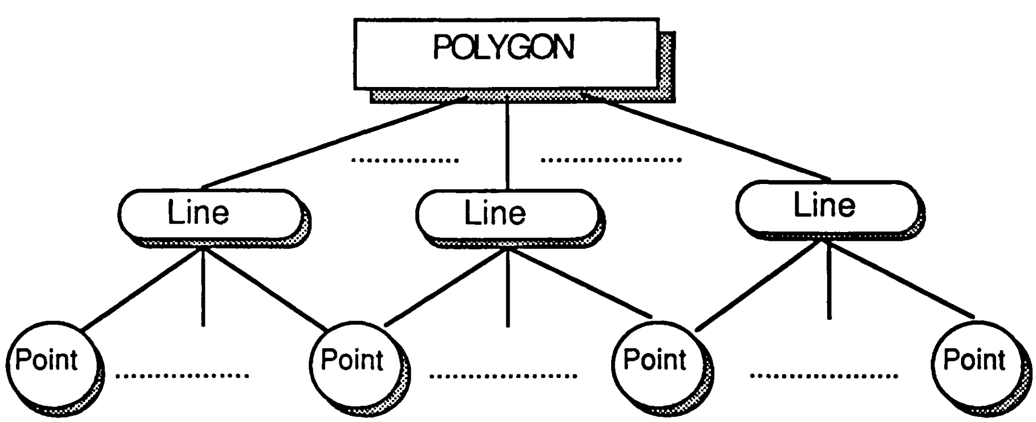


Figure 4.6 Vector representation.

A line is representation of an entity with a measurable length whose geometry is adequately defined by sets of point coordinates at the scale that it is to be displayed. An area is a representation of an entity which can be defined either as strings of coordinates representing its perimeter or as point giving a reference to the whole area.

4.5 Data Management.

Data management is the process of data storing, producing graphical display of data and analysing their characteristics using set of procedures. The system proposed consists of some procedures to satisfy the above requirements, so that it will be possible to extract, reproduce or display different types of data.

4.5.1 Types of data.

Data relevant to a parcel-based land information system can be distinguished in three categories (Dale and McLaughlin, 1988)[21] :

1- alphanumerical (i.e an attribute value).

2- Graphical on maps and aerial photographs (i.e colour, line type..).

3- Numerical in either vector or raster form. (i.e coordinates of a vertex of a polygon,...).

4.5.2 Data files.

The ways in which data can be organized in the computer are very important in any land-related information system, since they should be able to allow data to be accessed and cross- referenced quickly. Thus, information is quickly provided so that decisions can be made and actions initiated.

Collection of similar data form the simplest way of data storage, called File. A file consists of a number of related records and each record is made-up of a number of fields. More details about files and the use of them can be found in Burrough, P. A. (1986)[15] and Dale and McLaughlin, (1988)[21] and of course in many books about data organization in computers.

4.5.3 Database.

A database is a single collection of related data that can be used in many applications. In order to be able to access data from one or more files easily, it is necessary to have some kind of structure. The most common database structures are the hierarchical, network and relational.

The reasons of developing and using a database have been addressed by many. Date, C. J [22] gives some advantages when compared with applications which use private files. These advantages can be briefly given below :

- compactness,

- speed,
- less drudgery,
- centralized control of its operational data, which means that:
    - redundancy can be reduced,
    - inconsistency can be avoid,
    - the data can be shared,
    - standards can be enforced,
    - security restrictions can be applied,
    - integrity can be maintained,
    - conflicting requirements can be balanced,
- data independence.

However, some disadvantages also exist (see Date, C. J.,1986)[22]:

- an error in one input data record may be carried throughout the database.
- traditional processing jobs may run more slowly.
- major attention must be given to the security of the system.

The last of these is very important to Greek people, since they are suspicious of organizations which keep information relevant to them.

Chapter 5

Data Acquisition

5.1 Data classification

In order to map land-related objects for a parcel-based information system from aerial photographs, it is necessary to identify these objects and judge their significance. During this process certain tasks, such as detection, recognition, identification, analysis, and classification must be undertaken. Detection involves selectively picking out objects that are directly visible, for example buildings, or part of objects that are not clearly visible, for example part of boundary line, on the aerial photographs. Recognition and identification involve naming objects and analysis involves trying to detect the spatial order of the objects. Classification comes in to arrange the objects identified into an orderly system before they are introduced into parcel-based land information system.

There are various systems designed for classifying land-related information. Probably the most well-known is the one created by the United States Geological Survey (USGS). This classification system is expandable so that different government agencies or organizations may have flexibility in developing more detailed land classification. Thus, it has achieved widespread acceptance and it is used in a number of operational mapping programs. Details of the system can be found in Avery and Berlin (1985)[5].

According to geographic models presented in paragraph 4.3 two classification schemes of topographic features are proposed in this project. The first scheme uses as framework the classification system adopted by USGS (Appendix C.1) and it is applied to the first approach of the geographic modeling (Fig. 4.3). In the second scheme (Appendix C.2), applied to the second approach to the geographic modeling, the basic objects are the boundaries of a parcel. It is obvious that road and pavement information have got the same structure in both systems. The difference is that in the former, they belong to the third level of information, while in the second scheme of classification on the first level (see Appendix C). To be more precise, apart from road, pavement and water information, the first system uses an areal list type of classification while the second system uses a linear list type.

5.2 Data Capturing Methods.

Digital techniques, as previously described (para 2.2.1), introduce many changes in map compilation by photogrammetric methods. Analogue or analytical stereoplotters are used to derive coordinates of topographic features. Analytical stereoplotters are a very important technological achievement and they are widely used.

The development of the system for digital mapping was based on the hardware that already was available in the department of Photogrammetry and Surveying at University College London, giving an emphasis to the analytical plotter. The hardware configuration of the photogrammetric mapping system used in the project is shown in figure 5.1. All measurements from the aerial photographs were processed with the Kern DSR-1 analytical plotter. The electronic architecture of this instrument is based on a distributed concept (Appendix D). The main control computer was a PDP 11/73. This microprocessor computes all programs for the DSR-1 operating system and communicates with all other processors which are working on divided applications. The communication between user and the system is achieved with an alphanumeric terminal and a keyboard. As numerical and graphical information are required as output forms of a parcel-based land information system, the PDP 11/73 was used for storing the numerical data and the Kern GP-1 precision plotting table was the output unit for the real-time graphical output (not the final product).

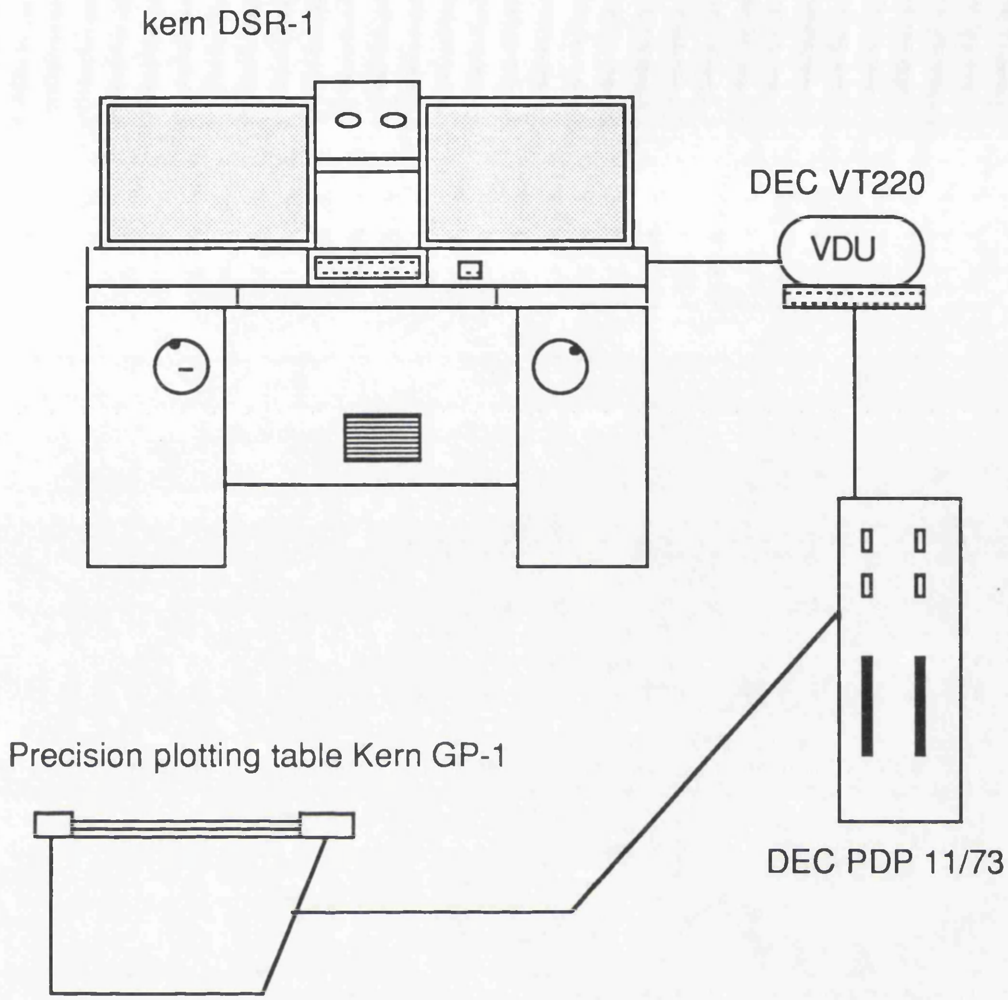


Figure 5.1 The photogrammetric mapping system.

An important characteristic of the DSR-1 is that its optical viewing system allows the binocular viewing of each photo-carrier and an individual zoom magnification. In addition to this the floating (measuring) mark is individually adjustable in size and brightness.

A large library of diagnostic and application software supports the DSR-1 system. The software includes a complete stock of diagnostic, aerotriangulation, profiling, altimetric and planimetric plotting programs. All programs work with a menu-technique and may be user defined in a main menu. For the current project the following programs were applied and defined in the main menu : 1) inner orientation 2) relative orientation 3) absolute orientation. Other programs, overlapping the whole project were : 1) project definition 2) control point input 3) MAPS-200. The program MAPS-200 (Microcomputer Aided Photogrammetric Station) is a program for the acquisition of photogrammetric data, compiled with on-line plotting and their registration. Orientation of a stereomodel is necessary for the data acquisition within MAPS-200. The features of this software may be distinguished as follows : 1) manuscript preparation, 2) on-line compilation, 3) symbols and line types. All these MAPS-200 functions are designed for operation built around the Kern menu approach. The manuscript preparation is a gridding program which provides for sheet preparation with virtually any type of grid lines, grid intersection symbols or annotation styles. The recorded digital data was structured according to project requirements. To this effect feature codes for all features that had to be represented either by line or symbol types were defined. These feature codes may be numerical or alpha descriptive. For each feature code the alpha description, the predefined symbols or line types, size,rotation, annotation and the pen number were defined and stored in a file (LIBRARY). During data collection, the feature was identified then the code was entered from the library or by typing a "message" before it was digitized. Thus, information concerning plot mode which in this project the straight-line mode was used, line and/or symbol type, pen selection, scale factor and alphanumeric data might have been entered, was recorded as feature code together with the coordinates. Data files were created with the CAM recording format which is a sequential ASCII text file. Editing of the recorded data was carried out off-line and it was the next stage of the project. The flow-chart shown on Figure 5.2 summarizes the digital photogrammetric system used.

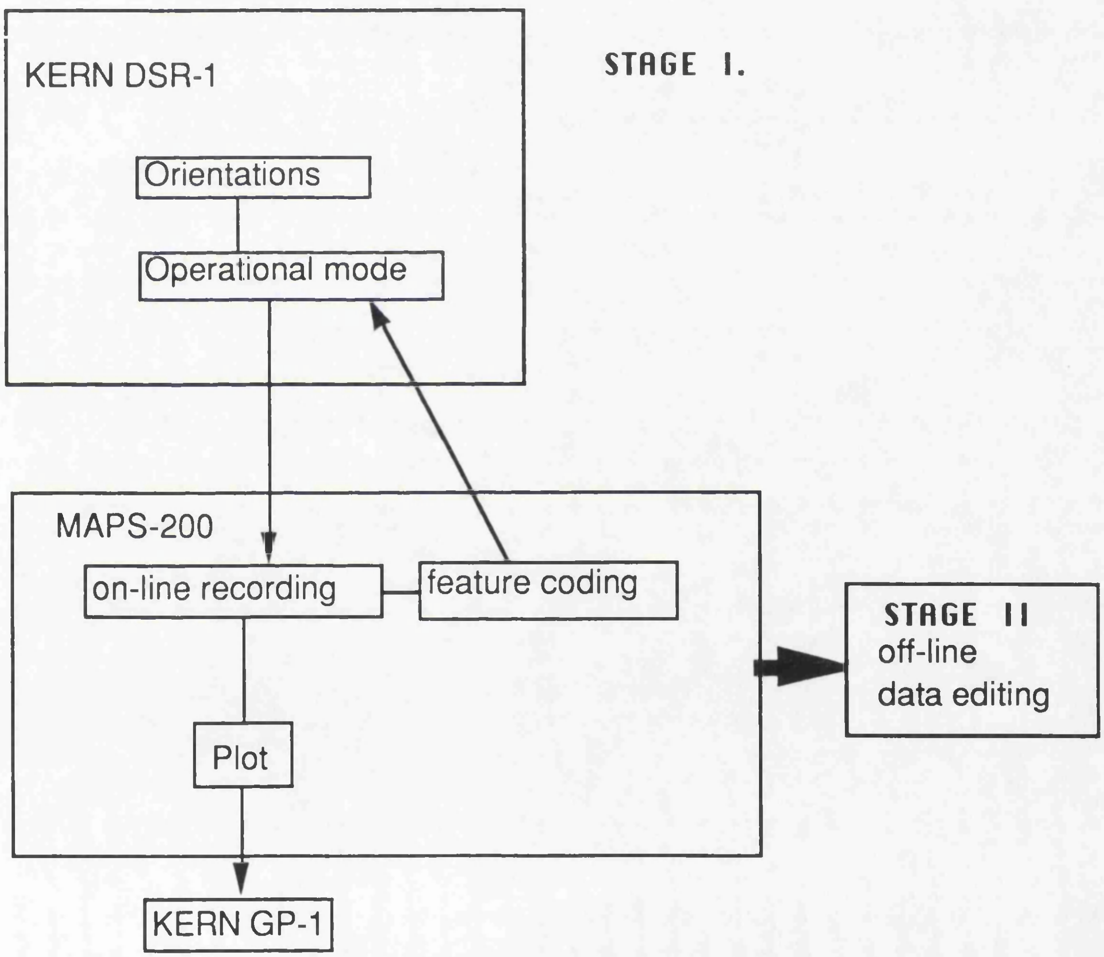


Figure 5.2 Project digital photogrammetric system.

The primary objective of this system is to select as much detailed information as possible to be input into a parcel-based land information system. Therefore, as it has been already referred (para. 4.3 and 4.4) two approaches are considered, and consequently two data capturing methods were applied :

1) "Closed" polygons and

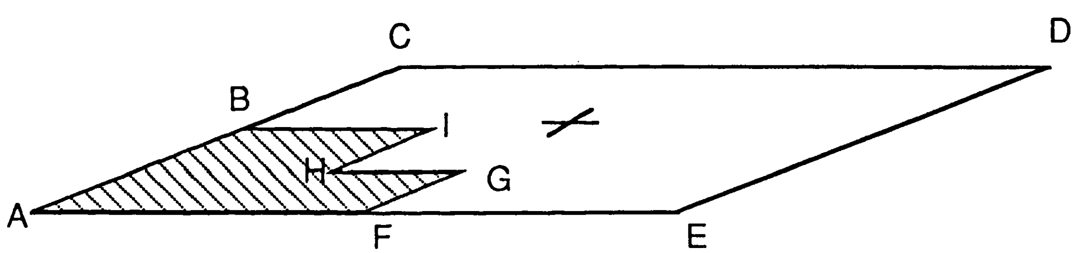
2) line-following (Spaghetti) method.

5.2.1 Line-following (Spaghetti) method.

The first step in developing this method was to investigate what features were going to be captured. Having determined the two classification schemes in paragraph 5.1 (Appendices C.1, C.2), the system which uses the linear list type of classification (Appendix C.2) is aligned with the current data capturing method. Thus, line and symbol definition was made in MAPS-200, according to this classification scheme. A cross symbol being used to identifying, as a centroid, parcel or field areas.

Features were tracked continuously and they were captured in any convenient sequence as series of strings where each string was coded and classified (Fig.5.3). The plot on the Kern GP-1 table acted as a record of progress. Features that were clearly visible on the photographs were obviously plotted faster than those were not clearly visible or not visible at all, since an interpretation process had to be made to classify and flag them for further investigation in later stages of cadastral surveys. Boundary information for instance in the Urban area (Fig. 5.3 - feature BC), was not generally visible on the photographs, the exception being buildings and walls located right on a parcel boundary. For dual line features (hedge, road, canal), only the centre line or one edge (bank of canal) was digitized.

It is obvious that some features might have been digitized twice or at least points of features were digitized more than once, each time probably with a slightly different values. In order to solve this problem these features and points must be identified as a limit to the amount of data can be handled on "Spaghetti" files. For these purposes the data had to be reformatted in a "links and nodes" structure (see chapter 7).



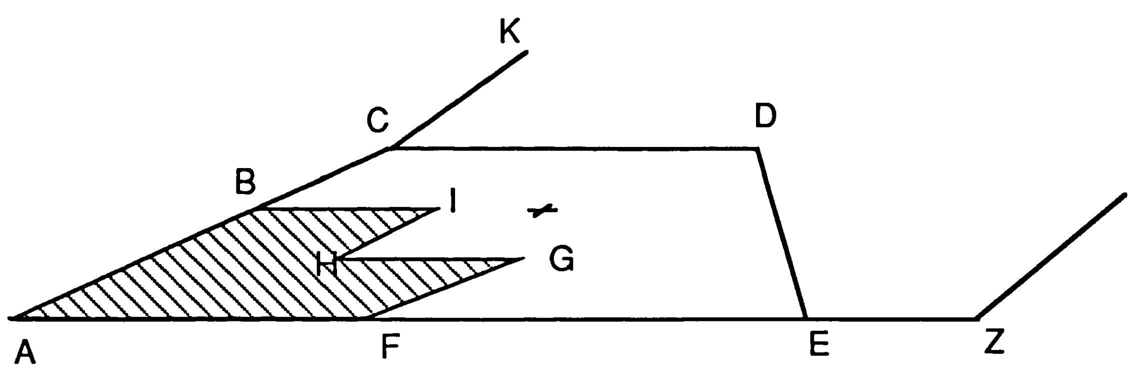
FAB : code 37 : wall of building as boundary.
BC : code 38 : undefined boundary-probably fence.
CDEF : code 35 : fence as boundary.
FGHIB : code 41 : building outline.
\+ : cross symbol as centroid.

Figure 5.3 "Spaghetti" Method.

5.2.2 "Closed" polygons method.

According to the classification scheme developed in Appendix C.1, features codes were created in the line / symbol library of MAPS-200 and features that collected as polygons were the following : 1) block of parcels 2) parcels 3) buildings (Fig. 5.4).

Special alpha descriptive data was entered by typing from the keyboard before the digitization of the feature to indicate and record more information about the feature itself. Thus, much of the effort in capturing such data concerned their accurate classification. Features were captured digitizing the polygon boundary as a coded and classified string of coordinates pairs for each vertex and intersection point in the X-Y-Z coordinate system. Thus, parts of features were digitized more than once.



ZEFABCK...Z : block of parcels : code 23.
EFABCDE : parcel : code 29 : undefined (: one of its boundary is not defined on the ground or it is invisible).
FABIHGF : building : code 1.
+ : cross sumbol : centroid.

Figure 5.4 "Closed" polygon method.

The FAB segment for instance (Fig. 5.4), was captured three separate times; firstly, as part of block of parcels polygon, secondly, as part of parcel polygon and thirdly, as part of the building. It is obvious that coordinate data redundancy does exist, a problem which is so important in data management of a parcel-based land information system. Besides the digitizing of blocks, parcels and buildings, features presented roads and pavements were also captured following the former method.

5.3 Evaluation of the Procedures.

The interpretation and plotting was carried out by the author of this thesis with no experience of analytical plotters, digital mapping and interpretation process, although with limited experience of plotting with analogue instruments.

5.3.1 Classification.

The aim of the classification procedure described above, was also to enable the users to retrieve and update the data, during the process and development of cadastral surveys. Thus, some state agencies will use these land related information in order to overcome current problems in their planning and their decisions, others will improve the data which they keep.

To provide the background information which is helpful for the further process of cadastral surveys and for a limited solution of the current complicated problems (Chapter 3) attention was paid to extract and map the critical features (parcels, buildings, boundaries of parcels). Subsequently, the corresponding interpretation was a straightforward recognition of features and it was not very time consuming. However, the following problems occured during this classification :

1. It was difficult sometimes to indicate the border or confirm line of a topographical unit. Therefore, the term "undefined" was used. The reason was that there was not either any demarcation of the ownerships or any other helpful source of additional information (e.g. maps).

2. It was difficult to see the elements separate from their use (Appendix C1: Agricultural land; level II).

Subsequently the classification was subjective and therefore to some degree inconsistent, which means that the need for ground verification is evident.

As far as the differences are concerned, between the two classification systems it is self-evident that each of them provides different type of information :

* in the first system (areal type of classification: Appendix C.1) information for the critical elements (parcels, buildings) is provided for the whole object and the minimum unit of interpretation was the building. On the other hand, in the second system (linear type of classification: Appendix C.2) the parcel boundaries serve as vehicles for information.

* in the latter approach (second system-Appendix C.2) the land cover information is not consider at all, because it will be captured later on.

It is obvious that more detailed (topographic) information is provided in the second system and, considering that one of the main concerns of this study is to select as much detailed information as possible (para. 5.2) for a parcel-based land information system, this classification scheme could be regarded so far, as more effective.

On the other hand both classification systems met the following criteria :

1. They are applicable over all of the country.
2. As the cadastre is proceeded, comparison will be possible between future data captured.

Another question which also arises is whether either of the systems will be in use for long term. It is well-known (B. Macarovic, 1984)[51] and (P. A. Burrough, 1987)[15] that between the primary data and the information end-products, the information structure can change several times, and subsequently the classification scheme will change. However, since further processing of data is essential in order to be prepared as input into a parcel-based land information system as well as due to display and presentation requirements because of land management problems, such a classification is required at least in short term basis.

5.3.2 DSR-1 Evaluation Procedure.

One of the most interesting experiences made in using the analytical plotter DSR-1 was the speed of carrying out the orientations, which took about fifteen (15) minutes. Starting from the interior orientation, there was no restriction upon where the photographs had to be set on the photo-carriers, the instrument guided the measuring mark in the approximate position of the four fiducials.

The next step after interior orientation is relative orientation. The instrument, is always used as a stereocomparator, so the photographs are always in position of the stereocomparator. Thus a set of parameters to form the relative orientation was needed. By removing the parallaxes of twelve (12) points, and after a short calculation, the results of the relative orientation were available. The result was the residual parallaxes in all measured points. Some points were remeasured or disregarded of the calculations because their result was not acceptable (Appendix E). It is worth noticing that the instrument again guided the measuring mark to the approximate position of the twelve (12) orientation points (preset by Kern). The absolute orientation was done by measuring ten control points in Urban area and eight in Urban-edge area (Appendix E). The sequence of measuring these points was completely free. Measuring two plan control points the instrument drove the measuring mark to the remaining plan-control. Several points were also remeasured because their result (residuals) was not acceptable. After accepting absolute orientation the standard procedure was to store the orientation parameters in files on floppy disk, where they could be recalled any time. This was very useful during the extraction of data where some failures occurred due to human or instrumental malfunction. The negative consequence of such phenomena would be the time loss required to re-activate the system. Performing interior orientation and recalling the stereomodels parameters from computer storage it took approximately five to ten minutes to re-activate the whole system.

Another problem related to model set up was that there were situations where the model had to be removed from the instrument due to its use by other people in the same period. Thus, the same model had to be re-established hours or days later. Again the same procedure as above, was followed.

At the time when the above problems arose a special care had to be taken on the already collected data. In MAPS-200 the last six recorded lines are displayed in the alpha-numeric terminal and these will be lost, if a failure occurs. Thus, there is no complete loss of the data and consequently the operator can return to the stage before the catastrophe in a very short time using the proper functions.

The most serious problem using photogrammetric methods for data acquisition concerns the accuracy of data captured (para. 2.2.2). This accuracy depends both on the registration method and on the source material. During data collection, features had to be classified and labeled to contain as much detailed information as possible. In doing these, skill and experience were needed and some time was spent away from the instrument looking at the plots provided or/and typing additional information, all these were source of errors. Material can be classified according to whether features are visible from air or ambiguously determined (e.g boundary which does not exist as line). Consequently digitization of the features was carried out considering the limits of buildings roof, existing parcel boundaries, and land use - land cover as parameters. Therefore, double measurements of sides of buildings or property boundaries, in both test areas, could not be avoided. Consequently positional accuracy is regarded very important and it expressed an error in the entire data collection process.

5.3.3 Data Recorded.

Digitizing a photogrammetric model is a complex task, as the operator has an additional duty, to interpret the features viewed. The interpretation of features for the compilation of the 1: 1000 scale map was a qualitative procedure. Many features (e.g boundaries) or part of features (e.g invisible corners of parcels or/and buildings) were not directly identifiable on the photographs but their presence was assumed and their location were inferred by the context of their surroundings. During data acquisition then, features were misinterpreted and subsequently they were misclassified due to operator error or poor source material. The acquisition of data is dependent on the skill and experience of the interpreter (operator) and, his familiarity with the area. The interpretation errors could be omitted if the results could be compared with the real situation or with existing maps (para. 4.3.1 and 4.3.1.2). The correction of these land-related data should be made in order to be input in a parcel-based land information system. For this reason features which require further attention were flagged (para. 5.3.1) and they should be corrected with field verification process.

Allowing for the above mentioned assumption and as no additional information was provided, the tables in figure 5.5 are given to demonstrate the amount of information obtained.

The urban area (fig. 5.5(a)) presented problems due to the high frequency of detail present. This was particularly noticeable during data acquisition with the "Spaghetti" method where detailed information had to be captured. Boundaries of fence type were sometimes difficult to be indicated. On the other hand boundaries of wall type were quite detectable.

In the urban-edge area (fig. 5.5(b)) more attention was paid to the determination of the parcels/fields and buildings than the land-coverage since the latter was quite clear. The solution of the former was relied on the land cover of the fields, while in the built-up parts, most parcels or boundaries of them were well-defined and well-detectable.

URBAN AREA

"CLOSED" POLYGONS

AREA	PARCELS		Percentage of defined parcels	BUILDINGS			
	Defined	Undefined		A	B	C	D
Block 1	9	7	56.25%	2	20	0	4
Block 2	28	14	66.66%	8	28	10	12
Block 3	10	2	83.33%	1	4	4	6
Block 4	16	3	84.21%	3	16	6	10
Block 5	14	9	60.86%	5	11	5	12

Note : Building A : a very old structure
Building B : a old structure
Building C : a new structure with old style roof (/\)
Building D : a new structure with new style roof (flat)

"SPAGHETTI"

Fence as boundary	40
Wall as boundary	94
Wall of building as boundary	187
Undefined boundary (possibly fence)	36
Undefined boundary (possibly wall)	17
Building outline (inside the parcel)	182

Figure 5.5(a) Data captured in urban test area.

URBAN-EDGE AREA

"CLOSED" POLYGONS

PARCELS		Percentage of defined parcels	BUILDINGS			
Defined	Undefined		A	B	C	D
247	24	91.14%	24	62	80	85

Note : Building A : a very old structure
Building B : a old structure
Building C : a new structure with old style roof (/\)
Building D : a new structure with new style roof (flat)

"SPAGHETTI"

Fence as boundary	147
Wall as boundary	208
Wall of building as boundary	270
Undefined boundary (possibly fence)	70
Undefined boundary (possibly wall)	18
Building outline (inside the parcel)	252
Hedge as boundary	113
Boundary defined by pegs	48

Figure 5.5(b) Data captured in urban-edge test area.

5.3.4 Accuracy.

Each mapping project has its own characteristics and its accuracy requirements need to be separately specified at the time of planning with due consideration of the final objectives. Accordingly, the results should be assessed to see if the accuracy specifications are met. On the other hand the establishment of acceptable criteria should be also made.

It was desirable in this project to have accuracy specifications from the relevant organisations or state agencies, but as it has mentioned earlier (Chapter 3), these type of specifications are not the same in all state agencies and furthermore, a new process of establishment of such standards has been started recently. Therefore, the graphical standards of accuracy were adopted as accuracy specifications. Consequently, the graphical accuracy of 0.15-0.20mm on the map scale served as criterion of the acceptance of the data acquisition process.

The total accuracy of measurements can be recognised as the sequence of the orientation accuracy and it is assessed according to project accuracy specifications. Hence, the following results (Appendix E) were obtained in the current project :

Urban area (No of Photos: 148770-148771)

Standard Deviation, Plan = 0.083m

Standard Deviation, Height = 0.125m

<u>**Urban-edge area** (No of Photos: 148772-148773)</u>

Standard Deviation, Plan = 0.158m

Standard Deviation, Height = 0.297m

Considering the map scale (1: 1000) then, the accuracy requirements will be : **Plan: 0.15m-0.20m** and **Height: 0.30m** (ASPRS, 1980)[3], both were met in both models. However, the results could be better, especially in the urban-edge area, if the quality of photographs was better and there was higher contrast between the control points and their surroundings. Thus, it becomes evident that the selection of control points by the mentioned state agency (para. 4.3.1.3), was poor.

5.4 Concluding Remarks.

Following two approaches, a basic classification of critical elements for a parcel-based land information system has been made. These are to be used in further process of cadastral surveys, as well as in limited solution of current land management problems, since they are common data in different state agencies. However, the use either of classifications systems could be made on short term basis.

The success of the photo-interpretation and the data acquisition processes relied upon the quality of photographs, which was not high, and on the skill and experience of the operator, since additional information was no provided. In view of these problems both procedures were very subjective. Special difficulties appeared in urban area during the implementation of the "Spaghetti" method of data acquisition due to frequency of detailed information or/and obscured features. In the urban-edge area the above two processes were carried out with an emphasis on the determination either of parcels/fields or their boundaries presenting no great problems. Consequently, the difficulties appeared in the urban area necessitate a much greater amount of field work than that required in the urban-edge area. Figure 5.6, shows the level of confidence for the identification of features captured, and in table of the figure 5.7, a comparison between the two data acquisition methods is presented, in terms of capturing time, computer space and frequency of changing feature type.

From the figures 5.6(a) and 5.6(b) it is obvious that the features which can be confirmed are only the buildings. Nevertheless, the others belong to the remaining two levels of confidence, since no additional information was available from maps or through the field verification process.

The figures obtained in the table of figure 5.7, indicate that the "Spaghetti" approach of data acquisition is undoubtedly much less time consuming and subsequently more cost effective, although not much difference exist in the computer space required. It is very noticeable, in the "Closed" polygons method, the time required to digitize a feature and assign its relevant non-spatial information.

The graphic standards of accuracy were regarded as accuracy requirements and, although better results could be obtained, they were satisfactory in both models.

URBAN AREA

"CLOSED" POLYGONS

Features	Confirmed	Probable	Possible
PARCELS		"defined"	"defined"
		"undefined"	"undefined"
BUILDINGS	D	A	C
		B	

Note : Building A : a very old structure
Building B : a old structure
Building C : a new structure with old style roof (/\)
Building D : a new structure with new style roof (flat)

"SPAGHETTI"

	Confirmed	Probable	Possible
Features	building outline	fence as boundary	fence as boundary
		wall as boundary	wall as boundary
		wall of building as boundary	wall of building as boundary

Figure 5.6(a) Level of interpretation confidence in urban area.

URBAN-EDGE AREA

"CLOSED" POLYGONS

Features	Confirmed	Probable	Possible
PARCELS	"defined"	"defined"	"defined"
	"undefined"	"undefined"	"undefined"
BUILDINGS	D	B	A
		C	

Note : Building A : a very old structure
Building B : a old structure
Building C : a new structure with old style roof (/\)
Building D : a new structure with new style roof (flat)

"SPAGHETTI"

	Confirmed	Probable	Possible
Features	building outline	fence as boundary	fence as boundary
		wall as boundary	wall as boundary
		wall of building as boundary	boundary defined by pegs

Figure 5.6(b) Level of interpretation confidence in urban-edge area.

AREA	URBAN		URBAN-EDGE	
Method	Spaghetti	"Closed" Polygons	Spaghetti	"Closed" Polygons
capture time (in hours)	8.16	15.50	22.33	31.85
computer space (in blocks)	298	330	661	642
frequency of changing feature type (in sec.)	51.15	209.32	54.47	207.2

Figure 5.7 A comparison of the two photogrammetric data acquisition methods.

Chapter 6

Data Processing

6.1 Introduction.

Among the objectives of the introduction and development of a digital mapping system is to improve the accuracy and reliability of land records (parcels, buildings, roads, etc) and maintain their integrity in the long term. The digital mapping element of an overall parcel-based land information strategy also forms the graphical window to a database which contains the full range of information. The creation of a "clean" database is the most important and complex task upon which the usefulness of the parcel-based information system depends. Therefore, errors which have arisen during the encoding and input of spatial and non-spatial data should be corrected as far as possible. This editing process was carried out separately from the actual photogrammetric data collection process, using the interactive editing and digitizing system LITES2 from Laser-Scan Laboratories, (Cambridge, England). This system is a module of the Laser-Scan Automated Map Production System <LAMPS>, and it has been specifically designed to work on digital, feature-oriented, cartographic data and offers facilities for reading, displaying, drawing, amending, creating and deleting features of any kind, including text.

6.2 LITES2 Interactive Graphical Editing and Digitizing System.

LITES2 runs in an environment of DEC VAX series computers under the operating system VMS. The hardware required comprises :

-Graphics screen for map display and editing.

-keyboard for command input.

-VAX computer for map processing and storage.

-Mouse for command input and cursor movement.

The configuration available in the department of Photogrammetry and Surveying at University College London also includes a digitizing table for digitizing graphical maps and a table puck for command input and cursor movement.

Apart from the actual editing and digitizing routines, LITES2 comprises the following modules :

-LSLSYSTEM. System support software, with additional utilities.

-MAPPING. Mapping kernel software, with various file libraries and control procedures (LAMPS components).

-IMP. IFF Map Processing, with twenty (20) commands and programs to manipulate IFF data files.

LITES2 works with the standard files of the LSL <LAMPS> system:

1). **IFF** files (Internal Feature Format), containing map data in the form of features, e.g. roads, buildings, etc. All features have a reference number, a code and **location X, Y**, they may also have various ancillary codes.

2) Three (3) graphics files, linked to the IFF data files namely :

* **FRT**. Feature Representation Table, defining the graphical representation of feature codes.
* **SRI**. Symbol Representation Interface, which is a library of symbols.
* **TRI**. Text Representation Interface, which is a library of text fonts.

3) LITES2 command files, setting up the hardware configuration and defining the commands which can be given from the keyboard, from menus, and by puck or mouse buttons.

LITES2 works in one of the fourteen (14) command states (Appendix F.). Some commands are valid in all states, others are limited to a few. The commands consist of a primary command, some followed by one or more secondary and possibly by a compulsory or optional argument. More than one-hundred-fifty

(150) commands are available grouped by functions into seventeen (17) classes (Appendix F).

6.2.1 Data File Format

As it has already been discussed (para. 5.2) files captured during photogrammetric data collection were created with the Kern-CAM recording format which is a sequential ASCII text file, which allows easy reviewing of the recorded data and translation to other file formats. Therefore, in order to process the data captured in the LITES2 system, the ASCII files from DSR-1 had to be translated into IFF files by means of a translation program.

In developing the translation program, the following basic requirements were considered :

-simple to use and to understand.

-some flexibility, handling only the cases of "CHANGE TO LINETYPE" and "CHANGE TO SYMBOL" of CAM format.

-creating the standard IFF file format by having :

  * a reference number,
  * a feature code,
  * perhaps, some ancillary codes,
  * only the plan (X, Y) coordinates, since the software to be used does not process features with Z coordinates.

In fact two translation programs were developed one for each data capturing method, with some common procedures. The two flowcharts shown in Appendix G.1 represent the processing steps in the programs.

6.3 Data correction

Errors arising during data collection can be grouped as follows :

1) Incompleteness in the spatial data which arose through omissions in the input of points, lines and areas in photogrammetrically digitized data.

2) Mislocation of spatial data which was the result of careless digitizing.

3) Incorrect links between spatial and non-spatial data were the result of incorrect identification codes being entered to the spatial data during digitization.

4) Moreover, points and lines may be digitized more than once.

Geometric correction was performed with ILINK utility of IFF Map Processing module. ILINK is an IFF geometry tidying and structuring utility which can join feature ends to ends, ends to lines (i.e to any point along a feature, including points along line segments between original feature vertices), or lines to lines (i.e feature alignments). It can also merge duplicate feature sections into single, break feature into separate features where they cross, or produce a link-node structure.

Prior to editing with ILINK, it was necessary to specify the features were to involved in the processing. Therefore, two MACRO[1] programs were developed one for each data capturing method, but with the same logical structure (Appendix G.2). To facilitate the geometric corrections, ILINK optionally generated three (3) LITES2 command files,according to data capturing method and to the project area (: urban or urban-edge). The flowcharts shown below represent the processing steps in ILINK module for each case (**Figures 6.1, 6.3, 6.4**).

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[1]**MACRO:** A text file containing a series of frequently used operations that can be executed by a single command.

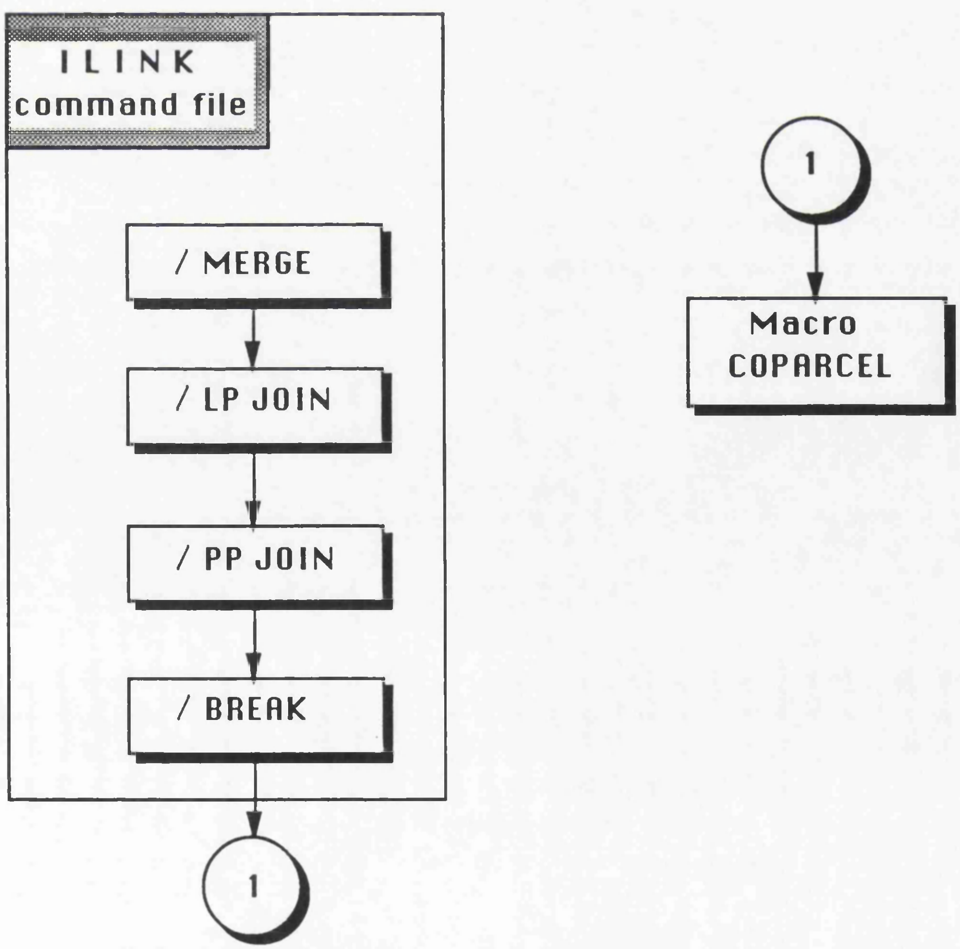
FIGURE 6.1

Problem Definition : correct geometric errors by :

1) merging duplicate feature into single.
2) joining feature ends and end to lines, and
3) break feature into separate features where they cross.

Needed Output : geometrically correct data from errors mentioned in paragraph 6.3

Needed Input : features which specify parcel boundaries and centroids (Urban area).



The basic data input for the program represented in figure 6.1, is data from the urban area collected with the "Spaghetti" method. The initial step was to MERGE duplicate feature sections into single features specified with a common feature code (shrfc=500). The next step was to move the free ends of features onto other line or point, using the feature-end to feature joining (LPJOIN) command. The selection of the feature to which a free end is to be joined is controlled by two tolerances :

* **the join tolerance, /JNTOL** which sets the distance below which the end point may be moved onto the target feature. If both the free end point and the intersection point on the target feature are from the same feature then they will only be joined if they are separated by more than the join tolerance distance along the feature.

* **the extension tolerance, /EXTOL** which sets the maximum distance by which one vector may be extended or truncated to meet another, before a vector end is moved off the original line of the vector, to a point within the join tolerance in any direction, causing it to rotate.

This command was applied using the VERTEX qualifier which gives priority to joining free ends to original feature vertices on the target linear feature. The vertices should be within the tolerance specified by JNTOL. The following step was to form junctions where lineal feature ends and/or point features almost touch. This was carried out using the feature-end to feature-end joining (PPJOIN) command. In this process the selection of the feature-end to which a free end is to be joined was also controlled by the two tolerances (JNTOL, EXTOL) described above.

After all these procedures, the data should be **geometrically** correct and it only remains to create links and nodes for data structuring. Using the command BREAK, features were broken into separate features at **every feature intersection point,** consequently, junctions were created and features broken only where existing features already touch or cross.

It is well-known that no automatic geometry correction software can correct all geometric errors in digitized data and some tasks can only be performed manually by a cartographic operator. After executing the BREAK command, problems arose in the data due to the creation of small features, which were an obstacle to further processing. Therefore, a MACRO program (COPARCEL) was developed which examined the length of a selected feature, then it tests if this length is smaller than a given tolerance deleting the feature if this condition is true. The flowchart in figure 6.2, represents the logical structure of this MACRO.

Figure 6.3 shows the procedure followed to clean-up the urban-edge data which were collected with the "Spaghetti" method. The first step was the execution of a command file with ILINK qualifiers with the order shown in figure 6.3(a), followed

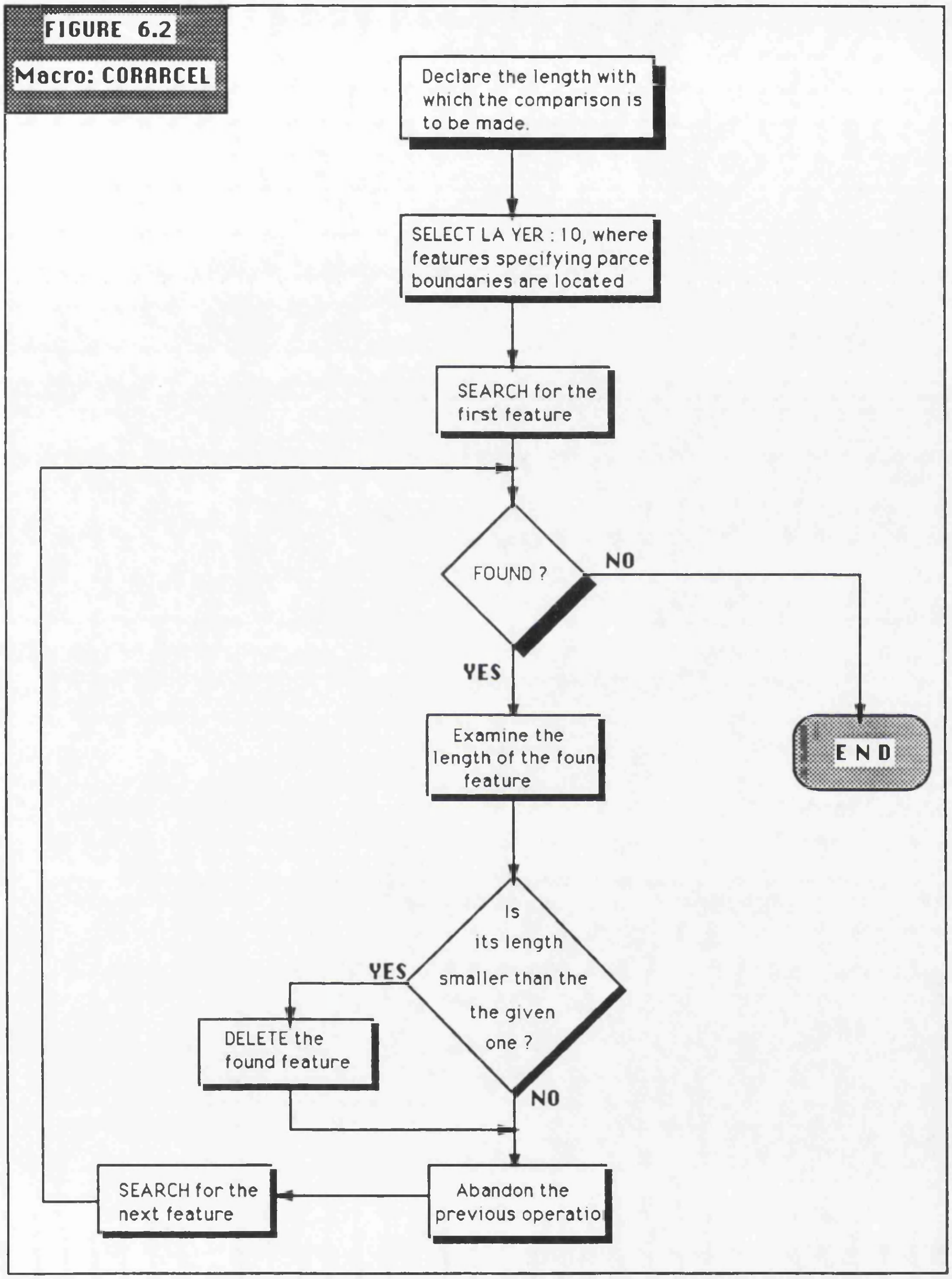


FIGURE 6.2
Macro: CORARCEL
Declare the length with which the comparison is to be made.
SELECT LA YER : 10, where features specifying parce boundaries are located
SEARCH for the first feature
FOUND ?
NO
YES
END
Examine the length of the foun feature
Is its length smaller than the the given one ?
YES
NO
DELETE the found feature
SEARCH for the next feature
Abandon the previous operatio

FIGURE 6.3(a)

Problem Definition : correct geometric errors by :

1) joining features ends to ends and end to lines.
2) merging duplicate features sections to single.
3) break feature into separate features where they cross.

Needed Output : geometrically correct data from errors mentioned in paragraph 6.3

Needed Input : features which specify parcel boundaries and centroids (Urban-edge area).

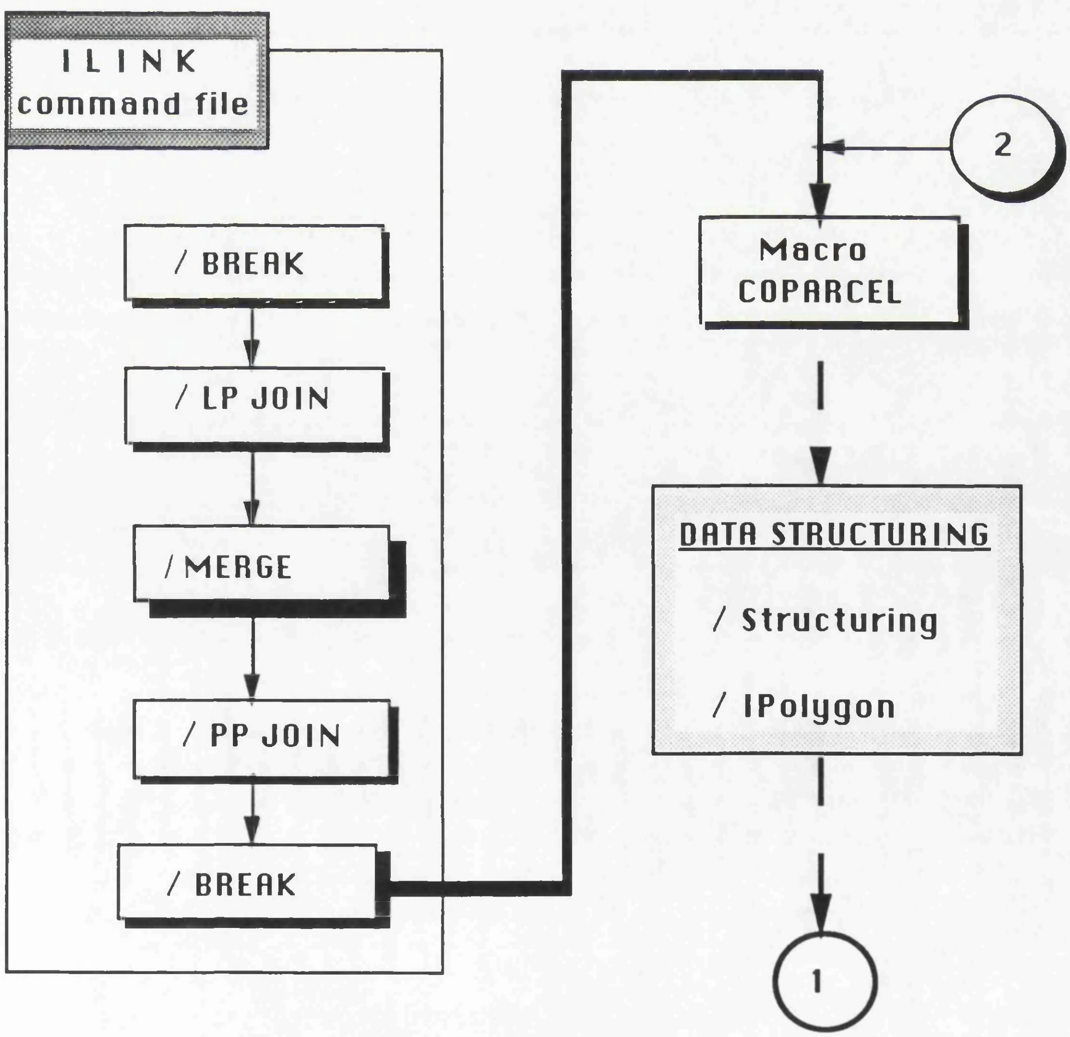
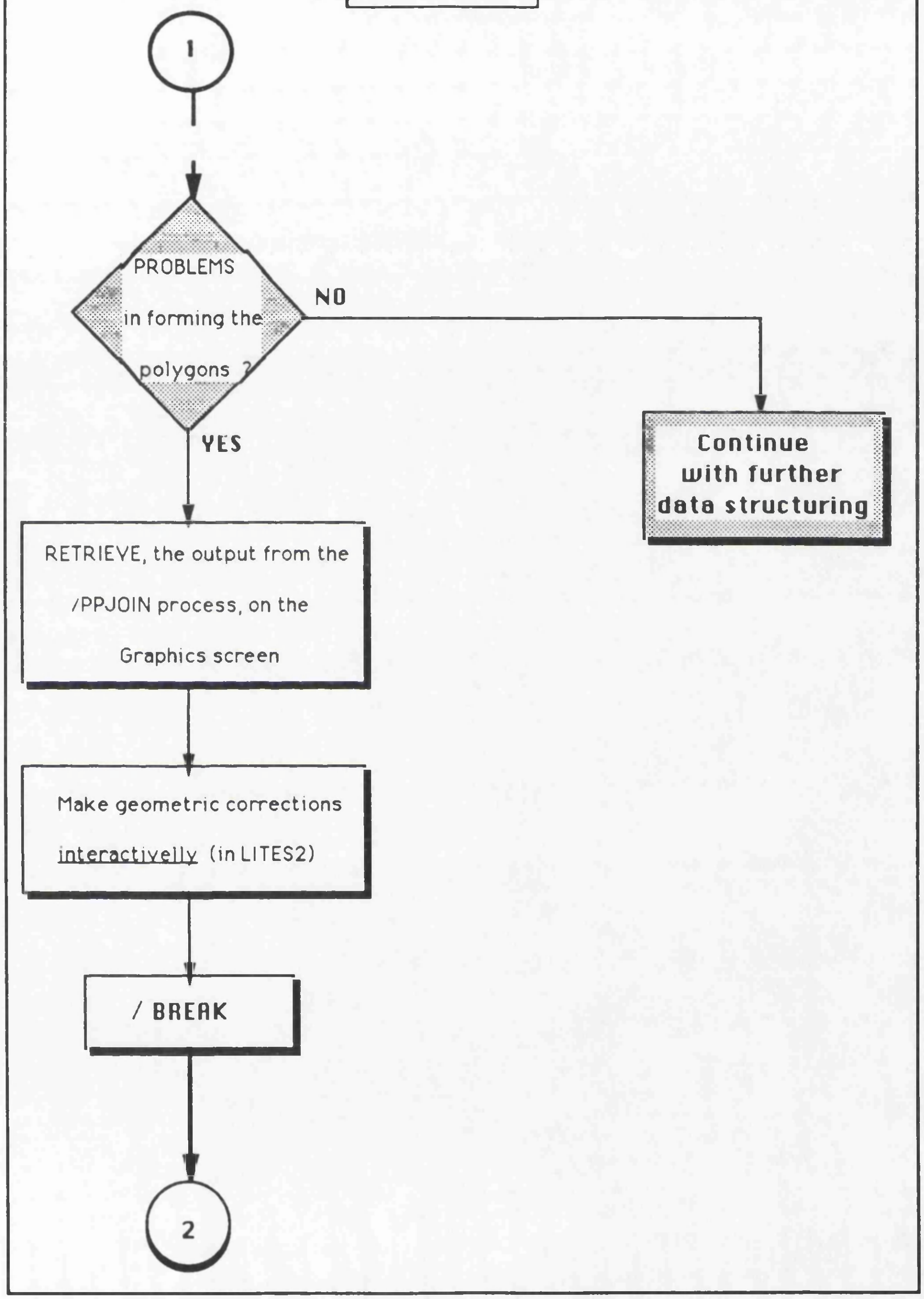


FIGURE 6.3(b)


1
PROBLEMS in forming the polygons ?
NO
YES
Continue with further data structuring
RETRIEVE, the output from the /PPJOIN process, on the Graphics screen
Make geometric corrections interactivelly (in LITES2)
/ BREAK
2

by the execution of the MACRO mentioned above which deletes very small features. As stated above, the data is ready for further processing (data structuring). Although corrections have been made by the command file and by the MACRO program, problems arose (fig. 6.3(b)) during the polygon formation (see chapter 7). As a result, the fault stage of the procedure had to be discovered and overcome. Knowing that BREAK command only creates links and nodes and STRUCTURE command (see chapter 7) records them properly, it was found that the PPJOIN process was causing the problems. Therefore, the output file, from this ILINK process, was retrieved and geometric corrections were made **manually**. Then the BREAK process was executed once again, defined in a command file for flexibility in carrying out the whole procedure (fig. 6.3(b)).

To perform the data cleaning process on data which were collected with the "Closed" polygons method from both urban and urban-edge area, the procedure shown in figure 6.4 was followed. Two (2) command files with ILINK qualifiers were developed for each area (because of different features) which may be distinguished in the following steps :

-STEP 1. ILINK commands for geometric corrections in undefined parcels.

-STEP 2. ILINK commands correcting undefined and defined parcels as well as buildings. The tolerance in this step is smaller than the one specified in STEP 1.

It is obvious from the flowcharts that few ILINK qualifiers (MERGE, BREAK) were not included in the programs. This happened because :

- a different data collection method and different determination of objects were followed.
- there was not need for using the BREAK process as the function of it is to separate the feature and create links and nodes for polygon formation, while the data were already in polygons form.

STEP 1

Problem Definition : correct geometric errors by :

1) feature alignment
2) joining feature ends to ends and end to lines

Needed Output : geometrically corrected data from errors mentioned in para. 6.3

Needed Input : features which specify undefined parcels.

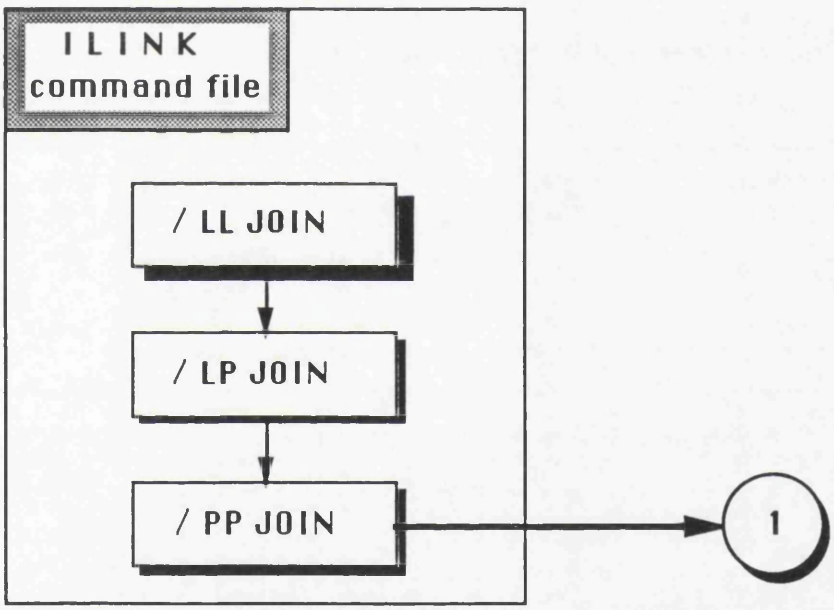


Figure 6.4(a). First step of data "cleaning" process in "Closed" polygons method (in both test areas).

STEP 2

Problem Definition : correct geometric errors by :

1) feature alignment

2) joining feature ends to ends and end to lines

Needed Output : geometrically corrected data from errors mentioned in para. 6.3

Needed Input : features which specify undefined and defined parcels, and buildings.

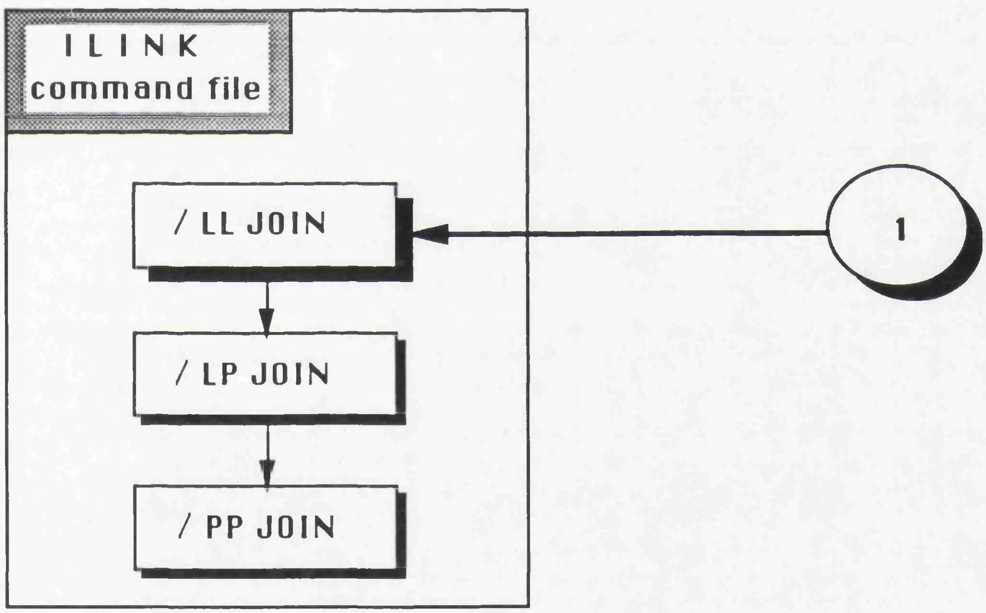


Figure 6.4(b). The second step of data "cleaning" process in "Closed" polygons method (in both test areas).

The new element in these programs were the feature alignment (LLJOIN) process which causes ILINK to bring parts of features together where any part of one linear feature comes within tolerance of any part of any other linear feature. The tolerance used to determine whether a feature should be aligned is specified using the JNTOL qualifier. The command qualifier FCP was also used within this process in order to determine feature alignment priority (in STEP 1).

6.4 Analysis of Procedures.

Positional accuracy does not express the realistic total error in the entire data collection process, since the level of it depends both on the registration method and performance as well as on the source material. Hence, a distinction can be made between the accuracy associated with coordinates - measurements-(i.e geodetic framework and random errors) and the accuracy associated with the human performance (e.g the ability of the operator to follow a given line).

The errors involved in the above described geometric corrections were caused by the operator and obviously belong to the latter type of accuracy. The level of data accuracy in the above mentioned procedures was dependent on the tolerance specified in each stage.

6.4.1 Tolerance.

It would be reasonable to assign the value of error appeared during data measurements to the tolerance. However, considering that :

- some features classified as "undefined" (low level of confidence)
- the inexperience of the operator
- careless digitizing
- the singularity of Greek situation (e.g land devided in small parts, ambiguous features even those classified as "defined").

all factors which caused the errors mentioned earlier (para. 6.3), it was regarded that a higher tolerance, in terms of absolute values, had to be chosen.

It is obvious that the decisions for the value of the tolerance had to be made separately for each data collection method, especially for the "Closed" polygons where a distinction of parcels was made.

6.4.2 Procedures and Tolerance.

In the "Spaghetti" method more attention had to be paid in the urban area due to the high density of detailed information and subsequently the detailed digitizing in short distances.

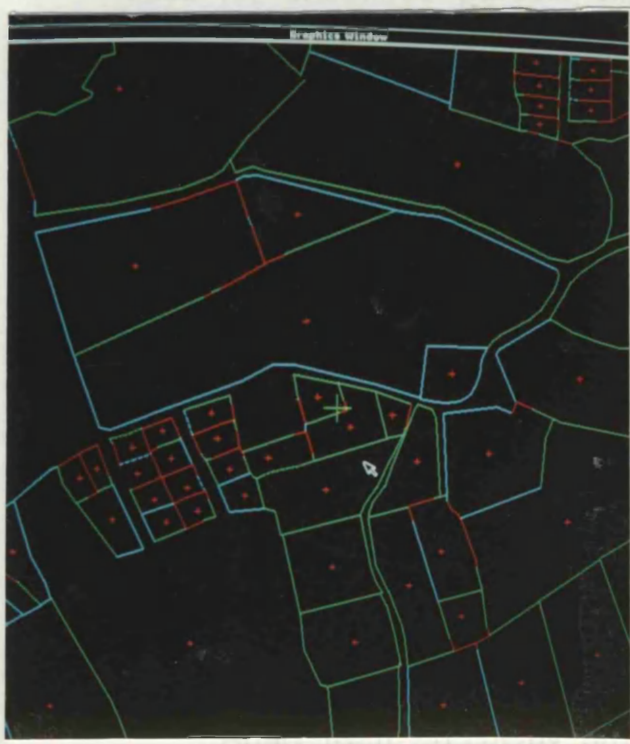
After some efforts where problems of the type illustrated in the Plate 1- (indicated with the arrow) were addressed, the final value of tolerance assigned was 1.2 metres. Then, the features presenting parcels and their centroids (Plate 2) were processed as described earlier. The total number of features in the initial input file was 480. In the output file of /PPJOIN process the number of features was reduced to 468, indicating that problems may arise during polygon formation. Another sign of problems during polygon formation is the distribution of nodes found joined to a different number of arms. Apart from the centroids (113) the final number of **unattached link ends** after /BREAK process was 16 (Appendix H.1).

Plate 1. Error due to the tolerance and detailed digitizing.

Plate2. Features presenting parcels and their centroids in URBAN area.

Since, in the urban-edge area there was not so much detailed information, it was expected that it could be possible to use a lower value of tolerance. However, the existence even of small number of built-up parts had an influence on the choice of the tolerance. Eventually after some efforts to avoid problems such as in Plate 1, the same value as in urban area was chosen.

Executing the ILINK command file showed in figure 6.3(a) the output features (after the /BREAK process) were 1387, while the input were 1138. The attempt to form the polygons failed due the loss of data and the subsequent creation of a new situation, which obviously was vital in the polygon formation process.



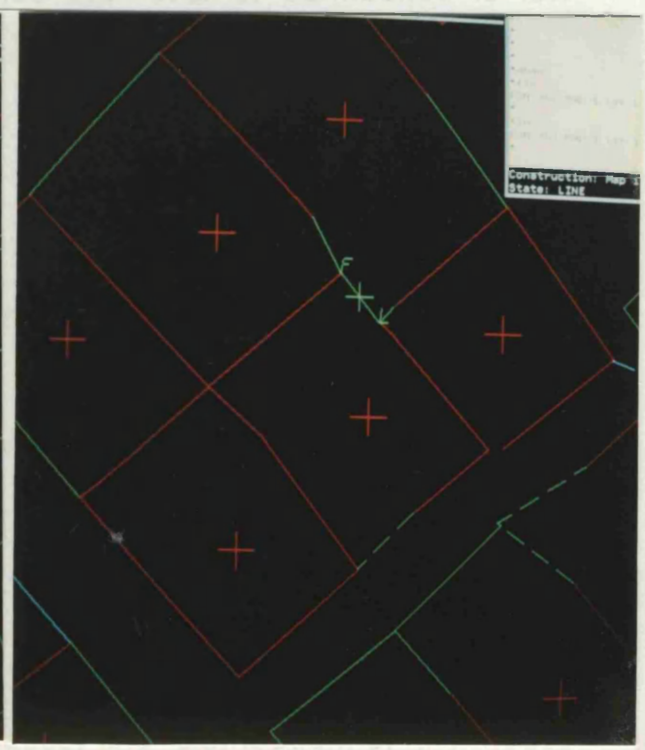


Plate 3 Plate 4

Taking advice from the list of IPOLYGON process (Appendix I.3) the possible place of error was indicated (Plate 1). After interactive correction (Plate 3) the /BREAK command was executed followed by the IPOLYGON process. However, even in that time the process failed indicating more errors. This time a duplicated feature, showed on the Plate 4 , was the cause of the problem. The final execution of the /BREAK command has as output : 1389 features, including 269 single point, with 14 unattached link-ends, which was rather a small number.

Following a completely different strategy to correct the errors caused during data acquisition with "Closed" polygons, it was obvious that the choice of tolerance had to be relied on a different strategy as well. First of all a different tolerance was used for undefined parcels since the level of confidence is low and consequently errors are much larger. Considering the Greek situation where boundaries may be designated (by the owners) with accuracy of 0.50m (Y. Maniatis, 1987)[53] or/and errors may occur of the order of 2.00m - 3.00 (A. Seitanidis, 1985)[76] due to the lack both of the demarcation of the parcels or other evidence of the determination of them (e.g accurate maps) as well as the current human performance (operator's interpretation), the value of the tolerance was set at 2.00m. The input features processed were 35 (closed) and after the execution of the entire first step (Fig. 6.4) they also remained.

Apart from /LLJOIN process, the distribution of the nodes found joined to different arms is the same in the two remaining processes (Appendix H.3). In the second step (Fig. 6.4) the tolerance had to be as smaller as possible since all parcels and buildings would be processed. However, it was impossible to assign a value of tolerance lower than 0.40m since problems (Plate 1) would then occur.

Problems of feature alignment (Plate 5) were solved after the execution of the /LLJOIN process (Plate 6) of the second step. However, errors of type like those shown on the Plate 7 arose during the execution of the other two ILINK commands (/LPJOIN, /PPJOIN). The input features processed were the same in the final output (Point: 113, Open: 8, Closed:281), but the distribution of the nodes found joined to the arms was different in each stage of the second step (Appendix H.3).

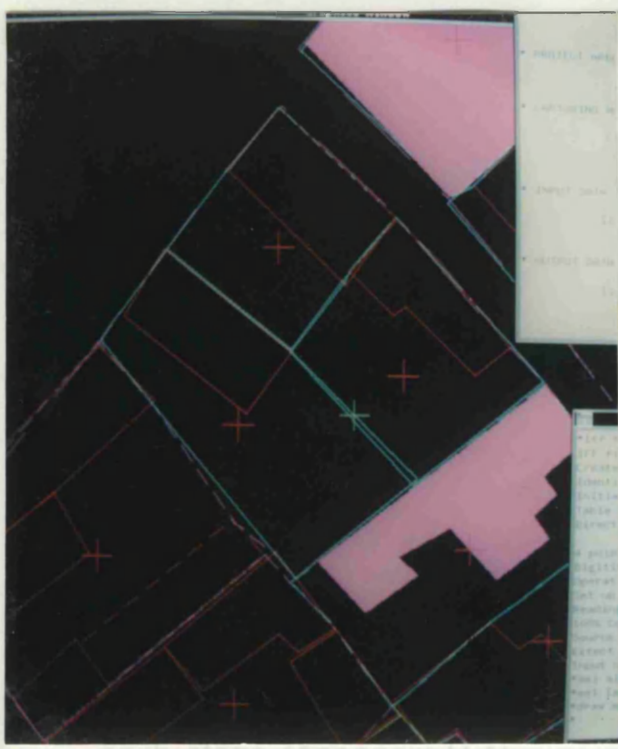


Plate 5

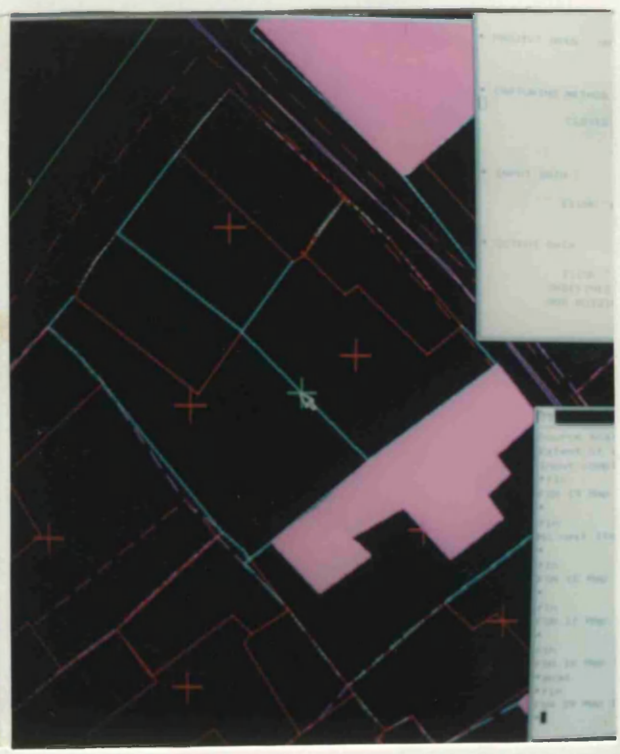


Plate 6

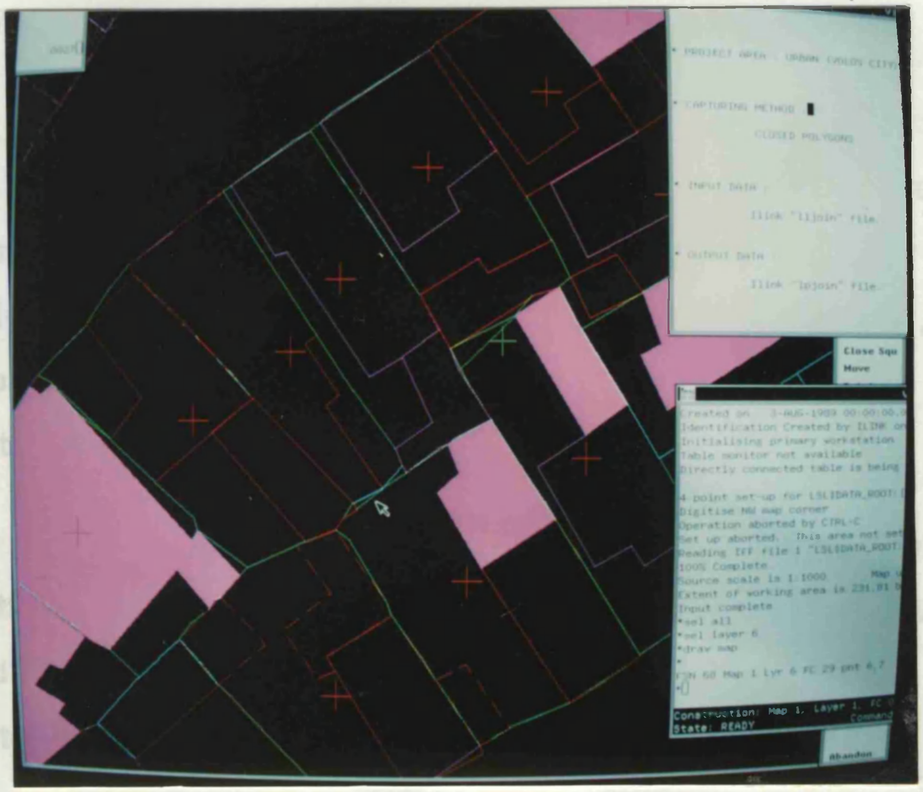


Plate 7

The same tolerance with the urban area (2.00m) was used during the first step of geometric correction in urban-edge area, where 4 Open, and 20 Closed input features processed giving an output of 24 Closed. The distribution of nodes was the same in the two last ILINK qualifiers (Appendix H.4). The same type of problems as in urban area also arose in the second step of the entire process, although the tolerance was set at 0.50m. The numbers of input features processed were as follows : Points: 272, Open: 27, Closed: 504, and the output data were : Point:272, Open: 8, Closed: 523, finally, the distribution of nodes varies in each stage (Appendix H.4).

6.5 Concluding remarks.

Any land related information which was collected by either of the data acquisition methods possess some degree of positional accuracy. The human performance was a major factor which had an influence on the level of the accuracy, and subsequently on the determination of the tolerance in both methods.

The specification of tolerances was relied mainly on the fact that problems like that shown on Plate 1, had to be avoided and to keep the data in their initial form (i.e Keeping as much cartographic data as possible).

It is also clear from figures: (6.1), (6.3) and figure 6.4 that the "Spaghetti method was more time consuming, especially in the urban-edge area , where many procedures should be followed in order to resolve the geometric problems.

A proportional comparison is made in the table of the figure 6.5, in terms of **unattached link ends**, between the two methods for each test area.

Data Acquisition Method	**Test Area**	
	Urban	Urban-edge
"Closed" Polygons	2.07%	2.26%
"Spaghetti"	3.29%	1.26%

Figure 6.5 Percentage of unattached link ends in each area.

It is evident that more unattached link ends finally created in the urban area captured with the "Spaghetti" method, indicating once more the difficulties of the urban data correction. On the other hand, in the urban-edge area the method seems to be much more effective.

Having taken all these measures to correct geometrically the data captured with both methods from both areas, the next stage was to structure the data in such a way in order to produce information relevant to a parcel-based land information system.

Chapter 7

Data Structure

7.1 Introduction

The previous chapter referred to the methods followed to clean the data captured by photogrammetry and to prepare them for further processing, by means of either creating links and nodes or/and completing the geometric corrections up to a certain level (ILINK qualifiers: JNTOL, EXTOL), since the data will need completion from field verification process.

In order to get a true representation of reality in a computer, it is necessary to obtain an unambiguous representation of this reality (para. 4.2) and to define a model (para.4.3). Being able to access any element of interest, the model has to be broken down into elementary units in long term storage that can be easily managed and checked for data consistency. On the other hand these elementary units serve as "building blocks" for short term applications.

From the above mentioned it appears that a parcel-based land information system can be considered to be built up from these elementary units. However, in this project two data modelling approaches were considered relying on the information organized around the parcel and two different data structure methods were developed. The basic goal of modeling, not only for geometry, is semantic completeness. Once applied to a problem, a model does not offer any more solutions to questions than those formally conceptualized.

7.2 Links and Nodes

The lowest level of model illustrated in figure 4.4 holds nodes and links, which were created by executing the BREAK command qualifier in data cleaning process, applied on spaghetti data and which form the geometrical and topological aspect. Geometry describes position, distances, areas, while topology describes sharing, connectivity and adjacency. On the other hand, in the first approach of data modeling in this project (fig. 4.3) the elementary unit, even after data cleaning is the polygon describing building.

Prior to proceeding to examination of data structuring it is worth defining the nodes and links :

* **Node.** A zero-dimensional object (entity) that is a topological junction and may specify geometric location. Its attributes can have metric information such as coordinates, but they need not.

* **Link.** A one-dimensional object (entity) that is a direct connection between two nodes. This implies that here is no node lying on a link

without being either its start or end point.
Moreover, no link may intersect itself and its shape need not be straight and depending on the application, attributes can be added.

These are the primitive and simple objects (entities) required for digital processing that can be used to construct higher level objects in the model presented in figure 4.4.

7.3 Topology

The maps on which inter-relations are immediately visible are easy to use. Though, these inter-relations should be realized in a digital file. The topologically structured data fulfils this requirement and also improves the spatial analysis capability of a parcel-based land information system (J. R. Herring, 1989)[34].

A general structure must accommodate point, linear, and areal features if it is to be useful in a broad range of applications. However, in order to investigate problems representing spatial and descriptive cartographic data in this project, two models were developed (fig. 4.3 and fig. 4.4) and as it was stated above (para. 7.1), according to them the entire process of data structuring was planned.

Starting from the model in which the basic unit of interest is the parcel's boundary and then the parcel itself (fig. 4.4), our data processing stopped at the stage where links and nodes were created and some geometric corrections were made by applying the MACRO : COPARCEL. Nodes and links are two-to-many related where each link is limited by exactly two nodes and a single node can be part of several links. The meaning of connection between nodes and links is the role each node plays for the link : either it is a start or an end point. This process was carried out by applying the ILINK/STRUCTURE qualifier on the output from the MACRO: COPARCEL software (fig. 7.1). This data

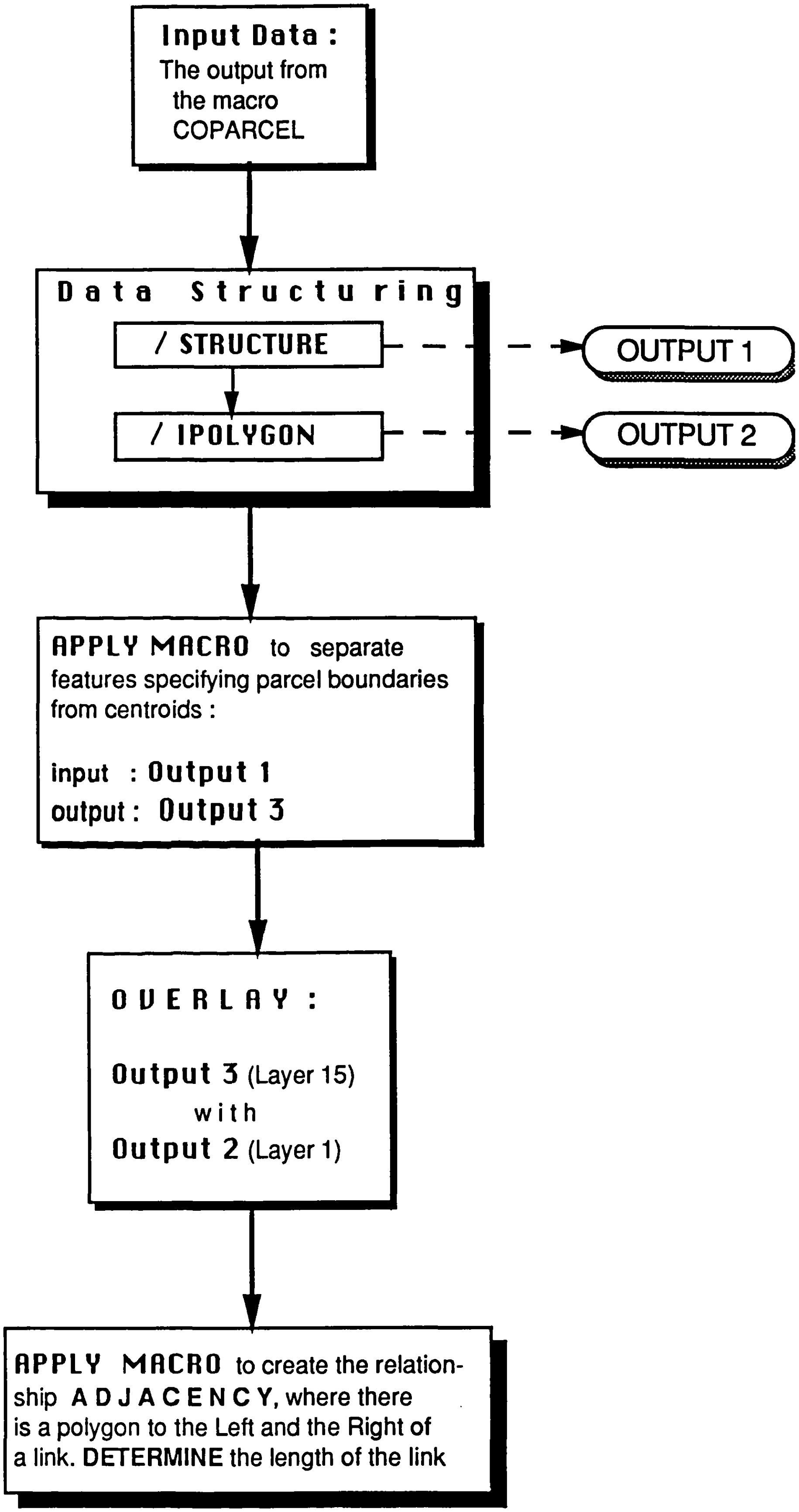


Figure 7.1. Operations followed for structuring the "Spaghetti" data (in both test areas).

structure contains information connecting every link record to the node records corresponding to each of its ends, and also connecting every node record to all of the link records which hold links ending at this node. The nodes in this link/node structure are all at the existing feature ends. An implicit /PPJOIN process is carried out with a near-zero join tolerance to determine end point connectivity.

Although such a useful information was the result of the STRUCTURE command it was not the interest stage of this research, but just an intermediate stage of structuring higher level objects which in this model (fig. 4.4) they were the polygons (parcels).

In order to form the polygons Laser-Scan's automatic IFF polygon creation and labeling utility IPOLYGON (fig. 7.1) was used. IPOLYGON is designed to be run in batch mode and all options may be specified on the command line. No user interaction is required during processing.

The labeling and checking of the consistency of polygons was made by "seed point assignment". The polygon label was extracted from the centroid data. The following rules were observed when creating and manipulating the centroids :

- a seed point must lie within the polygon to which it applies. It must not lie outside or on the edge of a polygon.

- every polygon must have a seed point.

- a polygon can have only one seed point.

- a seed point must have a single ST (STring) entry, containing a single locating point.

The centroids of the parcels fulfilled the above requirements.

The closed polygon boundaries were output to an IFF file as single features by applying the /POLYGONS option and labels obtained from seed points (:centroids) were transferred to the polygon boundary features. Messages and diagnostic output were directed to a specified text file using the LIST option within the IPOLYGON command.

By using the option /OPTION=AREA, polygon area statistics were provided. Finally, the labels obtained from the seed points were written to the ASCII output file.

To continue the data structuring process, more operations must be developed. These operations have to allow topological connections to exist as they are presented in figure 4.4. A one-to-two relationship was created between links and polygons. The functionality of the link can be seen as delineating polygon as well as separating polygons from two polygons : one to the right and one to the left. This structure includes the important topological relationship **adjacency**, where there is a polygon to the left and the right of a link.

In order to carry out this process the following steps were obeyed:

STEP 1 : Map Overlay.

The parcels of the region (either urban or urban-edge) are defined either as a set of links with specified attributes (output from ILINK/STRUCTURE command) or as a set of polygons with common feature (FC: 500; parcel boundaries) which were the output from IPOLYGON module. In order to associate both the links and polygons, the output from ILINK/STRUCTURE process had to be overlaid with the output from the IPOLYGON process in the LITES2 environment.

The result of overlaying the above two mentioned files (maps) would also involve the centroids (from ILINK/STRUCTURE) in the new map. This would be a problem since centroids were already associated with polygons (from IPOLYGON process). Therefore, a MACRO program was developed with the same logical structure as the one shown in Appendix G.2, in order to select the links which specify parcel boundaries and transfer them to another layer. After executing this MACRO program, the overlay process was carried out (fig. 7.1).

STEP 2. :

Once the required information (: links and polygons) was displayed together (but in different layers) then a MACRO program was developed to create the adjacency (Fig. 7.1). The program (Appendix J.1) starts by selecting the layer in which the **output3** (Fig. 7.1) is located and searching for a link. Then it selects the **output2** (Fig. 7.1) layer and finds the left and right polygons which correspond to the already found link and records their Feature Serial Number (FSN). Then, it returns back to the former layer and put the FSNs of the polygons as ancillary codes to the selected link. After finishing the whole overlay, it selects once again the layer with links and calculates the length for each link, putting it as ancillary code as well.

In contrast to the situation created above, the strategy for producing topological information from data which are considered as an areal (Fig. 4.3), was based on two fundamental concepts : the **composite** and the **inclusion**. Subsequently, a block of parcels

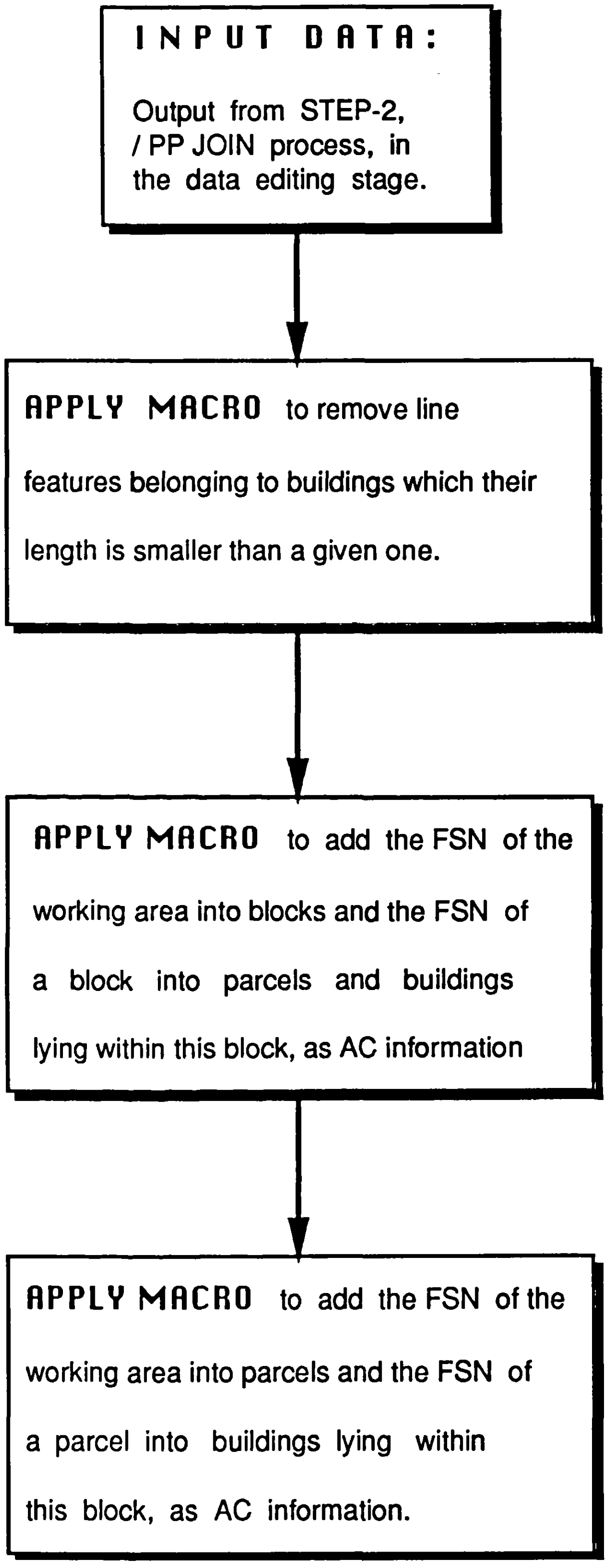


Figure 7.2. Operations followed for data structuring in "Closed" polygons method (in both test areas).

is composed of many parcels (one-to-many relationship) and a parcel may include buildings (one-to-many relationship). It is self-evident that it is important to contain information about, which parcels or buildings belong to a certain block or which buildings belong to a certain parcel, into a parcel-based land information system.

Two MACRO programs were written to meet the above mentioned requirements. Blocks, parcels and buildings were handled by selecting their Feature Serial Number and transferring them as ancillary codes to the lower lever of entity (Fig. 7.2). The logical structure of these two programs was the same and it is shown in Appendices J.3.1 and J.3.2. Before applying these MACRO programs, an error-checking process was carried out in order to detect and remove line features with a specified length, belonging to buildings which lay outside of a parcel (Fig. 7.2). It should be notice that although geometric corrections were made such type of problems were observed during the process. Developing a MACRO program (Appendix J.2) the above error-checking process was made.

7.4 Evaluation of the Output.

The photogrammetrically captured data was organized and structured in such way as to provide land related information required for effective future spatial data processing (cadastral surveys, basic user requirements). Each data collecting and processing technique preferred certain data structure as well as it was associated with a certain level of data accuracy.

In order to evaluate the two data structure approaches the completeness of data was used as main criterion.

In the Plates 8, 9, 10, 11, the two test areas are illustrated which were captured with the "Spaghetti" method. As it was predicted in the previous chapter the method was more effective in the urban-edge area, where there is not much loss of information (indicated by the arrow). In the urban area there is more loss of data (see cursor and arrow) in which some are obvious (cursor, Plate 9) and some not (arrow, Plate 9).

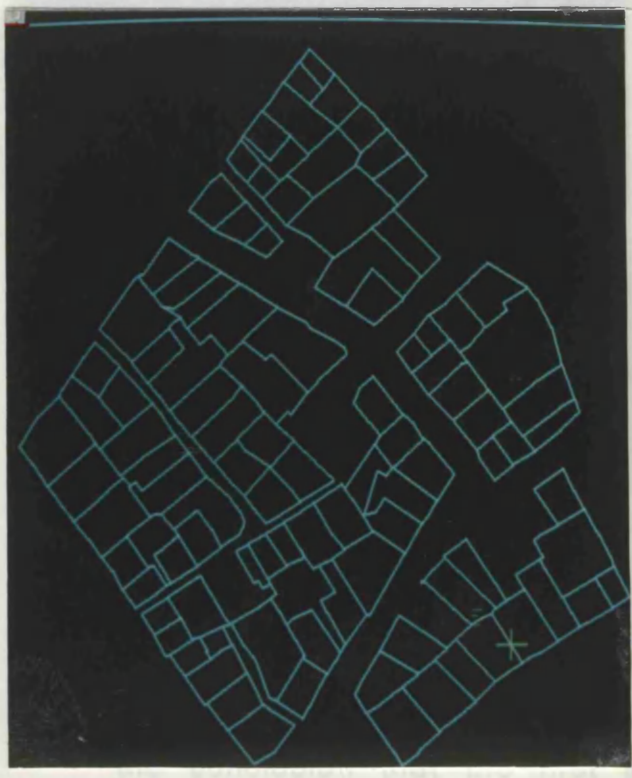


Plate 8. Output from IPOLYGON process-URBAN area.

Plate 9. Output after executing STEP-1

Plate 10. Output from IPOLYGON process.Urban-edge area.

Plate 11. Output after executing STEP-1.

Although it was expected that data captured with "Closed" polygons would present better results, Plate 12 clearly shows that this did not happen. The reason for that is obviously the different strategy followed to provide land related information. Subsequently, more time is required to recapture the data. Similar results obtained in the urban-edge area, giving finally the conclusion that the first approach (Fig. 4.3) of modeling presents a weakness in data completeness with consequently less cost- effective results.

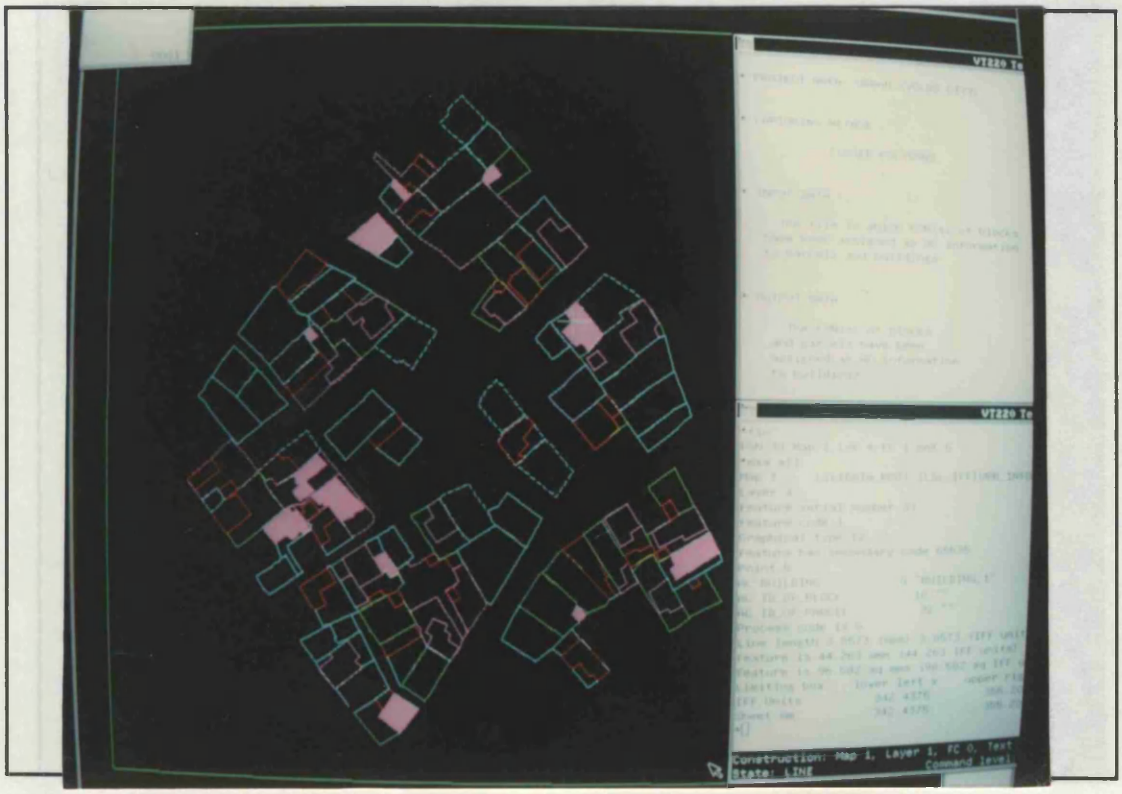


Plate 12. "Closed" polygons - Urban area after final structuring

In the Plate 13, the adjacency in terms of left and right hand polygons as well as the length of the current feature are shown (in the window). The number 65535 for instance, indicates the surrounding polygon, meaning that the feature does not have any left hand polygon previously captured and processed. It is also worth mentioning that the left hand (LH_boundary) polygon is actually the right one as the Plate is looked at. This means that the feature was digitized from the top to the bottom of the screen.

Plate 13. "Spaghetti" - Urban-edge area after final structuring

Plates 14, and 15, show the type of output after executing the two macros in urban and urban-edge data captured with "Closed" polygons respectively. In the Plate 14, information about the map, the working- area and the block which has been assigned to the parcel, is shown. While the Plate 15 shows information about the block and parcel which has been associated with the building.

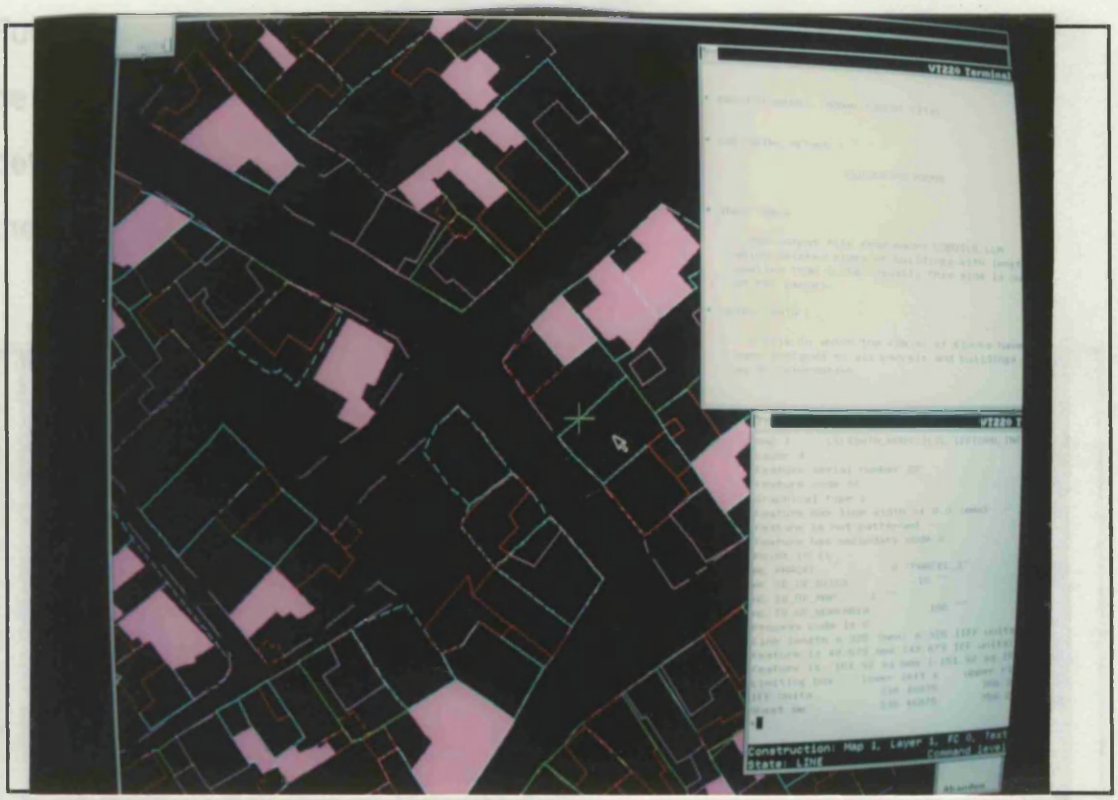


Plate 14. "Closed" polygons - Urban area after final structuring, where information is associated to the parcel

As far as the land related information obtained is concerned, it can be considered that basic topological information in both approaches was met to some degree. Considering though that the above approaches are proposed to be applied during a certain time of cadastral surveys (pre-cadastral) providing helpful information, they can be regarded satisfactory. However, examing the feasibility of both methods from the economical viewpoint it seems that the second approach of data modeling (Fig. 4.4) is much more attractive.

Furthermore, it provides much detailed information which will be very useful both in the future as cadastral surveys will be developed as well as in the satisfaction of user requirement at the same time.

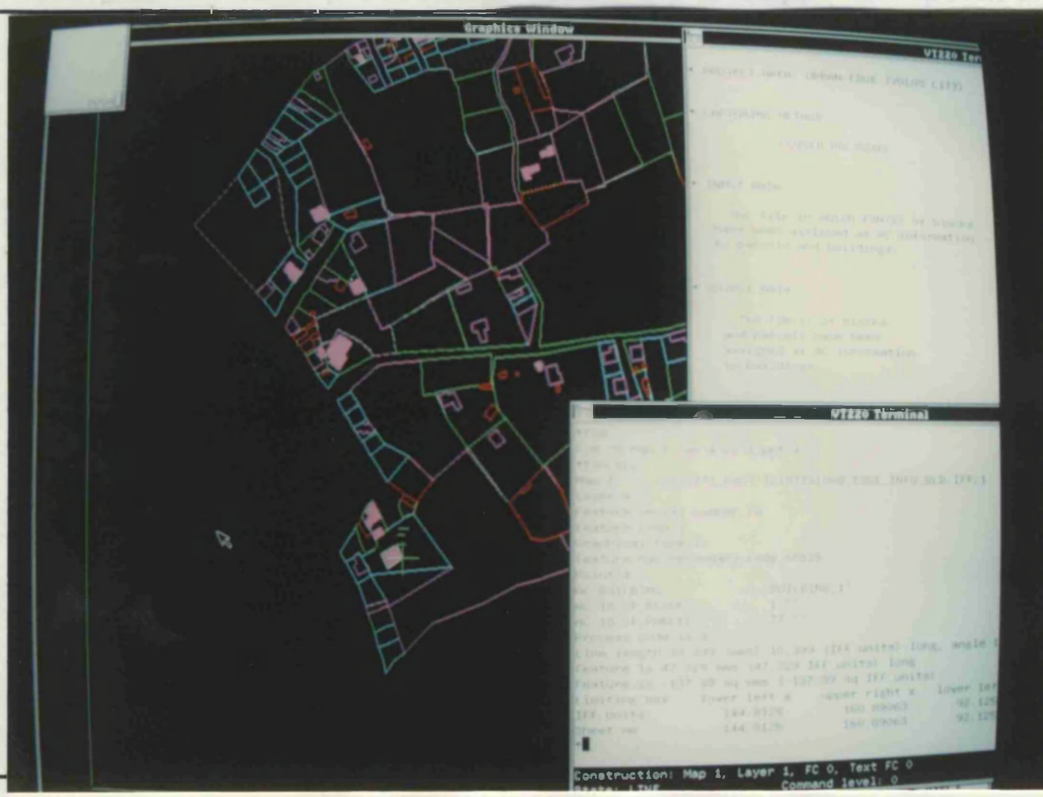


Plate 15. "Closed" polygons - Urban-edge area after final structuring, where information is associated to the a building. The error caused on the parcel still remains.

7.5 Summary.

In spatial data structures, real world entities are represented by cartographic objects. These objects have attributes that describe the object and relationships to other objects. Both spatial and non-spatial attributes and relationships may associated with these objects.

The emphasis of the current data structure did not require the development of a comprehensive set of operations for cartographic data processing. However, it supports operations which may deal with :

* feature type.
* feature identification number.
* area.
* adjacent polygons.
* polygons composed of, or included by lower level polygons.

However, the second approach (Fig. 4.4) allows more information to be provided in the range between high level objects (parcels : their area) and the low level objects (boundaries : their length). Subsequently, it is evident that it is much more effective to handle the current land related problems. Nevertheless, the issue of data inconsistency still remains to be resolved, since it involves such useful information, as for example the area of the parcel (Appendix K.1).

Non-spatial attributes were transferred to a database available in the department, in order to be able to answer a very small range of queries and to obtain familiarity with the procedure for elimination the data redundancy up to a very limited level.

Chapter 8
Database

8.1 Introduction

Database development can be viewed as a number of processes : *data investigation, data modeling, data base design, data base implementation and data monitoring.* The objectives in creating a data base include (P. F. Dale, J. D. Mclaughlin, 1988)[21]:

1. the structuring of the data to permit various methods of access.
2. the storing of the data in formats that are independent of current and potential applications.
3. the control of access to the data, including who is allowed to use or alter any data entry.
4. the facilitation of record updating, changing, or modification, including the insertion of new records and deletion of old,
5. minimizing of data redundancy.

The data modeling approaches discussed in chapter four (4) and analyzed in chapter seven (7) can be referred to as generalized models. They are generalized since they are independent of any specific Data Base Management Systems (DBMS)[2] (para.4.5). For the sake of simplicity, these approaches deal only with one level

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[2]**Data Base Management System (DBMS):** a set of computer programs for organizing the information in a data base. Typically, a DBMS contains routines for data input, verification, storage, retrieval and combination.

of information (cadastral) and in principle, the topological relationships analyzed in seventh chapter are probably a minimum requirement for the expansion of these simple models. The inclusion of other relationships will depend on a **full analysis** of the user requirements in particular situation.

Returning, though, to consider these models (fig. 4.3 and fig. 4.4) as an intermediate product in the process of data base development, their main purpose is to provide sufficient information for deriving a DBMS-specific data model. A DBMS helps to set up the database, there are various different types of DBMS each with its own structure. Most of the currently existing DBMSs are the hierarchical, network or relational (para. 4.5.3) and they represent the ways in which data elements can be linked in a logical way (figure 8.1), as determined by the user.

TYPE OF DATA STRUCTURE	How Elements are Logically Linked in a File
HIERARCHICAL	Parent element may have many children.
NETWORK	Parent element may have many children and child element may have more than one parent.
RELATIONAL	Elements in a table are linked to elements in the same row and the same column.

Figure 8.1. Concept summary of data structures.

As it is obvious two different database design concepts were developed (but they were not fully analysed, due to the limited time), one for each data model (fig.4.3 and fig.4.4), following the relational data structure because it can ensure the long term flexibility of the system (see Date, 1986) [22] as well as due to a relational database (ORACLE) system being available in the department of Photogrammetry and Surveying at University College London.

8.2 Project Concept

A relational database is a database that is perceived by its users as a collection of tables (and nothing but tables) (C. J. Date, 1986)[22]. To make the relational data base design more understandable the following definitions should be given :

* **Field (attribute),** a meaningful item of data, such as an area of a parcel or its Feature Serial Number (FSN).

* **Record,** a collection of items (fields), that relates to a single unit, such as a parcel.

* **Table,** a grouping of related records, such as all parcels; sometimes referred to as a **relation**.

The objectives of designing the relational database were :

1. to show how data relate to each other.

2. to satisfy some basic user requirements, having in mind that more will be demanded.

3. to establish a limited guide-line of database creation since this database will support the cadastral mapping process of Greece and the same time it will allow users to view, to access and to analyze information on freely defined criteria.

The integration of a relational database to the models (fig.4.3 and fig.4.4) requires the definition of entities and their relationships. In the fourth (4th) chapter (para.4.3) these definitions have already been made.

Starting from the model represented in figure 4.4 the **relations** (**Tables**) for the entities should be create first. The **relation** for the boundary entity will include as **fields** (**attributes**) (Figure 8.2-Table 1) :

* its Feature Serial Number (FSN).
* type.
* the FSN of the left side polygon (LP).
* the FSN of the right side polygon (RP).
* its length, in metres.

On the other hand the **relation** of the parcel entity will have (Figure 8.2-Table 2) as **attributes** :

* the FSN of the parcel.
* the area of the parcel.

Having determined the relationships between the entities in this model (para. 4.3 and fig.4.4), the next stage of the data base design is to form the **relation** of these relationships. It is self-evident that the two relationships are actually the same. Hence only a **relation** will be created having as **attributes** (Figure 8.2-Table 3) :

* the FSNs of the parcels.

* the FSNs of the boundaries.

It should be noticed that a parcel in the above mentioned **relation** (Figure 8.2-Table 3) will appear more than once (at least four times) **but** corresponding in different boundary. The same will happen with boundaries (it will appear twice). Subsequently, no two **records** (rows) in the **relation** will have exactly the same values in all of the **fields** (**attributes** / columns).

The identification (ID) key(s)[3] of the **records** for the **relation** represented in Figure 8.2-Table 1, are the Feature Serial Number (FSN) of the boundary and the FSN of the parcel, while in **relation** represented in Figure 8.2-Table 2, will be **both** the FSN of the parcel and the FSN of the boundary.

The same strategy will be followed -i.e creating firstly the **relation** for each entity and then developing the **relation** for the relationships- to design the database for the model approach

[3]**Identification keys :** Keys which are referred as primary keys, candidate keys, etc, in data base computer science bibliography. (see C. J. Date-1986, G. Wiederhold-1986).

developed in figure 4.3. On the tables (Figure 8.2-Tables 4, 5, 6, 7, 8) below, the forms of **relation** of the current model are shown. The identification key(s) of the records are obvious in the entities; their FSNs, while in relationship between Block and parcels (para. 4.3) the ID key is the FSN of the parcel and in relationship between parcel and buildings the ID key is the FSN of the building.

Prior to utilizing the ORACLE software to create the above defined **relation** for each model (fig. 4.3 and fig. 4.4), the data of interest that are stored in IFF format (para. 6.2.1) had to be translated into files in the form of columns and rows. Therefore, as an example, a translation program (Appendix K.2) was

SPAGHETTI

FSN of boundary	Type	LP	RP	Length

Table 1. Relation for the entity : BOUNDARY.

FSN of parcel	Area

Table 2. Relation for the entity : PARCEL.

FSN of parcel	FSN of boundary

Table 3. Relation for the relationship between PARCEL and BOUNDARY.

"CLOSED" POLYGONS

FSN of Block	Type

Table 4. Relation for the entity : BLOCK.

FSN of parcel	Type

Table 5. Relation for the entity : PARCEL.

FSN of building	Type

Table 6. Relation for the entity : BUILDING.

FSN of parcel	FSN of Block

Table 7. Relation for the relationship between PARCEL and BLOCK.

FSN of building	FSN of parcel

Table 8. Relation for the relationship between BUILDING and PARCEL.

FIGURE 8.2

for the "Spaghetti" model of database design, corresponding to Table 1 (Fig. 8.2).

8.3 A General Discussion

As it has already stated (para. 4.3) in a parcel-based land information system, data organized around the parcel and they are the basis of much of a country's activity. These data must be organized and structured in such a way as to provide the type of functions required for effective analysis. Hence it is necessary to store and manage both data items and the relationships between data entities.

In the database approach examined above (para. 8.2) attributes associated with the graphical entities structured in order to be handled within the database, while coordinate information was not stored. Hence the model is conceptually simple and involves storage of attribute data and elementary operations on **relation**. It also involves relationships between the entities without major upheavals in the existing data.

It is worth mentioning that many of the attributes referred previously (para. 4.3 and para. 8.2) were attached during processing to the graphic data (para. 6.2), but there is not any reference about their relationships or topology. Besides, large quantities of structured information could not be stored for it would be too inflexible, and any intention to copy ancillary information to the graphic system would make no sense . The feature serial numbers (FSN) in the graphic system served as pointers to entries in the relational database approach developed above.

It is useful to think in terms of two databases, the graphic and attribute, at this stage (pre-cadastral-para. 1.2) of cadastral surveys, because much can be gained by approaching both of them using conventional database techniques. Moreover, they will be of a size that is relatively easy to manage. Additional thematic information will be introduced easily without affecting the graphic data and creating errors within it. Such information could be, at least at this stage, building quality and historical record (when, by whom and how the data derived).

The development of such a database will have as result the dramatic increase in productivity of land-related information and will be cost effectiveness in terms of hardware requirements and skilled staff. Furthermore, since data is entered only once, each subsequent use is a saving.

Questions and problems will arise that will require additional research to answer and solve. These include the flexibility of the system in long term basis as the data will be increased and more user requirements will arise. Moreover, a thorough research and design is needed to associate the graphic and attribute database in order to avoid likely inflexibilities of the whole system. However, in short term basis the configuration proposed above (although not fully analysed) it will be more economical in terms of computer and user time, aspects so vital under the Greek circumstances, to update or modify the data.

Chapter 9

Conclusions and Recommendations

9.1 Project.

The aim of the study was, both to define guide lines as well as to address estimates of cost, for greater ease and speed of collecting, processing and analysing land related information, which is critical to a parcel-based land information system, resulting in :

- greater use of information during cadastral surveys since the data structure will be made in way that relates directly to the needs of the operational functions.
- enhanced accuracy, currency and comprehensiveness, up to a certain level, of the information in order to be much more effective in the current management problems.

The research was carried out in two phases, the first was concerned with defining both the data modeling schemes, and the classification of basic data for a parcel-based land information system as well as the photogrammetric methods adopted to collect these data; the second dealt with data editing and data structuring processes in order to produce "clean" information relevant to such a system.

In the previous chapters conclusions were expressed separately for each stage. However, they are summarized below.

The operator had had no previous experience of analytical plotters, digital mapping and interpretation processes. These factors, as well as the fact that no additional information was provided (e.g maps, field verification) resulted in the capture of less data with a lower quality than would be possible in a production environment.

Although its major application is still in topographic mapping, photogrammetry in recent years has made significant contribution in field of cadastral surveys. Photogrammetric techniques for cadastral mapping have been tested and applied by many countries and found to be sufficiently accurate. However, this could not also be an outcome of this project, since neither extensive use of photogrammetry was made nor were the test areas of large extent. Nevertheless, under these limitations, it was clearly indicated that by applying photogrammetric procedures data can be captured accurately, up to a certain level, resulting also in a rapid process of data collection.

Data was captured with a specific map scale in mind as well as with the aim of establishing an archive of spatial data to meet a general set of demands. By applying two data acquisition methods, the speedier, more comprehensive and less labour intensive way of capturing the critical features for a parcel-based land information system was defined. The outcome of this examination was that the line-following ("Spaghetti") method was less time consuming and consequently more cost effective. The detailed data captured by this method is more suitable to serve both as background information for the further development of cadastral surveys as well as platform to solve current land management problems.

Particularly important to the creation of a parcel-based land information system is to have "clean" data input. In order to improve the accuracy and reliability of captured data, an editing process had to be carried out. Efforts made to correct the mistakes and blunders were relied on the choice of the tolerance. This also affected by the digitization method and the desire to keep as much cartographic information as possible. More difficulties appeared during the urban data correction, resulting in more time required.

A fundamental requirement of a parcel-based land information system is an up-to-date, comprehensive and easily accessible information. The critical information needed is about parcels, their associated non-graphic attributes as well as their relationships. The approach presented in figure 4.4 met the above requirements, since it provides information both about the parcel itself and its boundaries as well as its adjacency. Furthermore, this set of demands was met without much upheaval of the data (e.g. loss of data).

A significant outcome of the data collection and data editing procedures is that they are the most time consuming tasks in creating a parcel-based land information system, and they are affected by the human performance, determing the level of data accuracy. These necessitate the data collection to be made according to the long-term requirements of the system. In addition, it is very economical to collect the data only once to satisfy all the needs that are bound to appear in the future.

According to the all above it is a fact that parcel boundaries are shown only in their apparent relative positions with respect to planimetric features and can not be considered accurate for legal delineation of land ownership. Hence, the resulted information (both spatial and non-spatial) can only provide a topologically correct index to parcels with the associated information boundaries can be mapped more precisely and accurately as time and resources allow. Actually, while creating the digital map it is not necessary to obtain the accuracy for tomorrow. The existing information can be used and gradually improved in the future.

Although this study serves as a guide to the better understanding of photogrammetric data acquisition, data editing and structuring procedures for a Greek parcel-based land information system, the associated problems can not fully appreciated until more research has been conducted. It is suggested that future research include :

1. Use of larger scale aerial photography (1: 4000) to have a more complete assessment of detail visible (critical for cadastral surveys). Thus, a much greater appreciation of problems of data capture (digitization and interpretation) will be gained and following this, a logical strategy can be adopted for future developments such as road and height information or/and hardware investments.

2. Extension of the test areas, since the current were insufficient to give a complete use and consequently a better assessment of classification scheme (linear type). This would also help the in depth investigation of feature coding process, resulting in a better approach. In addition, more data will be processed into editing stage to fully estimate the time required and consequently the cost effectiveness. Furthermore, to evaluate whether mistakes and blunders are appeared with higher frequency in photogrammetrically collected data (especially using analogue stereoplotters, equipped with computing facilities, since they are the majority of existing stereoplotters in Greece) and also to assess the cost of ground verification process.

3. A survey to investigate user requirements (e.g roads, height information) which may be structured topologically during this period (pre-cadastral) resulting in the more effective use of the land related information. The outcome of this will be the development of more sophisticated

software for current problems predicting though, future developments.

4. Although from economical and manageable standpoints the database configuration proposed would serve as a temporally solution of the database design issue, considering the above, they will provide the means to a more complete design and ways of communication between spatial and non-spatial databases. This should be based both on the cost and current needs as well as on the increasing requirements of the future. The outcome will be the greater understanding of associated problems arising to interface with future corporate systems.

9.2 General Considerations.

The research carried out gives an emphasis to the use of analytical plotters and software packages available in the department of Photogrammetry and Surveying at University College London. However, some considerations should be made concerning the Greek reality where few analytical plotters exist (only 3 or 4) and data processing and structuring packages are not in the every day use. In fact most of the stereoplotters available are analogue and to the author's knowledge, packages for data editing and structuring are not available at all.

It is very obvious that software for data editing and structuring should be acquired or/and developed in order to gain the benefits of computers in the whole procedure (cadastral surveys) from the very beginning stages. Thus, a modern management of all activities and services on the land will be addressed.

As far as the analogue stereoplotters are concerned, it is clear that their product should be in digital form and consequently they should be interfaced with a computing facility. Hence, orientation procedures and, facilities both for manipulation of digitized data and for any desired transformation of measured model coordinates, will allow the use of more refined and powerful data collection methods for compilation of detailed information, resulting in reduction of time, cost and internal procedures (e.g less staff to complete the maps). However, problems concerning compatibility between such systems with editing facilities will arise. In to this end investigation and development of data exchange software must be made. Nevertheless, it is evident that, by a careful system analysis, a proper selection of hardware and software can be made and the optimum version of the compilation system will be determined.

Another issue which must also discussed is the demarcation of boundaries. It was implicitly indicated in the current research the problems created due to the lack of defined boundaries. Actually, it is an issue which has examined by many around the world and obviously it was also a topic of many scientific considerations in Greece. However, according to the author's knowledge, solutions have not been proposed yet and it still remains on the top of the "cadastral agenda".

Rokos (Rokos, 1981)[74] states that demarcation of boundaries should be made after the verification process (owners, titles) and then they will be marked to be visible on the aerial photographs. On the other hand Zeimpekis and Seitanidis (Zeimpekis-Seitanidis,1987)[97] state that under the current circumstances it is a utopia to define and mark properly the parcel boundaries before the aerial photographic procedure take place, because of 1) large deviation of land in small ownerships, 2) lack of suitable equipment (it is not stated clearly if they mean photogrammetric equipment) and finally 3) of time consuming and cost. However, Mcentyre (J. G. Mcentyre, 1983)[57] states that a parcel should be physically locatable on the ground before its description is entered into a multipurpose cadastre.

It is evident from the above that the demarcation task is very important and it needs a thorough investigation and analysis. Nevertheless, the Organization of Cadastral and Mapping of Greece (O. C. M. G.) specified (§ 5.2.3 of Technical Specifications For Photogrammetric Mapping in Rural areas, 12-10-1988) that boundaries should be mapped as follows :

> " Enclosures, fences, hedges and other artificial and physical boundaries will be mapped as a line which presents the central line of the boundary, as it (boundary) is appeared on the photographs. Boundaries of special cultivations (vineyards, olive-trees, etc), visible on the photographs,

will be mapped with special type lines only then, when they do not coincide with the ownership boundaries".

The main question which immediately arises is : " How will the operator distinguish an ownership boundary from cultivation boundary ? ", since no additional information will be provided. It is obvious that this type of mapping will necessitate additional work (both on the field and the office), and the photogrammetric procedures will be degraded, resulting in low data quality.

On the light of the above it is more evident that a research is demanded to investigate possible solutions. Probably, a good start would be the evaluation of demarcation process in some areas of high value (e.g. urban-edge, due to the increasing residential development) or/and in some high interest rural areas (due to E. E. C. requirements).

Finally, it is worth mentioning the current evolution of photogrammetric map compilation systems to more versatile, resulting in the better manipulation of data. A typical example is of the direct display of graphical records of digitized features in the 3-D space of stereoscopic model and the dynamic display, i.e the play-back of digitized features in the model space. Moreover, the editing stage is made on-line since it is clear which features have been captured and how. This obviously means that much time is gained and the most important, the process is carried out by the same person (operator). Besides that, data can be structured (according to the user requirements) and entered into the database (which is integrated with the photogrammetric system) on-line providing topological relationships. Obviously some systems are more versatile than others. For example, the P-series of Zeiss are integrated with a cartographic system (PHOCUS) (para. 2.2.1). On the other hand the new photogrammetric workstation of Wild (S9-AP) is integrated with a land information system (S9) (para. 2.2.1).

It is evident that these integrated systems provide powerful solutions to the up to the present day problems. However, the cost effectiveness factor has a major influence on their justification. Additionally, although more powerful photogrammetric systems are available on the market the factor which still remains very important in the whole process is the operator. A poor operator can render results from the best photogrammetric system worthless. Facing the new integrated systems the operator should have some knowledge of the operations carried out by these systems but the question which arises is : " **Which level of knowledge should the operators have to use such systems ?** ".

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[56] **McCabe, F. (March-1988) :** "Logic and Objects". OOPS! : The newsletter of the BCS (British Computer Society) special interest group on Object-Oriented Programming and Systems.

[57] **Mcentyre, J. G. (1983) :** "Parcel Definition". XVII International Congress of F. I. G, (701.5). SOFIA.

The types of description utilized to identify a parcel of land in data records in the United States are explained. Problems existing in these description procedures as they would affect their insertion into a modern multipurpose cadastre are analysed. Recommentations as to how integrate present day descriptions into a new land data bank without carrying ambiguities and discrepancies into the new system are presented.

[58] **McEwen, R. B. /L. E. Starr (1984) :** "Research for the USGS digital cartography program". Technical papers of ASPRS-ACSM, Fall convention, p: 325-333. San-Antonio-TEXAS.

[59] **Mclaren, R. A. (1984) :** " Photogrammetric data acquisition: The intelligent approach". XV Congress of ISPRS, Com.II, p: 368-377. RIO JE JANEIRO.

[60] **Mclaughlin, J. (1983) :** "Standards for Multipursose Cadastral Systems". XVII International Congress of F. I. G, (701.4). SOFIA.

This paper briefly examines some of the major issues entailed in developing standards for multipurpose cadastres. Consideration is given to user requirements, and to technology, systems and policy issues. The recommendations of the Multipurpose Cadastre Panel of the U.S. National Research Council are reviewed.

[61] **Menke, K. (1989) :** "Cartographic Output and Data Exchange in a L.I.S.". Proceedings of the international seminar and workshop : 'Photogrammetry and Land Information Systems '. EPFL, LAUSANNE.

[62] **Ministry of Finance-Dept. of Technical Services, (1985) :** "Problems in Protection of the State Property". Two-Day Seminar in "Applications of Plans and Real estate titles", p: 429-464. University of Thessaloniki. In Greek.

[63] **Moellering, H. (1986) :** "Developing Digital Cartographic Data Standards for the United States". AutoCarto, p: 312-321. LONDON.

[64] **Moren, A. (1980) :** "Digital photogrammetric mapping at the National Land survey of Sweden". XIV Congress of ISPRS, Com. V/I, p: 540-551. HAMBURG.

In this paper, a brief description of application software and Map database in the National Land Survey of Sweden is given. Procedures followed for the maintenance of the system are briefly discussed. Finally, the profitability of the system is stated.

[65] **Nystrom, D.A./B.E. Wright /M.P. Prisloe /L.G. Batten (1986) :** "USGS - Connecticut Geographical Information System Project". Technical papers of ASPRS-ACSM, Vol(3), p: 210-219.

[66] **Palimaka, J. /Halustchak, O. /Walker, W. (1987):** "Integration of a spatial and relational database within a G. I. S." Technical Papers of ASPRS-ACSM, Vol. (3), p:131-140.

[67] **Pryer, E.J. (1986):** "Land Registration in England and Wales: A distinctive system". XVII F.I.G, Com. 7, TORONTO, p:70-85.

[68] **Quinn, J.M.P. (1986) :** "Deriving and using an Object Based Model of a mapped area from a Feature Coded Representation". AutoCarto, p: 59-68. LONDON.

[69] **Radwan, M. M /J. Kure /M. Al-Harthi (1988) :** "Data Structuring in Topographic Databases". XVI Congress of ISPRS, Com.IV, p: 317-325. KYOTO.

This paper outlines the general considerations to be taken into account in data structuring for multipurpose applications, paying particular attention to the establishment of spatial relationships between data elements, both on a horizontal level within in a single map layer and between separate map layers.

[70] **Rainio,A. (1986):** "The L.I.S - project in Finland". XVIII International Congress of F. I. G. TORONTO.

[71] **Report of the Greek Land Registry Commitee (1982):** "International Workshop for Cadastre" . ATHENS.

The report is a proposal presented by the work team which has been constituted by the Minister of Physical Planning, Housing and Environment for the purpose of studing and preparing technical spacifications for the means and procedures of land surveying, land registering and the implementation of city planning studies. Later, the objectives of the team expanded to include other subjects among which was a proposal for the preparation of a National Land Registry.

[72] **Rokos, Dem. (1981) :** "Natural Resources, Cadastre and Integrated Surveys", p. 304. Ed. Paratiritis-THESSALONIKI. In Greek.

[73] **Rokos,Dem. (1981):** "A critical analysis of the problem of Cadastral surveys in Greece. Presuppositions and proposals". XVI International Congress of F. I. G., (708.3). MONTREUX.

This paper attempts a critical analysis on the Cadastre problem in Greece, containg a critico-historical view of the efforts to legislate the National Cadastre and an analytical exposition on the actual situation of infrastructure development studies. It continues with an analysis, from ideological point of view, of the National Cadastre as the basis of the socio-economic development and it ends to an analysis of presuppositions, offering, also, precise proposals for the problem as a whole.

[74] **Rokos,Dem. (1981):** "Cadastre and Land Consolidation. Land Policy", p. 276. Ed. Mavromatis-ATHENS. In Greek.

This book combines, in depth, historic information related to Cadastre (not only in Greece but worldwide) with technical, scientific and socio-economic considerations for the creation of a Parcel-Based Land Information System in Greece.

[75] **Ruotsalainen, R. (1984) :** "Experiences with photogrammetric map compilation as part of a digital mapping system". XV Congress of ISPRS, Com.IV/8. RIO JE JANEIRO.

In this paper, the experiences with different photogrammetric recording systems are reported and the requirements for a compenhensive system are suggested.

[76] **Seitanidis, A. (1985) :** "Discordance Examples of Theoretical and Practical aspects of Land Registry Plans. A suggestion to delete them". Two-Day Seminar in "Applications of Plans and Real estate titles", p : 497-512. University of Thessaloniki. In Greek.

The reliability of the current land registry plans is examined, resulting in the need of determing national technical specifications. A proposal is made to solve the current situation.

[77] **Simmerding, F. /J.L.G. Henssen (1986) :** "Demarcation of property boundaries in different countries". XVIII International Congress of F. I. G., (704.1). TORONTO.

[78] **Simonson, G. / Westermark, E. / Wiberg, B. (1980) :** "Digital Mapping". XIV Congress of ISPRS, Com.IV/I. HAMBURG.

[79] **Smith, K. E. / Zdonik, S. B. (1987) :** "Intermedia: A case study of the differences between relational object-oriented database systems". OOPSLA proceedings, pages: 452-465.

[80] **Smith, S. D. (1987) :** "A Geographic Information System for the Macintosh microcomputer". Technical papers of ASPRS-ACSM, Vol.(5), p: 18-23.

[81] **Spooner, R. (1989) :** "Advantages and problems in the creation and use of a topologically structured database". Proceedings of the international seminar and workshop : ' Photogrammetry and Land Information Systems '. EPFL, LAUSANNE.

[82] **Strangalis, S. (1985) :** "Technical problems in Plans of the Land Surveying Dept. at Ministry of Agriculture". Two-Day Seminar in "Applications of Plans and Real estate titles", p: 467-476. University of Thessaloniki. In Greek.

[83] **Tokmakidis, K. (1985) :** "Site division in villages by the Ministry of Agriculture". Two-Day Seminar in "Applications of Plans and Real estate titles", p: 513-527. University of Thessaloniki. In Greek.

A brief review in carrying out the site division in villages by Ministry of Agriculture is remarked. Some problems caused while such a fitting in a village with valid division of the above Ministry are given. The methodology of this fitting is given in such a way to eliminate errors. At last an example of a wrong fitting is reported and the problems caused are described.

[84] **Uhlenbruck, M. /N. Bartelme (1989) :** " Spatial Data : Storage and Access". Proceedings of the international seminar and workshop : 'Photogrammetry and Land Information Systems '. EPFL, LAUSANNE.

[85] **Ulrike Stampa-Wessel** : "The use of analytical plotters for the establishment of Land Information Systems". XV Congress of ISPRS, Com.II, p: 443-449. RIO JE JANEIRO.

[86] **Visvalingam, M. /P. Wade /G.H. Kirby (1986)** : "Extraction of area topology from line geometry". AutoCarto, p: 156-165. LONDON.

[87] **Vlachos, D. (1979)** : "Topography Lectures". Textbook in Topography, Volumes A, B. Engineering Faculty of University of Thessaloniki.

[88] **Vlachos, D./E. Kapokakis/D. Rokos/K. Tokmakidis/A. Tsomou (1986)** : "Reliability of photogrammetric and topographic methods in compilation of cadastral Plans". Two-Day Scientific Meeting in : "Prospects of the Greek Cadastre", p: 371-393. National Technical University of Athens. In Greek.

[89] **Walker, A. S. (1987)** : "Input of photogrammetric data to Geographical Information Systems". Paper read at: G.I.Ss Today, a seminar held at Salford College of Technology.

[90] **Watkins, J. / Newton, M. (March-1988)** : "Implementing Objects in Prolog". OOPS! : The newsletter of the BCS (British Computer Society) special interest group on Object-Oriented Programming and Systems.

[91] **Wiederhold, G (1983)** : "Database Design". McGraw-Hill, LONDON.

[92] **Wiederhold, G. (1987) :** "File organisation for database design". McGraw-Hill, LONDON.

[93] **Wolf, P. R. (1986) :** "Elements of Photogrammetry". International Student Edition (2nd Edition). McGraw-Hill.

[94] **Zarzycki, J. M. (1987) :** "Towards a computerized mapping database for the province of Ontario". Conference of Commonwealth Surveyors, paper No: L-2.

[95] **Zegheru, N. (1980) :** "Automation in Photogrammetric Cadastral Surveyings". XIV Congress of ISPRS, Com.IV, p: 782-789. HAMBURG.

[96] **Zegheru, N. / Gheorghiu, D. / Fusoi, A. / Doroghy, Z. (1984) :** " A database used in digital cadastral mapping". XV Congress of ISPRS, Com. IV, p: 531-535. RIO JE JANEIRO.

[97] **Zeimpekis, A./A. Seitanidis (1987) :** "Methods and Procedures to create a cadastral system for rural and urban-edge areas". Information Circular (issue 13) of the Association of Rural and Land Surveying Engineers of Northern Greece, p: 32-45. In Greek.

Field surveys, photogrammetric surveys and combination of them are discussed for the creation of a Cadastral system. Organizational aspects for the maintenance and updating of the system are examined. Cost estimation of the cadastral surveys as well as staff requirements are addressed.

APPENDICES.

APPENDIX A.

APPENDIX A.1 Type and possible source of classified land related information

DATA	Possible source	Data type
Situation	maps, imageries	points/lines/polygons
Surface shape	maps, imageries	lines
Area of the unit	calculations	number
Valuation	census/analysis	number
Ownership	census-deeds	titles
Encumbrances	census-deeds	records (tables)
Limitations	census-deeds	records (tables)
Cultivated crops		polygons
Irrigated crops		polygons
Orchards		polygons
Vineyards		polygons
Pastures		polygons
Abandoned fields		polygons
Forests(kind,shape,area)		polygons
Houses		polygons, points
Schools		polygons, points
Shopping centers		polygons, points
Parks or playgrounds		polygons
Monuments		polygons, lines
Athletic fields		polygons, points
Hospitals		polygons, points
Gas stations/garages		polygons, points
Electrical power plants		polygons
Electrical power substations	thematic maps, photointerpretation, census.	polygons
Steel towers for electric lines		points
Pipelines		lines
Petrolium/chemical products industries		polygons, points
Water plants		polygons
Dams		lines, polugons
Coal mining		polygons, points
Metal mining		polygons, points
Stone quarrying		polygons, points
Oil-drilling		points
Rivers		lines
Lakes		polygons
Streams		lines
Shorelines		lines
Cliffs		lines, polygons
Slopes		lines, polygons
Erosion		lines, polygons
Rock outcrops (kinds)		polygons
Hogbacks		lines, polygons
Faults		lines
Dikes		lines

(continued)

APPENDIX A.1 (...continued)

Type and possible source of classified land related information

DATA	Possible source	Data type
Bridges	↓	polygons, lines
Canals or drainage ditces		lines
Water tanks		polygons
Motorways		polygons, lines
Highways	thematic maps,	polygons, lines
Railroad	photointerpretation	polygons, lines
Railroad terminals	census.	polygons
Bus terminals	↑	polygons
Boat docks and piers		polygons
Airports		polygons
Radio/T.V transm. tower		polygons,points
Quality of water	thematic maps	polygons
pollution	reports, analysis	polygons
Population	thematic maps	polygons
Traffic conditions	reports, analysis	polygons

APPENDIX A.2.

Technical characteristics of Land Information Management Systems in several countries.

COUNTRY	Land Registry	Boundaries	Geometric represen.	Parsel identific .	Form of parcel referenc.
Finland	different kinds of L .I. S	accurate survey	Vector and Raster	Number	parcel-corners coordinates
Italy	- parcel map - parcel directory - land property register - list of the owners	accurate survey	Vector	Number	centroid
England	titles (only after sale)	general defined	Vector	Number/ address	centroid
Australia	Torrens title system	accurate survey	Vector and Raster	-title reference -valuation number and address - street intersections as parcels	- centroids - boundary coodinates - both of the above - parcel corner coordinates

APPENDIX B.

APPENDIX B.

Mapping Data in Greek State Agencies.

I. ARMY GEOGRAPHIC SERVICE.

1. TRIAGULATION : Class 1, 2, 3, 4.
   Files----Map Scale 1:50,000

2. SURVEYING : Class 1 (11,000km length)
   : Class 2 (4,500km length).

3. GENERAL PURPOSE MAPS :
   a- 1:1,000,000
   b- 1:500,000
   c- 1:250,000
   d- 1:100,000
   e- 1:50,000
   f- 1:25,000
   g- 1:5,000

4. AERIAL PHOTOGRAPHS :
   a- 1:40,000 taken in 1945.
   b- 1:30,000 taken in 1960.
   c- 1:30,000 - 1:40,000
   taken between 1968-1972.
   d- 1:15,000 - 1:20,000
   taken between 1963-1981.

II. MINISTRY OF PHYSICAL PLANNING, HOUSING AND ENVIROMENT.

1. DEPARTEMENT OF CARTOGRAPHY

1:200	1:500	1:1,000	1:2,000	1:5,000	1:10,000	1:20,000	**TOTAL BOARDS**
645	2716	5847	5936	5747	430	615	**21936**

Projections : HATT from 1922 - 1973
UTM from 1973 - present.

2. DEPARTMENT OF CITY - PLANNING APPLICATIONS

22,000 Charts in scales : 1:200 - 1:5,000.

3. SECTION OF SURVEYING APPLICATIONS

1,557 Boards in scales : 1:100
1:200
1:500

4. DEPARTMENT OF PHOTOGRAMMETRY

Photographs in scales between : 1:4,000 - 1:20,000.

III. MINISTRY OF AGRICULTURE.

a- 22,000,000str (2,200,000ha) : 1:5,000
b- 500 housing projects : 1:1,000
c- reforesting programs 80% : 1:5,000
20% : 1:2,000

IV. MINISTRY OF FINANCE.

a- coast line : 1:500

b- known state property : 1:2,000

V. HYDROGRAPHIC SERVICE.

records and maps of coast line.

map scales : 1:500

1:1,000

1:2,000.

APPENDIX C.

APPENDIX C.1

Areal type of classification scheme.

LEVEL I	LEVEL II	LEVEL III	LEVEL IV	LEVEL V	LEVEL VI
URBAN / BUILD-UP LAND	Residential	High density	Parcel - block	80% <= defined boundary	
				50% <= defined boundary <=80%	
				defined .boundary <=50%	
			Parcel	defined without building	
				defined with a building	
				defined with >=2 building	
				undefined without building	
				undefined with a building	
				undefined with >=2 building	
			Building	new structure - new style roof	
				new structure - old style roof	
				old structure	
				very old structure	
	Transportation Communication Utilites	Roads	main	single	
				dual	
			secondary	single	narrow
				dual	
			Slip _ road		
			Blind _alley		
			untarred > 4 m		
			untarred < 4 m		
		Pavements	with width >3m		
			with width <3m		
			not completely visible-incorrect		
	Industrial	Electric power distribution station			
		Other industrial			
	Urban_edge area				
AGRICULTURAL LAND	Cropland	defined field			
		undefined field			
	Grove	defined field			
		undefined field			
	Orchard	defined field			
		undefined field			
	Pasture	defined field			
		undefined field			
	Abandoned	defined field			
		undefined field			
	Nurcery	defined field			
		undefined field			
WATER	Canal	bank of canal			

APPENDIX C.2

Linear type of classification scheme

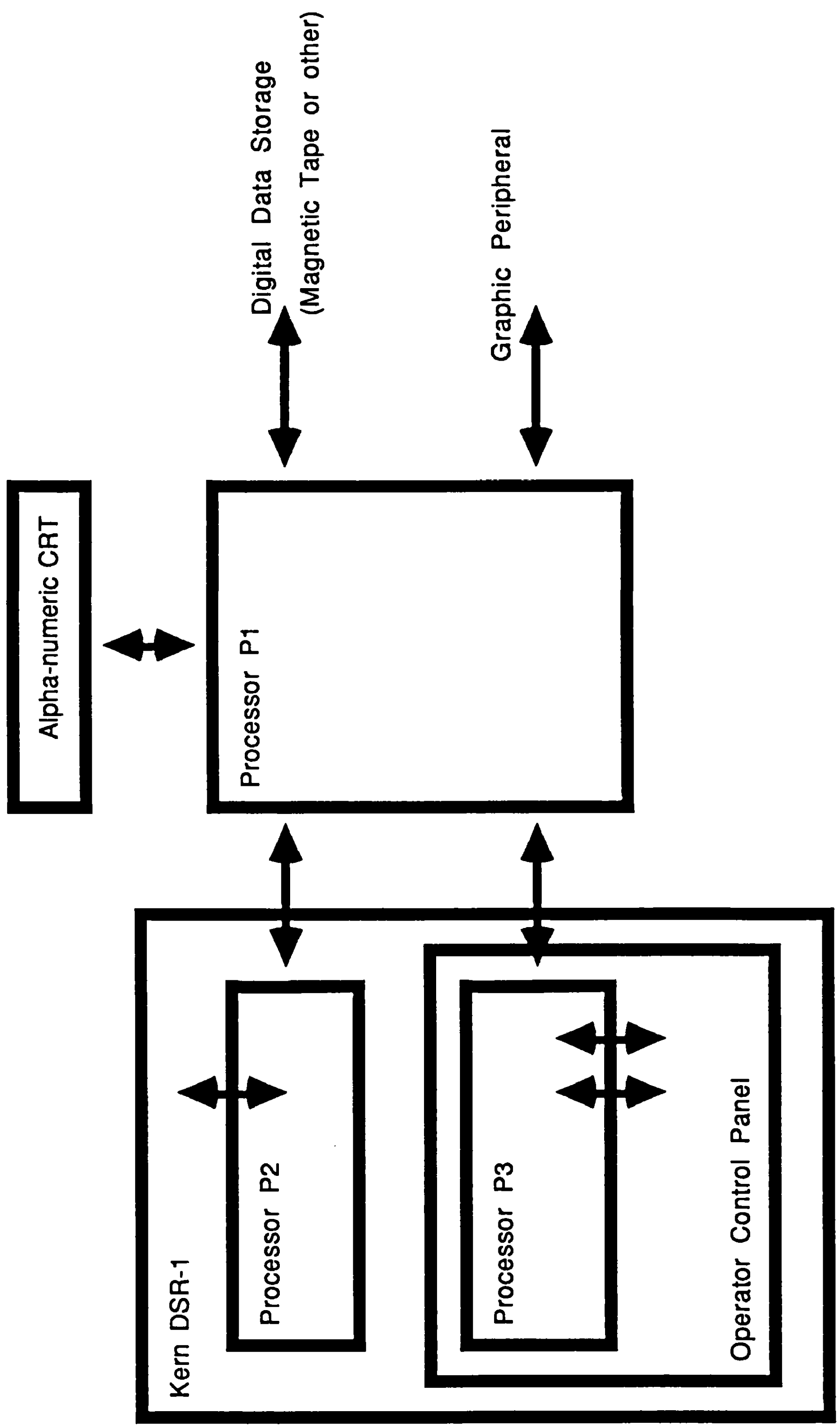
LEVEL I	LEVEL II	LEVEL III	LEVEL IV
BOUNDARY	Defined	fence	
		wall	
		wall of building	
	Undefined	fence ?	
		wall ?	
	Hedge		
	Defined by pegs		
BUILDING	Outline in the parcel/field		
WORKING AREA			
ROAD	Main	single	
		dual	
	Secondary	single	narrow
		dual	
	Slip-road		
	Blind-road		
	untarred > 4m		
	untarred < 4 m		
PAVEMENTS	with width > 3m		
	with width < 3m		
	not completely visible-incorrect		

APPENDIX D.

APPENDIX D.

KERN DSR-1 Distributed Computing Architecture.

(after Kern brochure 206e, 7.84).



APPENDIX E.

APPENDIX E.

Orientations

E.1 Inner orientation.

Inner orientation includes preparations necessary to re-create the geometry of the projected cone of rays to duplicate exactly the geometry during the original exposure. This geometry is defined by following parameters which are also called elements of interior orientation : 1) the camera constant (also called focal length or principal distance), 2) location of principal point, 3) all the distortion parameters (it is referred to principal point and fiducial marks).

Input to the "inner orientation" program were the principal distance of the camera and the fiducial coordinates. All these were determined in the "camera management" program, where a camera calibration certificate was not available and as principal point of autocollimation and point of best symmetry zero values were entered. The calibrated values of fiducial coordinates were not also known. Therefore, a maximum of four (4) fiducials were digitized for each photograph and a principal point with zero coordinates was calculated as the intersection of the lines joining opposite fiducials. Instrument image coordinates x, y for each photo-carrier of the diapositive fiducials were then read. From this information the "inner

```
Kern DSR-1 Operating System 718.1X0.0147:E
------------------------------------------

Inner Orientation Measuring Scheme
----------------------------------

This file is called INNER.SCH


This file has been updated : 02-MAR-88
                      Time : 23:41:27
                  Operator : PDM

Fiducials should be measured =
( Biocular Independent,
  Biocular Simultaneously,
  Stereoscopically         )

Number of measurements on each Fiducial Mark          =   1 times
Remeasure if discrepancy between measurements exceeds =  10 microns

Transformation Mathematical Model = AFFINE

Conformal e=sqrt(a*a+b*b)-->scale      Conformal x=+a*x+b*y+c
w/o scale x=+a/e*x+b/e*y+c                       y=+b*x-a*y+d
          y=+b/e*x-a/e*y+d

Affine x=a1*x+b1*y+c1
       y=a2*x+b2*y+c2

Tolerance value to reject a fiducial mark =   10 microns



Selected Camera for Left And Right Photographs = 23
----------------------------------------------

Camera Serial Number          = VOLOS-GR
Camera Type                   = ZEISS
Lens Type                     = ?
Date of Calibration Report    = ?
Principal Distance            =  152.520 mm
Number of Fiducial Marks      =  4
Shape of Fiducial Marks       = DOT
 (dot,cross arms,wedge)

Fiducial #            Xmm                  Ymm

    1               -1.214              -112.996
    2              112.999                -1.194
    3                1.214               112.963
    4             -112.966                 1.194

Principal Point of AutoCollimation:  0.000         0.000 mm
Point of Best Symmetry            :  0.000         0.000 mm

Distortion Information
----------------------

Mean Distortion Values
Distortion Interval       =  20 mm

                                Distortion Values (1..16) microns

    MEAN                          0   0   0   0   0   0   0   0

                                  0   0   0   0   0   0   0   0
```

Kern DSR-1 Operating System 718.1X0.0147:E

This file is called INNER.MEA

This file has been updated : 02-MAR-88
Time : 23:41:28
Operator : PDM

Model Identification : Base-Out Model

Left photograph number = 148770
Right photograph number = 148771

Selected camera:

	Serial Number	Principal Distance
Left Camera	VOLOS-GR	152.520 mm
Right Camera	VOLOS-GR	152.520 mm

Inner Orientation Results :

Left Plate : AFFINE Transformation

Number of Fiducial Marks = 4

Point	Fiducial Coordinates Xum	Yum	Measured Coordinates Xum	Yum	Residuals VXum	VYum
1	-1214	-112996	121442	14104	-2	-16
2	112999	-1194	235871	125708	2	16
3	1214	112963	124322	240098	-2	-16
4	-112966	1194	9918	128464	2	16

Largest Residual = 16 um at Point Number = 1

Transformation Matrix - Left Measuring System to Left Fiducial System

Rotation and Scale		Shift
1.000029	-0.002000	-122629.3
0.001627	0.999824	-127279.3

Transformation Matrix - Left Fiducial System to Left Measuring System

Rotation and Scale		Shift
0.999968	0.002001	122880.0
-0.001627	1.000172	127101.8

Right Plate : AFFINE Transformation

Number of Fiducial Marks = 4

Point	Fiducial Coordinates Xum	Yum	Measured Coordinates Xum	Yum	Residuals VXum	VYum
1	-1214	-112996	115249	12417	-8	-12
2	112999	-1194	229868	123651	8	12
3	1214	112963	118501	238401	-8	-12
4	-112966	1194	3883	127152	8	12

Largest Residual = 14 um at Point Number = 1

Transformation Matrix - Right Measuring System to Right Fiducial System

Rotation and Scale		Shift
0.999855	-0.003644	-116393.1
0.004922	0.999819	-125966.0

Transformation Matrix - Right Fiducial System to Right Measuring System

Rotation and Scale		Shift
1.000127	0.003645	116867.0
-0.004924	1.000164	125413.5

Left Lens Distortion

Left Distortion Interval : 20 mms

Left Distortion Values :

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Right Lens Distortion

Right Distortion Interval : 20 mms

Right Distortion Values :

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

END OF FILE

Kern DSR-1 Operating System 718.1X0.0147:E

This file is called INNER.MEA

This file has been updated : 16-SEP-88
Time : 3:11:28
Operator : PDM

Model Identification : Base-Out Model

Left photograph number = 148772
Right photograph number = 148773

Selected camera:

	Serial Number	Principal Distance
Left Camera	VOLOS-GR	152.520 mm
Right Camera	VOLOS-GR	152.520 mm

Inner Orientation Results :

Left Plate : AFFINE Transformation

Number of Fiducial Marks = 4

Point	Fiducial Coordinates Xum	Fiducial Coordinates Yum	Measured Coordinates Xum	Measured Coordinates Yum	Residuals VXum	Residuals VYum
1	-1214	-112996	113169	12792	-1	-17
2	112999	-1194	228062	123949	1	17
3	1214	112963	116947	238800	-1	-17
4	-112966	1194	2083	127606	1	17

Largest Residual = 17 um at Point Number = 1

Transformation Matrix - Left Measuring System to Left Fiducial System

Rotation and Scale		Shift
0.999841	-0.005971	-114287.7
0.005611	0.999689	-126401.5

Transformation Matrix - Left Fiducial System to Left Measuring System

Rotation and Scale		Shift
1.000125	0.005973	115057.0
-0.005613	1.000277	125795.0

Right Plate : AFFINE Transformation

Number of Fiducial Marks = 4

Point	Fiducial Coordinates Xum	Yum	Measured Coordinates Xum	Yum	Residuals VXum	VYum
1	-1214	-112996	115074	11134	-6	-16
2	112999	-1194	228732	123362	6	16
3	1214	112963	116367	237161	-6	-16
4	-112966	1194	2718	124903	6	16

Largest Residual = 17 um at Point Number = 1

Transformation Matrix - Right Measuring System to Right Fiducial System

Rotation and Scale		Shift
0.999817	0.005023	-116316.9
-0.003749	0.999721	-123679.7

Transformation Matrix - Right Fiducial System to Right Measuring System

Rotation and Scale		Shift
1.000164	-0.005025	115714.5
0.003751	1.000261	124148.2

Left Lens Distortion

Left Distortion Interval : 20 mms

Left Distortion Values :

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Right Lens Distortion

Right Distortion Interval : 20 mms

Right Distortion Values :

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

END OF FILE

orientation" program solved an affine coordinate transformation, using least squares, to locate the principal point and determine the relationship of the two photo-coordinate systems with respect to the instrument's image coordinate measurement system. The form (2) has six unknown parameters, the a's and the b's, although the real unknowns are only five Mx, My, K, Xo, Yo, for each photograph. The result of the inner orientation was the residuals and the a's and b's for two transformations : *measuring system to fiducial system and fiducial system to measuring system.*

$$X = (Mx)*(X')*(\cos K) + (My)*(Y')*(\sin K) + Xo$$

(1).

$$Y = -(Mx)*(X')*(\sin K) + (My)*(Y')*(\cos K) + Yo$$

or

$$X = (a1)*X') + (a2)*Y') + a0$$

(2).

$$Y = (b1)*(X') + (b2)*(Y') + b0$$

In the general case one could expect all residuals to be less than ten microns (10μm), but in both pair of photographs that was not met (see lists) although remeasurements were made. This probably happened because of the age of the film (photographs were taken on 1982), but if it is considered that in analogue instruments usually the inner orientation is made with accuracy of order of 25-30μm (C. D. Burnside,1985)[14], the above values finally were accepted.

E.2 Relative orientation.

The primary purpose of relative orientation is to orient the two photographs so that each corresponding pair of rays from the two photographs intersect in space. This usually can not be made due to different kinds of distortion (lens, atmospheric, etc). Thus, the objective of relative orientation is to orient the two photographs so that the condition of intersection is as nearly achieved as possible (ASPRS,1980)[3].

The condition of intersection is expressed mathematically by the collinearity equations (see P. R. Wolf,1986)[93]. The relative orientations of the two pairs of the photographs in the current project were made according to one-projector method. As it is clear from the lists the right projector was used while the elements of the left one were set zero. Twelve pre-positioned points were used and for each point four collinearity equations were used in the program. The system of collinearity equations that was formulated contained five unknown elements for the right photo (omega, phi, kappa and By, Bz), plus three unknown model coordinates (X, Y, Z) for each point used in the solution. Using 12 points , 48 equations were applied involving 41 unknowns. Details on the procedure can be found in many text books of photogrammetry (e.g. P. R. Wolf)[93].

As in inner orientation so in here, the expected residuals should be less than 10μm (Manual of DSR-1 operating system). This actually was achieved in both pair of photographs giving small standard deviations. It is worth noticing that although in

Kern DSR-1 Operating System 718.1X0.0148:D

This file is called RELATI.MEA

This file has been updated : 02-MAR-88
Time : 0:14:44
Operator : PDM

Project : GREECE

Model Identification : Base-Out Model

Left photograph number = 148770
Right photograph number = 148771

Left principal distance = 152.520 mm
Right principal distance = 152.520 mm

Relative Orientation Elements Used :

LEFT		RIGHT	
KAPPA =	No	KAPPA =	Yes
PHI =	No	PHI =	Yes
OMEGA =	No	OMEGA =	Yes
BY =	No	BY =	Yes
BZ =	No	BZ =	Yes

Initial Values For Elements

LEFT		RIGHT	
KAPPA =	0.0000 gons	KAPPA =	0.0000 gons
PHI =	0.0000 gons	PHI =	0.0000 gons
OMEGA =	0.0000 gons	OMEGA =	0.0000 gons
BY =	0.000 mms	BY =	0.000 mms
BZ =	0.000 mms	BZ =	0.000 mms

BX = 81.923 mms

Number of Parallax Points = 14

Fiducial Coordinates

Point	Name	Xl um	Yl um	Xr um	Yr um
1		-3757	1838	-85690	-5751
2		-2423	2037	-84348	-5526
3		83423	-9713	2333	-15852
4		91969	-5368	10655	-11344
5		3717	96771	-79467	87952
6		1641	99374	-82334	90397
7		89773	99505	4048	92203
8		92089	100674	6602	93410
9		2981	-101903	-76341	-111099
10		620	-99413	-78793	-108556
11		87140	-103465	9010	-111527

12	91856	-100421	13714	-108311
13	80554	-7176	-577	-13343
14	86486	-101933	8308	-109947

Model Coordinates

Point	Name	Model Coordinates X mm	Y mm	Z mm	Parallax Py um
1		-3.724	1.822	-151.199	-1
2		-2.402	2.021	-151.222	3
3		83.337	-9.705	-152.363	-3
4		91.671	-5.351	-152.026	0
5		3.648	94.993	-149.716	2
6		1.595	96.586	-148.244	-3
7		86.798	96.205	-147.462	-6
8		89.344	97.676	-147.970	6
9		3.033	-103.677	-155.171	-2
10		0.630	-101.086	-155.087	1
11		88.352	-104.904	-154.637	2
12		93.080	-101.761	-154.548	-4
13		80.484	-7.170	-152.388	1
14		87.681	-103.341	-154.624	3

Largest Parallax = 6 um at Point Number = 8
Standard Deviation Of Parallaxes = 3.9 um

Computed Elements

LEFT		RIGHT	
KAPPA =	0.0000 gons	KAPPA =	-1.0859 gons
PHI =	0.0000 gons	PHI =	0.2676 gons
OMEGA =	0.0000 gons	OMEGA =	1.5341 gons
BY =	0.000 mm	BY =	2.437 mm
BZ =	0.000 mm	BZ =	-0.333 mm

BX = 81.923 mm

Rotation Matrix - Left Fiducial System to Model System

1.000000	0.000000	0.000000
0.000000	1.000000	0.000000
0.000000	0.000000	1.000000

Rotation Matrix - Right Fiducial System to Model System

0.999846	0.017057	0.004203
-0.016951	0.999566	-0.024095
-0.004612	0.024020	0.999701

Projection Centre Coordinates

	Corrected for Curvature and Refraction X mm	Y mm	Z mm	Not Corrected X mm	Y mm	Z mm
Left :	0.000	0.000	0.000	0.000	0.000	0.000
Right :	81.910	2.437	-0.330	81.923	2.437	-0.333

Earth Curvature Correction Coefficients

1.083832E-09 5.419162E-10 1.546926E+05

Atmospheric Refraction Correction Coefficients

Left Camera :	-2.878029E+00	-3.692979E-05	0.000000E+00
Right Camera :	-2.878029E+00	-3.692979E-05	0.000000E+00

Kern DSR-1 Operating System 718.1X0.0148:D

This file is called RELATI.MEA

This file has been updated : 16-SEP-88
Time : 6: 2:56
Operator : PDM

Project : GREECE

Model Identification : Base-Out Model

Left photograph number	= 148772
Right photograph number	= 148773
Left principal distance	= 152.520 mm
Right principal distance	= 152.520 mm

Relative Orientation Elements Used :

LEFT	RIGHT
KAPPA = No	KAPPA = Yes
PHI = No	PHI = Yes
OMEGA = No	OMEGA = Yes
BY = No	BY = Yes
BZ = No	BZ = Yes

Initial Values For Elements

LEFT		RIGHT	
KAPPA =	0.0000 gons	KAPPA =	0.0000 gons
PHI =	0.0000 gons	PHI =	0.0000 gons
OMEGA =	0.0000 gons	OMEGA =	0.0000 gons
BY =	0.000 mms	BY =	0.000 mms
BZ =	0.000 mms	BZ =	0.000 mms

BX = 79.938 mms

Number of Parallax Points = 12

Fiducial Coordinates

Point	Name	Fiducial Coordinates Xl um	Yl um	Xr um	Yr um
1		-4621	-7559	-83867	-8240
2		-9418	-1599	-88636	-2394
3		76003	4408	-5932	4717
4		66293	21545	-15447	21737
5		-6129	102863	-87552	102687
6		13381	91452	-67707	91429
7		93050	105641	10182	107194
8		83390	104311	908	105689
9		21765	-108865	-56309	-107564
10		-15528	-95454	-92557	-94881
11		83665	-108331	3478	-106461
12		80284	-93182	-19	-91686

Model Coordinates

Point	Name	Model Coordinates X mm	Y mm	Z mm	Parallax Py um
1		-4.580	-7.488	-151.174	8
2		-9.350	-1.591	-151.409	-6
3		73.472	4.260	-147.443	-3
4		64.431	20.942	-148.238	4
5		-6.103	102.430	-151.872	6
6		13.329	91.091	-151.925	-9
7		90.413	102.646	-148.194	-2
8		81.476	101.918	-149.015	3
9		21.400	-107.035	-149.961	10
10		-15.397	-94.654	-151.236	-7
11		81.080	-104.986	-147.804	-5
12		77.853	-90.360	-147.899	1

Largest Parallax = 10 um at Point Number = 9
Standard Deviation Of Parallaxes = 7.7 um

Computed Elements

LEFT		RIGHT	
KAPPA =	0.0000 gons	KAPPA =	-0.8987 gons
PHI =	0.0000 gons	PHI =	0.3386 gons
OMEGA =	0.0000 gons	OMEGA =	-1.0108 gons
BY =	0.000 mm	BY =	1.956 mm
BZ =	0.000 mm	BZ =	0.291 mm

BX = 79.938 mm

Rotation Matrix - Left Fiducial System to Model System

1.000000	0.000000	0.000000
0.000000	1.000000	0.000000
0.000000	0.000000	1.000000

Rotation Matrix - Right Fiducial System to Model System

0.999886	0.014116	0.005319
-0.014199	0.999773	0.015877
-0.005093	-0.015951	0.999860

Projection Centre Coordinates

	Corrected for Curvature and Refraction			Not Corrected		
	X mm	Y mm	Z mm	X mm	Y mm	Z mm
Left :	0.000	0.000	0.000	0.000	0.000	0.000
Right :	79.925	1.955	0.294	79.938	1.956	0.291

Earth Curvature Correction Coefficients

1.083832E-09 5.419162E-10 1.546926E+05

Atmospheric Refraction Correction Coefficients

Left Camera :	-2.878029E+00	-3.692979E-05	0.000000E+00
Right Camera :	-2.878029E+00	-3.692979E-05	0.000000E+00

inner orientation the request was not met (residuals were larger than 10μm) in relative orientation there was not any problem. The coordinates of projection centres were also calculated both with correction of curvature and refraction.

E.3 Absolute orientation.

Absolute orientation is the procedure of the establishment of the model by way of fixing the scale, positions, tilts and azimuths with reference to the ground system of coordinates.

In Urban area (photos : 148770-148771) ten control points were used while in Urban-edge (photos: 148772-148773) eight, with values of weights equal to one. A three-dimensional coordinate transformation for each model was carried out and the residuals of used points were displayed, as well as the final values of omega, phi, kappa and the perspective centres coordinates. The standard plan and height deviation were also calculated.

Using an analytical plotter the expected plan accuracy on the well-defined points (e.g. control points) usually is of the order of 3-4μm in model coordinates at photo scale (C. D. Burnside, 1985)[14], which is about 0.03m on the ground (4μm * photo-scale: 7000) and the height accuracy could be calculated from the form (E.3.1) (C. D. Burnside,1985)[14].

$$m_z = (0.004\%)^*(Z) \qquad \text{(E.3.1).}$$

Kern DSR-1 Operating System 718.1X0.0149:E

This file is called ABSOR.MEA

This file has been updated : 04-MAR-88
Time : 1:37:10
Operator : PDM

Project Name = GREECE

Ground Control File Name = GROUNV.DAT

Model Identification :

Left photograph number = 148770
Right photograph number = 148771

Ground control coordinates and results :

Number of control points = 10

	Point Name	Ground Coordinates E	N	H	PW	PH
1	V31	133904.92	595248.57	0.00	1.0	0.0
2	V18	134009.00	596112.71	0.00	1.0	0.0
3	V17	134632.91	596096.18	0.00	1.0	0.0
4	V71	134598.13	595716.71	0.00	1.0	0.0
5	V32	134532.64	595398.31	0.00	1.0	0.0
6	V31H	0.00	0.00	8.58	0.0	1.0
7	V18H	0.00	0.00	22.00	0.0	1.0
8	V17H	0.00	0.00	31.46	0.0	1.0
9	V71H	0.00	0.00	24.66	0.0	1.0
10	V32H	0.00	0.00	20.30	0.0	1.0

	Point Name	Residuals DE	DN	DH
1	V31	-0.11	0.00	NOT MEA
2	V18	0.05	-0.05	NOT MEA
3	V17	-0.07	0.03	NOT MEA
4	V71	0.06	-0.06	NOT MEA
5	V32	0.07	0.08	NOT MEA
6	V31H	NOT MEASURED		-0.05
7	V18H	NOT MEASURED		0.04
8	V17H	NOT MEASURED		-0.01
9	V71H	NOT MEASURED		-0.11
10	V32H	NOT MEASURED		0.12

Standard Plan Deviation = 0.083 Standard Height Deviation = 0.125

	Point Name	Model Coordinates X um	Y um	Z um
1	V31	10	-41859	-151935
2	V18	15477	83276	-149052
3	V17	105886	80561	-148395
4	V71	100647	25614	-149224
5	V32	91005	-20504	-149937

6	V31H	709	-41700	-154682
7	V18H	16578	81849	-150560
8	V17H	107345	82483	-149021
9	V71H	100514	24392	-151021
10	V32H	89599	-20219	-152486

Initial Values :

Rotations (gons)

	KAPPA	PHI	OMEGA
Left :	0.0000	0.0000	0.0000
Right :	-1.0860	0.2678	1.5343
Common :	0.0000	0.0000	0.0000

Projection Centre Coordinates

	X	Y	Z
Left :	0.000	0.000	0.000
Right :	81923.000	2437.000	-333.000

Shifts Model to Ground System

X0	Y0	Z0
0.000	0.000	0.000

Model to ground scale : 1 um = 1.0000000 ground units

Final Values :

Rotations (gons)

	KAPPA	PHI	OMEGA
Left :	0.2089	0.1049	-1.1154
Right :	-0.8771	0.3727	0.4189
Common :	0.2089	0.1049	-1.1154

Projection Centre Coordinates

	E	N	H
Left :	133905.671	595555.791	1070.988
Right :	134471.009	595574.423	1067.464

Shifts Model to Ground System

E0	N0	H0
133905.671	595555.791	1070.988

Model to ground scale : 1 um = 0.0069016 ground units

Left fiducial to ground matrix :

0.9999986	-0.0000289	0.0016482
0.0000000	0.9998465	0.0175200
-0.0016484	-0.0175199	0.9998452

Right fiducial to ground matrix :

0.9998375	0.0170677	0.0058554
-0.0170293	0.9998335	-0.0065796
-0.0059675	0.0064788	0.9999615

Model To Ground Levelling Matrix :

0.9999986	-0.0000289	0.0016482
0.0000000	0.9998465	0.0175200
-0.0016484	-0.0175199	0.9998452

Model To Ground Plan Matrix :

0.0069016	-0.0000227	133905.671
0.0000227	0.0069016	595555.791

END OF FILE

Kern DSR-1 Operating System 718.1X0.0149:E

This file is called ABSOR.MEA

This file has been updated : 16-SEP-88
Time : 5:34:18
Operator : PDM

Project Name = GREECE

Ground Control File Name = DK:GROVO2.DAT

Model Identification :

Left photograph number = 148772
Right photograph number = 148773

Ground control coordinates and results :

Number of control points = 8

	Point Name	Ground Coordinates E	N	H	PW	PH
1	V16	135654.39	596049.02	0.00	1.0	0.0
2	V16H	0.00	0.00	71.00	0.0	1.0
3	V33	135014.36	595206.62	0.00	1.0	0.0
4	V34	135534.95	595240.38	0.00	1.0	0.0
5	V62	134981.40	596200.98	0.00	1.0	0.0
6	V33H	0.00	0.00	31.95	0.0	1.0
7	V34H	0.00	0.00	56.73	0.0	1.0
8	V62H	0.00	0.00	42.84	0.0	1.0

	Point Name	Residuals DE	DN	DH
1	V16	-0.05	-0.19	NOT MEA
2	V16H	NOT MEASURED		0.14
3	V33	0.13	-0.05	NOT MEA
4	V34	-0.01	0.04	NOT MEA
5	V62	-0.07	0.19	NOT MEA
6	V33H	NOT MEASURED		0.15
7	V34H	NOT MEASURED		-0.18
8	V62H	NOT MEASURED		-0.11

Standard Plan Deviation = 0.158   Standard Height Deviation = 0.297

	Point Name	Model Coordinates X um	Y um	Z um
1	V16	88864	68118	-147404
2	V16H	88647	68296	-147798
3	V33	-1780	-58742	-149794
4	V34	74739	-51492	-146821
5	V62	-10862	87479	-151134
6	V33H	-3889	-60210	-150922
7	V34H	75110	-52341	-147377
8	V62H	-10815	88605	-152335

Initial Values :

Rotations (gons)

	KAPPA	PHI	OMEGA
Left :	0.0000	0.0000	0.0000
Right :	-0.8923	0.3566	-0.9986
Common :	0.0000	0.0000	0.0000

Projection Centre Coordinates

	X	Y	Z
Left :	0.000	0.000	0.000
Right :	79938.000	1915.000	288.000

Shifts Model to Ground System

X0	Y0	Z0
0.000	0.000	0.000

Model to ground scale : 1 um = 1.0000000 ground units

Final Values :

Rotations (gons)

	KAPPA	PHI	OMEGA
Left :	-1.8514	0.0058	1.3072
Right :	-2.7437	0.3624	0.3086
Common :	-1.8514	0.0058	1.3072

Projection Centre Coordinates

	E	N	H
Left :	135037.395	595584.016	1064.658
Right :	135580.283	595581.187	1066.831

Shifts Model to Ground System

E0	N0	H0
135037.395	595584.016	1064.658

Model to ground scale : 1 um = 0.0067895 ground units

Left fiducial to ground matrix :

1.0000000	0.0000019	0.0000905
0.0000000	0.9997892	-0.0205325
-0.0000905	0.0205325	0.9997892

Right fiducial to ground matrix :

0.9998855	0.0140164	0.0056915
-0.0139896	0.9998909	-0.0048489
-0.0057589	0.0047680	0.9999717

Model To Ground Levelling Matrix :

1.0000000	0.0000019	0.0000905
0.0000000	0.9997892	-0.0205325
-0.0000905	0.0205325	0.9997892

Model To Ground Plan Matrix :

0.0067866	0.0001974	135037.395
-0.0001974	0.0067866	595584.016

END OF FILE

Having the average flight height equal to 1068m the accuracy is of the order of 0.043m. These accuracy requirements were not met in the current project. Considering though the mapping scale, which is 1:1000 a reasonable average accuracy of heights at control points should not be more than 0.30m ((ASPRS, 1980)[3] , (S. K. Ghosh,1988)[28]), a requirement which was met in both models. This map scale also allows planimetric errors of the order of 0.15-0.20m (0.15-0.20mm on the map scale) (D. G. Vlachos, 1979)[87] so then, the results were finally accepted.

APPENDIX F.

APPENDIX F.

F.1. LITES2 command states.

* INITIAL (for starting)
* READY (for operating level)
* LINE
* CIRCLE
* SYMBOL
* TEXT
* EDIT
* MODIFY
* ON
* CONSTRUCT
* RECOVER
* WINDOW
* MACRO
* AC

F.2. LITES2 commands

* INITIALISATION
* OPTIONS
* COMMAND HANDLING
* GENERAL
* IDENTIFICATION

* CONSTRUCTION
* CONSTRAINT
* POSITIONING
* EDITING
* JOINING
* TEXT AND SYMBOLS
* ATTRIBUTES
* ANCILLARY
* CODING
* INTEROGATION
* WINDOWING
* EXITING
* MISCELLANEOUS

APPENDIX G.

APPENDIX G.1.1

Translation Program for "Closed" Polygons data.

Problem Definition : Translate map data from KERN CAM format to the LASER-SCAN IFF format.

Needed Output : Map data in IFF format having : Feature Serial Number (NF), Feature code (FS), Ancillary Code information (AC), and only the X, Y coordinates.

Needed Input : "Closed" polygons data.

EXPLANATION OF ROUTINES.

Routine Give_Prompt.

Routine in which the CAM input file, the Output IFF as well as the name of Libraries where the correspoding codes **from** CAM **to** IFF format are located, have to be specified. The X and Y range of the file (map) have to be also specified in this routine.

Routine Coordinate _Range.

Routine which handles the RA entry records which are the maximum extent of the data in the IFF file. It is used by plot and display programs to work out whether to clip the file, and what scale it can be displayed at.

FORMAT RA X-min Xmax Ymin Ymax

Routine History.

A routine which inserts a blank history entry in files created from CAM files, in order the IFF history mechanism can work. This is an optional mechanism for automatically recording statistics each time they are updated, so that it may be determined which users and programs contributed to the final state of the file. The statistics are stored in the HI (History) entry within the IFF file.

FORMAT
HI
'date' 'time' 'username' 'program' 'fuction' 'elapsed' 'cpu' 'status'

Routine Map_Descriptor.

This routine inserts the default MD entry of Laser's Scan. This entry will contain data describing the origin, projection and coordinate system of the IFF file. Thus, a change to the map descriptor must be accompanied by the appropriate changes to all point data in the file.

Routine Section_Level_Entries.

This routine inserts the following entries which are specific to sections (sections are used to separate the data resulting from different digitizing sessions), and they occur in the following order :

NS - New Section identification.

CC - Cubic Coefficients for coordinate transformation.
It defines a tranformation between two coordinate systems to be used by a post-processing program to transform all points in the file into the same coordinate space.
-The default are inserted.

CP - Corner Points for coordinate transformation. It defines the control points for the section, in both original (current) and destination (target) space. IFF control points are always used in the order NW, SW, SE and NE.
-They are inserted as they have been determined earlier (routines Give_Prompt and Coordinade_Range).

Routine Read_Ancillary_Code.

Routine which reads (from the CAM file) the typed land related information (Message) of a feature.

Routine Change_To_Linetype.

Routine which handles the case of 'CHANGE TO LINETYPE' by reading the message related to a parcel-based L.I.S. ,(by using the previous routine) the feature code, the X, Y, Z, coordinates in CAM format, and **translates** them to a feature code, a text with a code (AC) previously specified and only the X, Y, coordinates of the current feature, in Laser's Scan IFF format.(see Example below).

C A M Format

```
 ..........................
 ..........................
AA 1019    0    "CENTROID OF PARCEL_33"       {Message}
CHANGE TO SCALE              1.000000
CHANGE TO SYMBOL  43         CENTROID (CROSS){F.Code in CAM}
CHANGE TO OBJECT
CHANGE TO HOUR               5.32
 135089.60  595812.73        42.18
AA 1017    0    "PARCEL_33"                   {Message}
CHANGE TO LINETYPE  25         PARCEL DEFINED {F.Code in CAM}
CHANGE TO STRAIGHT
CHANGE TO HOUR               5.35
CHANGE TO PEN UP
 135081.94  595817.06        42.51
CHANGE TO PEN DOWN
 135081.32  595809.02        44.50
 135083.40  595808.89        44.50
 135088.11  595808.69        45.97
 135096.17  595808.63        47.78
 135098.58  595808.08        47.78
 135098.73  595816.47        43.18
 135081.94  595817.06        42.51
AA ......................................{Message}
.......................................
```

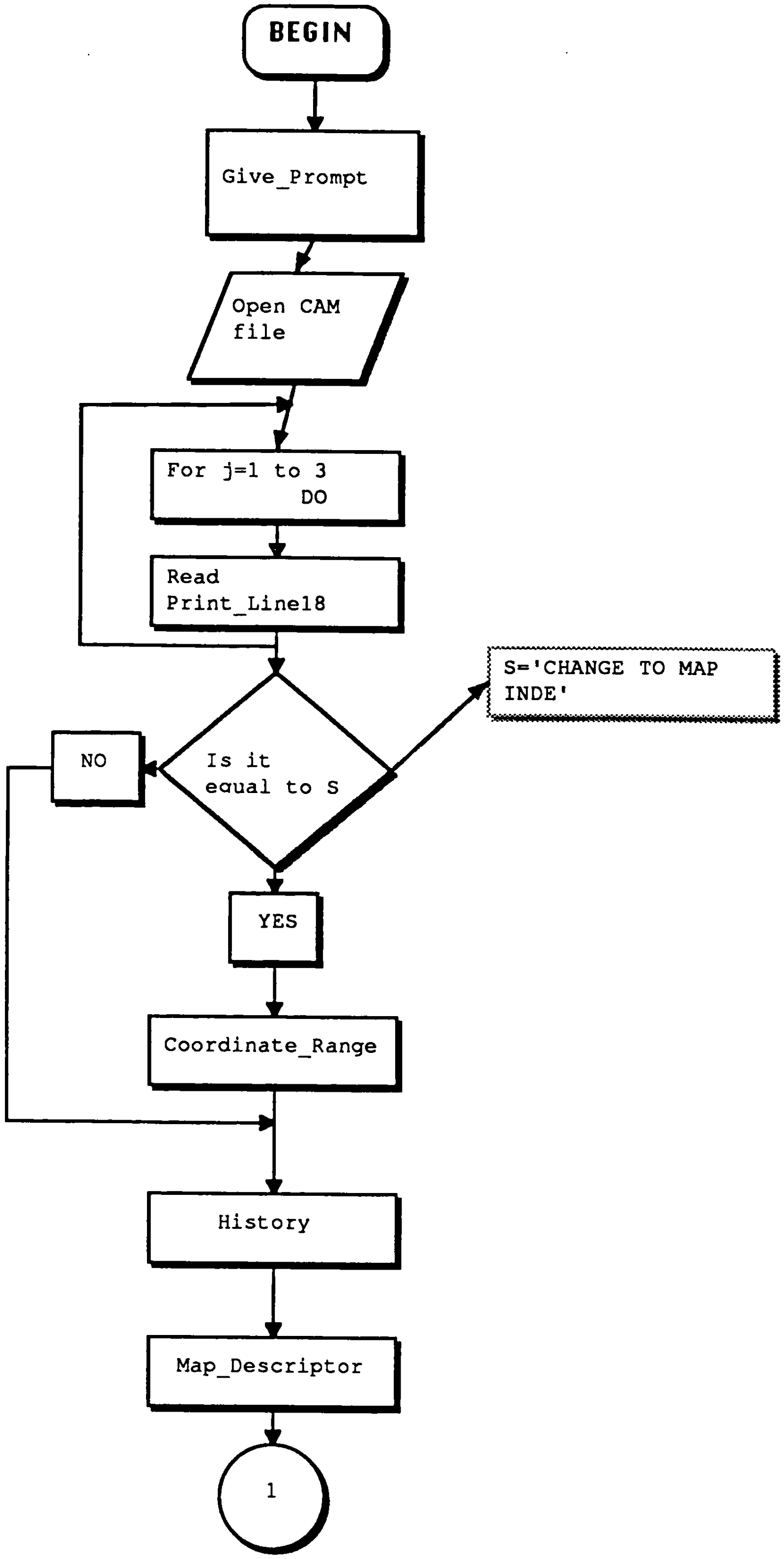
I F F Format

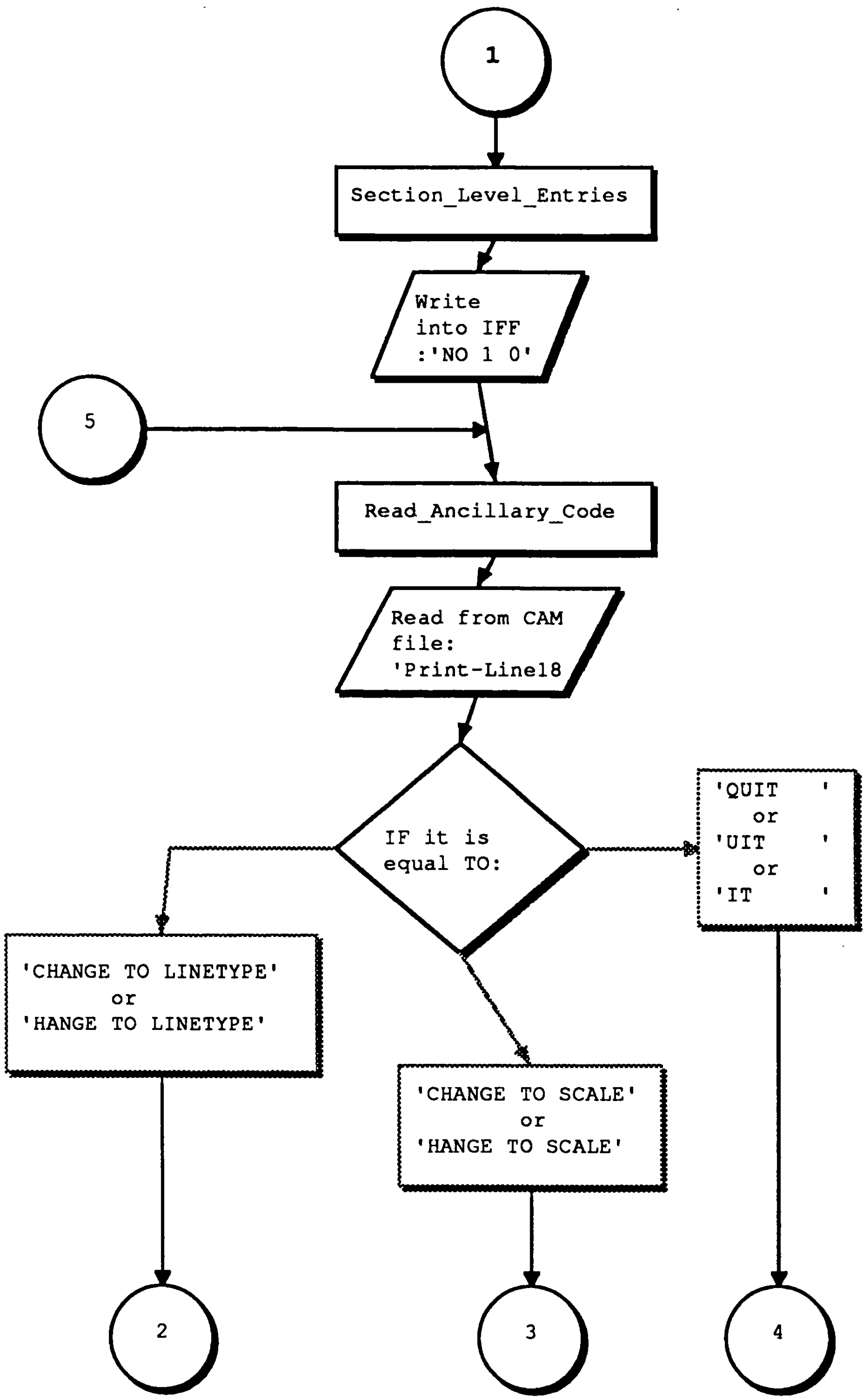
```
  ......................
EF
NF    100                     {New Feature serial number}
FS   321                               {Feature Code in IFF}
AC 1019  0  "CENTROID OF PARCEL_33"{Ancillary Information}
TH   0
ST    1  0                  {Number of STring of coord.}
```

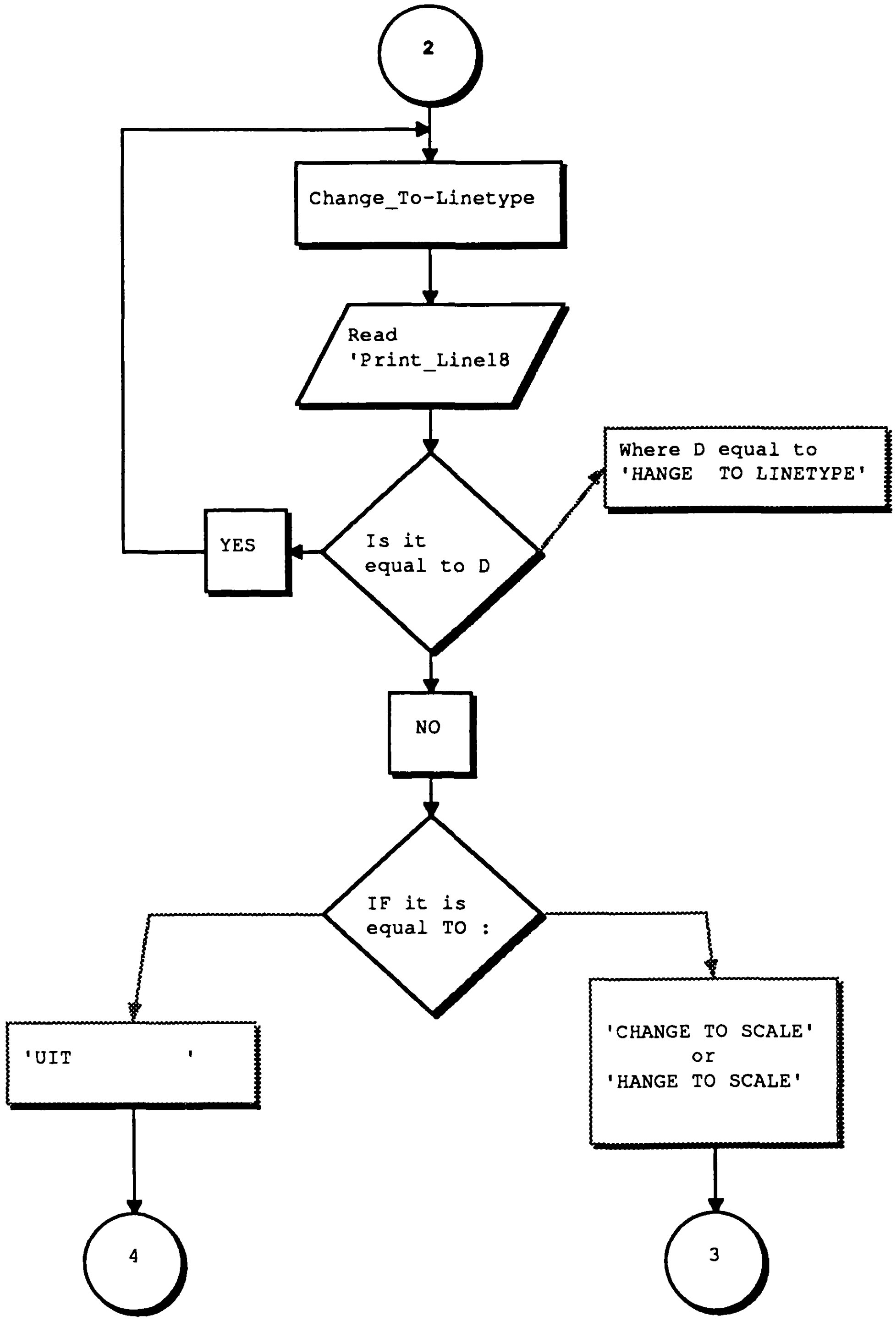
```
  135089.60  595812.73
EF                                        {End of Feature}
NF    101
FS   153
AC 1017    0   "PARCEL_33"
TH   0
ST    8  0
  135081.94  595817.06
  135081.32  595809.02
  135083.40  595808.89
  135088.11  595808.69
  135096.17  595808.63
  135098.58  595808.08
  135098.73  595816.47
  135081.94  595817.06
EF
NF    102
........................
```

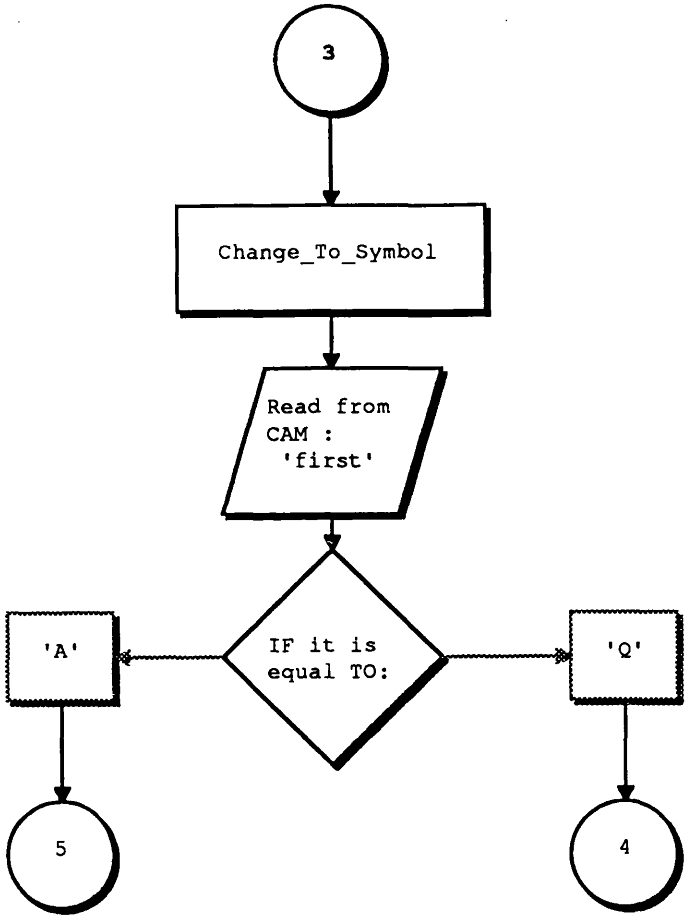
Routine Change_To_Symbol.

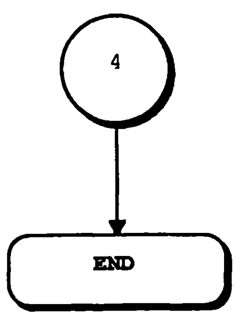
Routine which handles the case of 'CHANGE TO SYMBOL' by reading the message related to a parcel-based L.I.S. (by using the routine Read_Ancillary_Code), the feature code (it is the cross, representing the centroid of a parcel), the X, Y, Z, coordinates in CAM format, and **translates** them to a feature code, a text with a code (AC) previously specified and only the X, Y, coordinates of the current feature, in Laser's Scan IFF format.(see Example above).


BEGIN
Give_Prompt
Open CAM file
For j=1 to 3 DO
Read Print_Line18
S='CHANGE TO MAP INDE'
Is it equal to S
NO
YES
Coordinate_Range
History
Map_Descriptor
1


1
Section_Level_Entries
Write
into IFF
:'NO 1 0'
5
Read_Ancillary_Code
Read from CAM
file:
'Print-Line18
IF it is
equal TO:
'QUIT '
or
'UIT '
or
'IT '
'CHANGE TO LINETYPE'
or
'HANGE TO LINETYPE'
'CHANGE TO SCALE'
or
'HANGE TO SCALE'
2
3
4


2
Change_To-Linetype
Read
'Print_Line18
Where D equal to
'HANGE TO LINETYPE'
YES
Is it
equal to D
NO
IF it is
equal TO :
'UIT '
'CHANGE TO SCALE'
or
'HANGE TO SCALE'
4
3


3
Change_To_Symbol
Read from
CAM :
'first'
IF it is
equal TO:
'A'
'Q'
5
4


4
END

APPENDIX G.1.2

Translation Program for "Spaghetti" data.

Problem Definition : Translate map data from KERN CAM format to the LASER-SCAN IFF format.

Needed Output : Map data in IFF format having : Feature Serial Number (NF), Feature code (FS), and only the X, Y coordinates.

Needed Input : "Spaghetti" data.

EXPLANATION OF ROUTINES.

Routine Give_Prompt.

Routine in which the CAM input file, the Output IFF as well as the name of Libraries where the correspoding codes **from** CAM **to** IFF format are located, have to be specified. The X and Y range of the file (map) have to be also specified in this routine.

Routine Coordinate _Range.

Routine which handles the RA entry records which are the maximum extent of the data in the IFF file. It is used by plot and display programs to work out whether to clip the file, and what scale it can be displayed at.

<u>FORMAT</u> RA X-min Xmax Ymin Ymax

Routine History.

A routine which inserts a blank history entry in files created from CAM files, in order the IFF history mechanism can work. This is an optional mechanism for automatically recording statistics each time they are updated, so that it may be determined which users and programs contributed to the final state of the file. The statistics are stored in the HI (History) entry within the IFF file.

<u>FORMAT</u>

HI

'date' 'time' 'username' 'program' 'fuction' 'elapsed' 'cpu' 'status'

Routine Map_Descriptor.

This routine inserts the default MD entry of Laser's Scan. This entry will contain data describing the origin, projection and coordinate system of the IFF file. Thus, a change to the map descriptor must be accompanied by the appropriate changes to all point data in the file.

Routine Section_Level_Entries.

This routine inserts the following entries which are specific to sections (sections are used to separate the data resulting from different digitizing sessions), and they occur in the following order :

NS - New Section identification.

CC - Cubic Coefficients for coordinate transformation.

It defines a tranformation between two coordinate systems to be used by a post-processing program to transform all points in the file into the same coordinate space.

-The default are inserted.

CP - Corner Points for coordinate transformation.

It defines the control points for the section, in both original (current) and destination (target) space. IFF control points are always used in the order NW, SW, SE and NE.

-They are inserted as they have been determined earlier (routines Give_Prompt and Coordinade_Range).

Routine Change_To_Linetype.

Routine which handles the case of `'CHANGE TO LINETYPE'` by reading the feature code, the X, Y, Z, coordinates in CAM format, and **translates** them to a feature code, and only the X, Y, coordinates of the current feature, in Laser's Scan IFF format.(see Example below).

C A M Format

```
 ..........................
 ..........................
CHANGE TO SCALE            1.000000
CHANGE TO SYMBOL  43       CENTROID (CROSS){F.Code in CAM}
CHANGE TO OBJECT
CHANGE TO HOUR             1.10
 135006.62  596129.04      43.92
CHANGE TO LINETYPE  36     WALL AS BOUNDARY{F.Code in CAM}
CHANGE TO STRAIGHT
CHANGE TO HOUR             1.12
CHANGE TO PEN UP
 135002.81  596139.04      44.63
CHANGE TO PEN DOWN
 134995.62  596131.08      43.00
CHANGE TO LINETYPE  37     BUILD-WALL:BOUND{F.Code in CAM}
CHANGE TO STRAIGHT
CHANGE TO HOUR             1.12
CHANGE TO PEN UP
 134995.62  596131.08      43.00
CHANGE TO PEN DOWN
 135005.43  596120.55      42.81
CHANGE TO LINETYPE  36               .......{F.Code in CAM}
..................
```

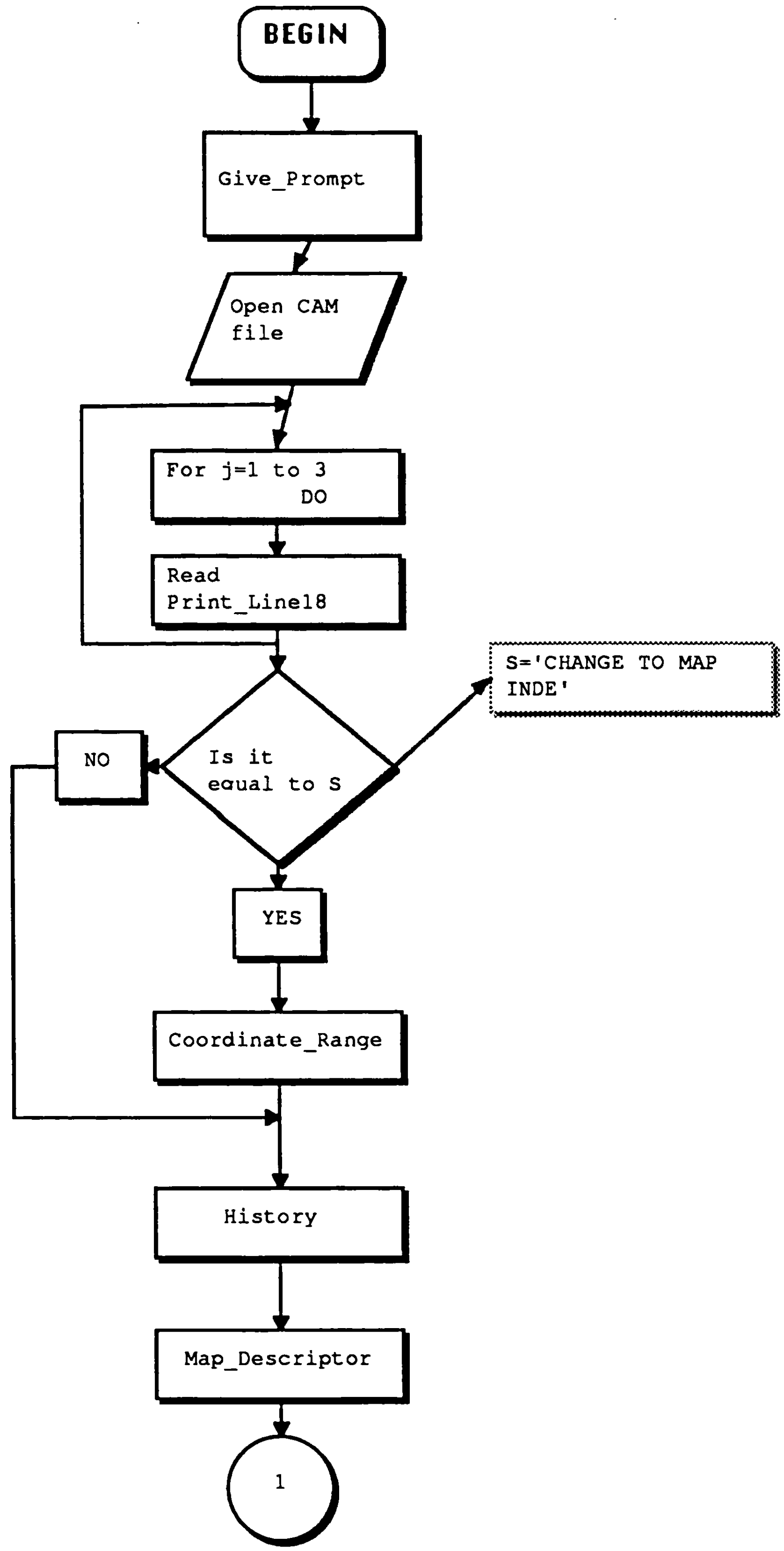
I F F Format

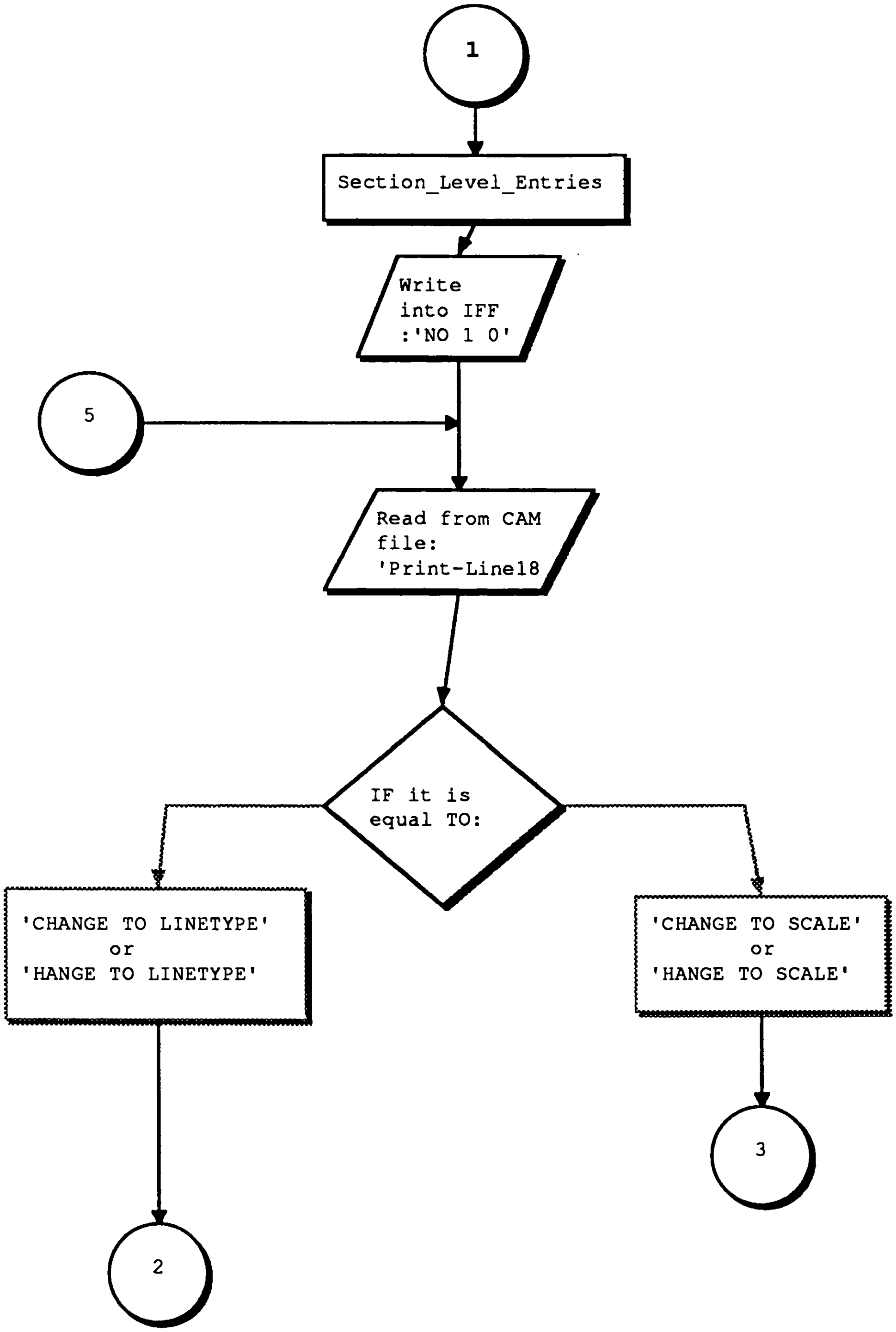
```
  ......................
EF
NF     53                        {New Feature serial number}
FS   321                         {Feature Code in IFF}
TH   0
ST    1  0                  {Number of STring of coord.}
  135006.62  596129.04
EF                               {End of Feature}
NF     54
FS   401
TH   0
ST    2  0
  135002.81  596139.04
  134995.62  596131.08
EF
NF     55
FS   402
TH   0
ST    2  0
  134995.62  596131.08
```

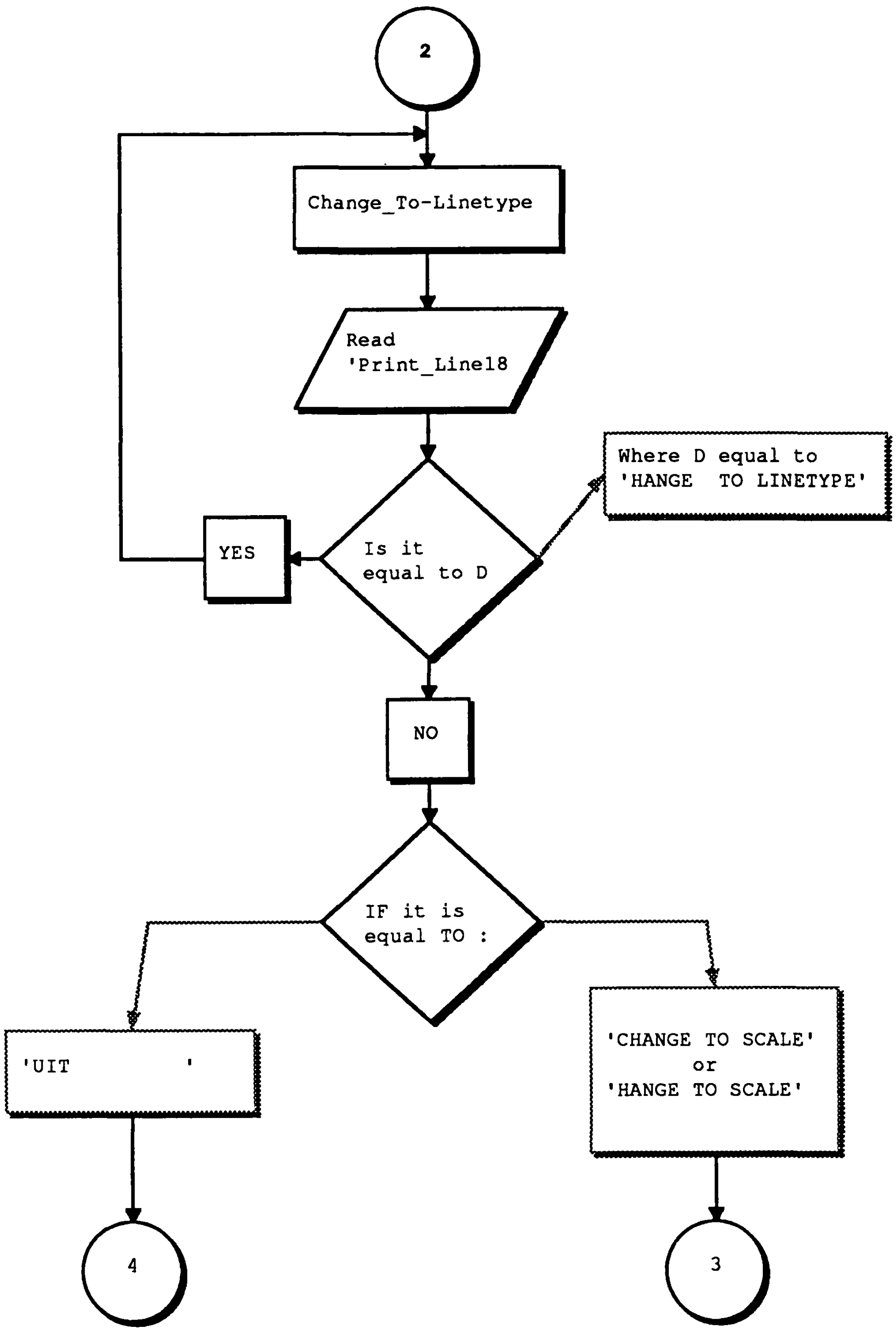
```
  135005.43  596120.55
EF
NF     56
FS   401
........................
```

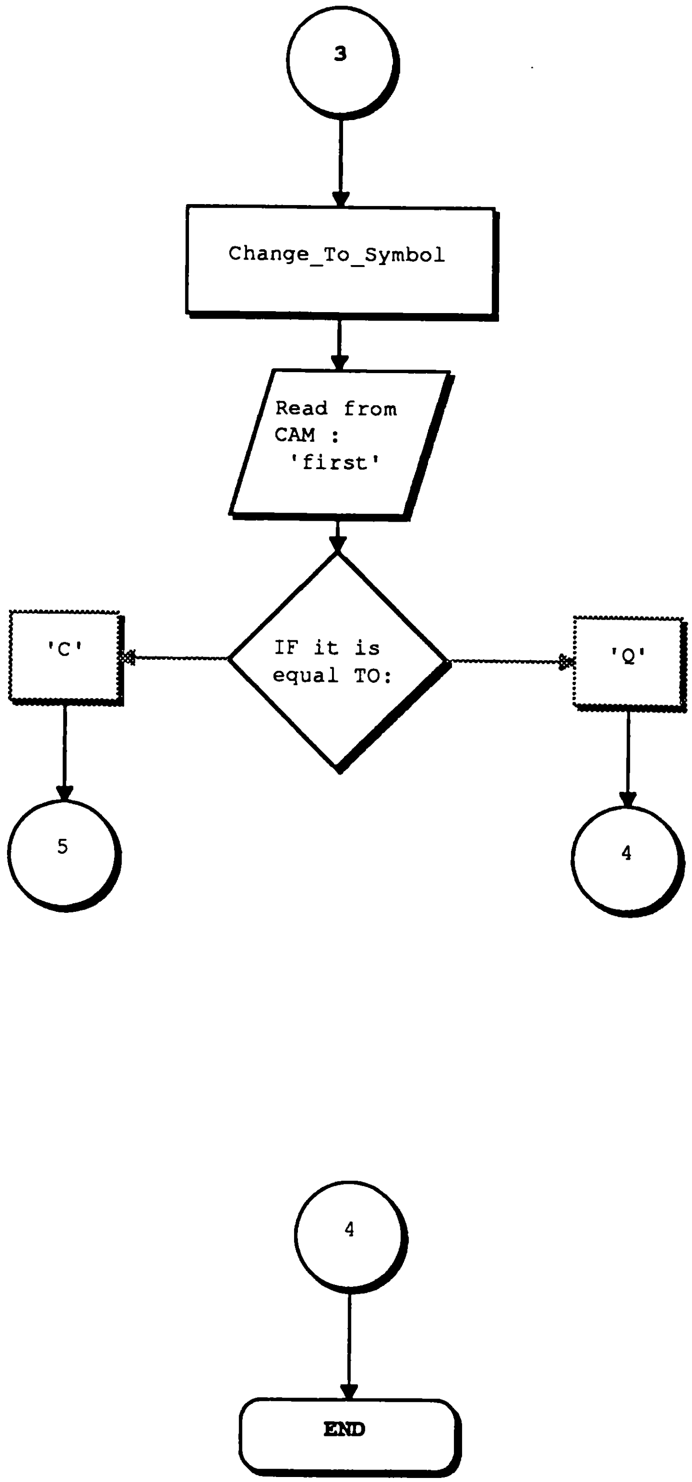
Routine Change_To_Symbol.

Routine which handles the case of 'CHANGE TO SYMBOL' by reading the feature code (it is the cross, representing the centroid of a parcel), the X, Y, Z, coordinates in CAM format, and **translates** them to a feature code, and only the X, Y, coordinates of the current feature, in Laser's Scan IFF format.(see Example above).


BEGIN
Give_Prompt
Open CAM file
For j=1 to 3 DO
Read Print_Line18
S='CHANGE TO MAP INDE'
Is it eaual to S
NO
YES
Coordinate_Range
History
Map_Descriptor
1


1
Section_Level_Entries
Write
into IFF
:'NO 1 0'
5
Read from CAM
file:
'Print-Line18
IF it is
equal TO:
'CHANGE TO LINETYPE'
or
'HANGE TO LINETYPE'
'CHANGE TO SCALE'
or
'HANGE TO SCALE'
2
3


2
Change_To-Linetype
Read
'Print_Line18
Where D equal to
'HANGE TO LINETYPE'
YES
Is it
equal to D
NO
IF it is
equal TO :
'UIT '
'CHANGE TO SCALE'
or
'HANGE TO SCALE'
4
3


3
Change_To_Symbol
Read from
CAM :
'first'
IF it is
equal TO:
'C'
'Q'
5
4
4
END

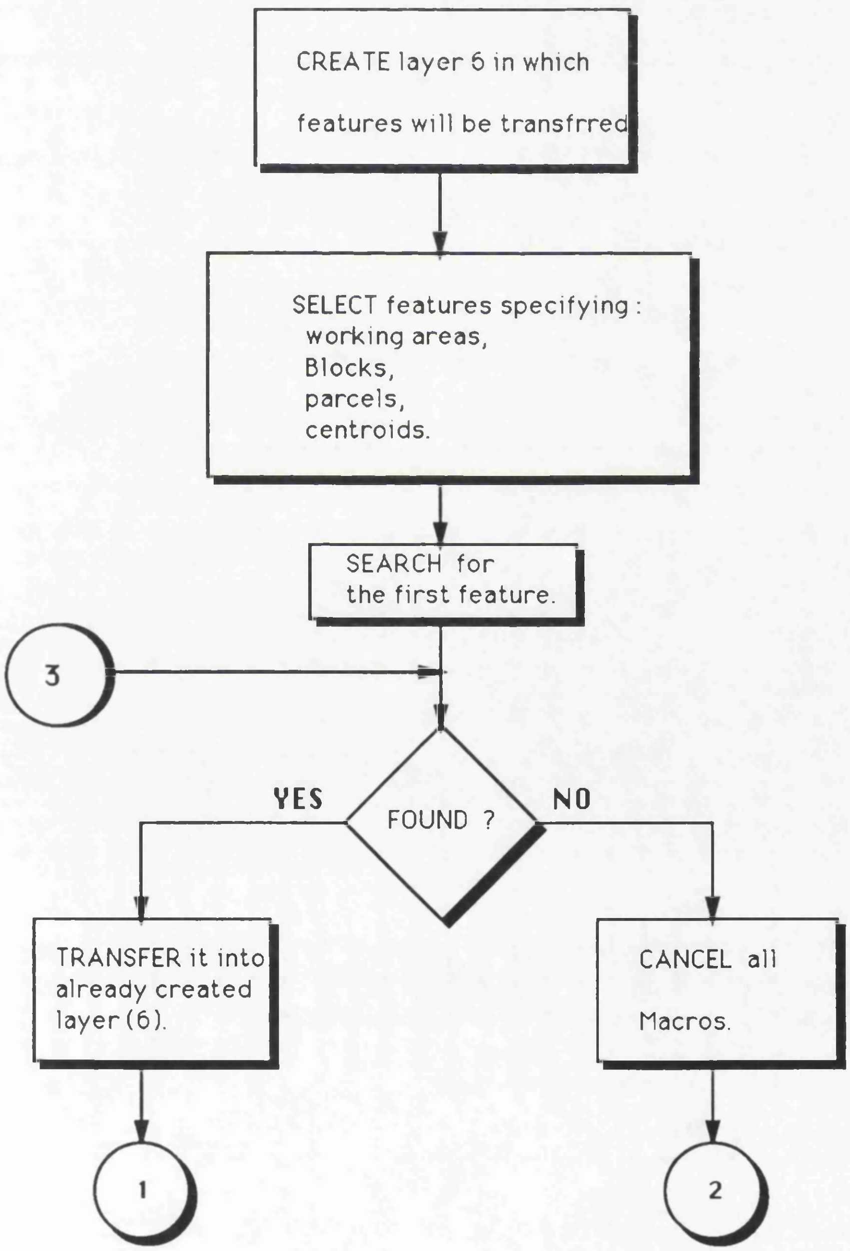
APPENDIX G.2.

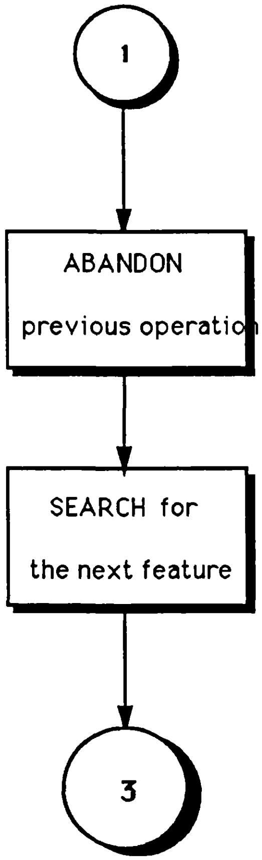
G.2.1.

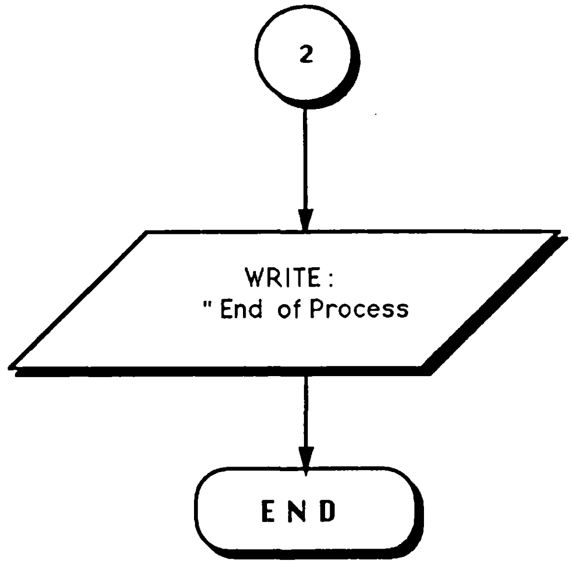
Problem Definition : Transfer features which specify : working areas, Blocks, parcels and centoids into another layer.

Needed Output : Working areas, Blocks, parcelsand centroids will be located in a different layer from rest of data.

Needed Input : Project area ("**CLOSED" POLYGONS**).




1
ABANDON
previous operation
SEARCH for
the next feature
3


2
WRITE :
" End of Process
E N D

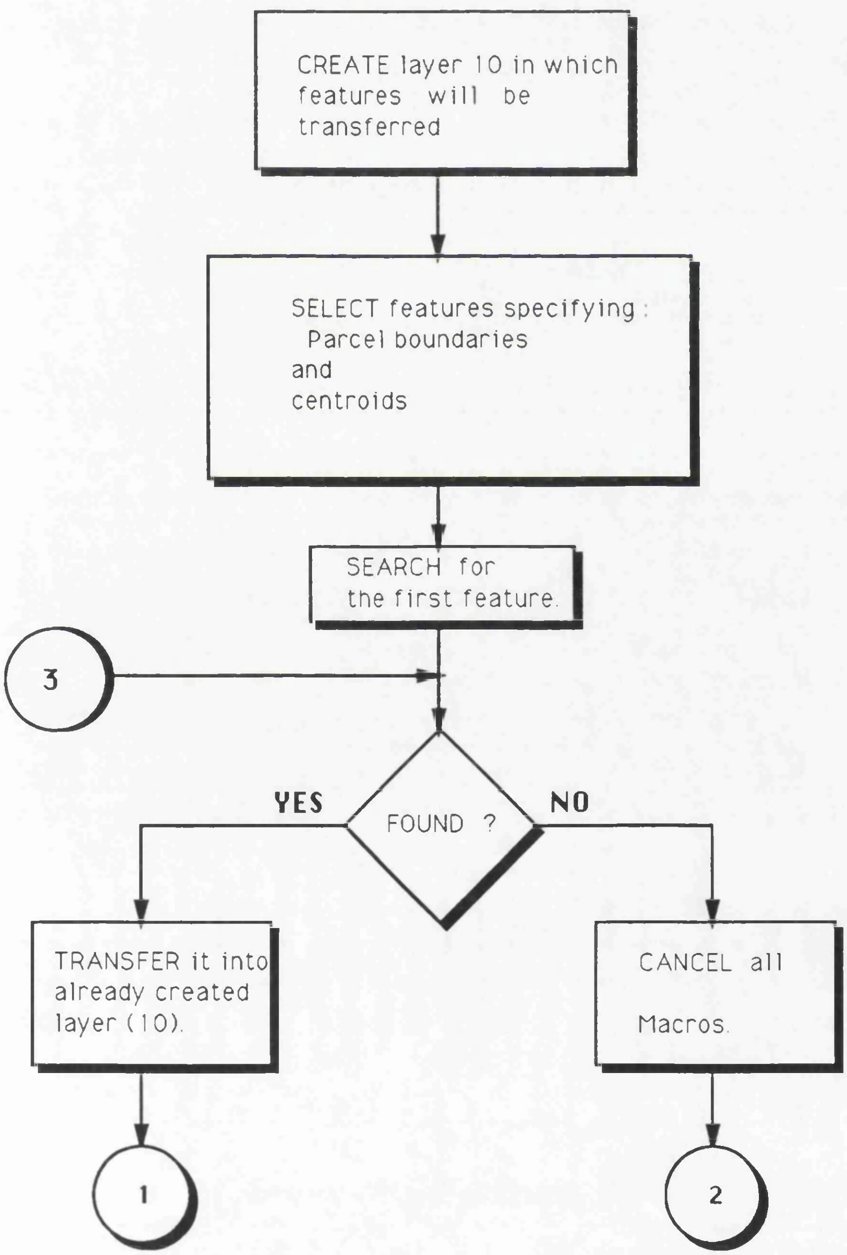
APPENDIX G.2

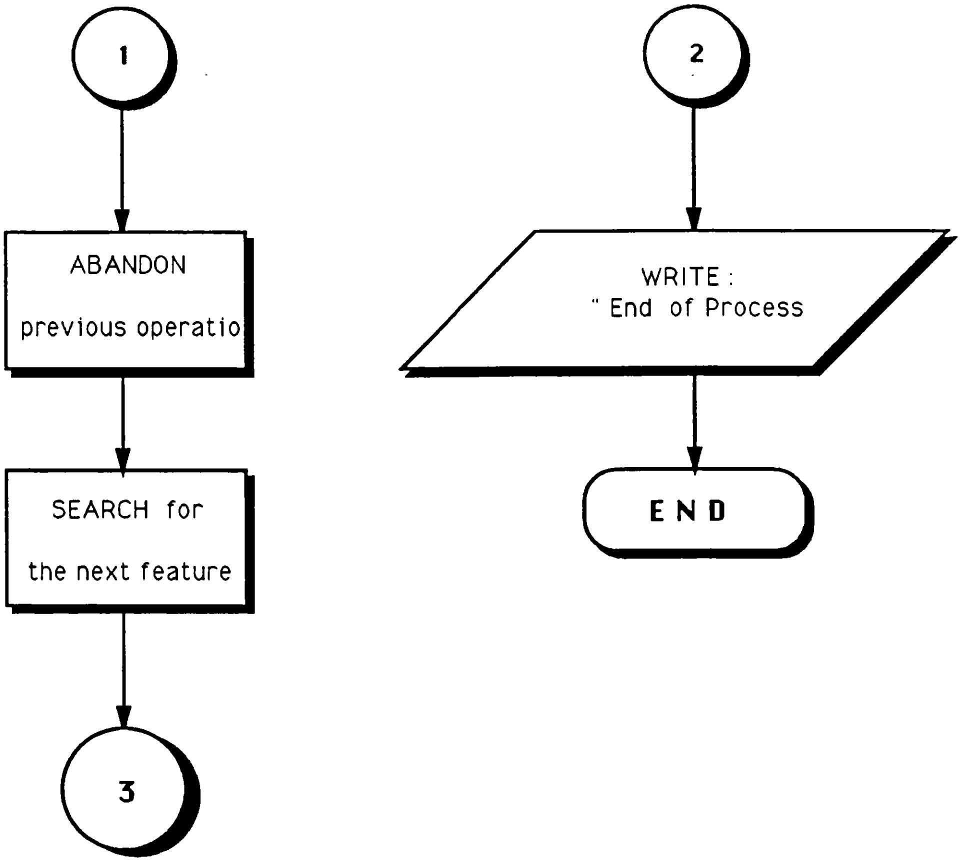
G.2.2.

Problem Definition : Transfer features which specify : parcel boundaries and centoids into another layer.

Needed Output : Parcel boundaries and centroids will be located in a different layer from rest of data.

Needed Input : Project area (**"SPAGHETTI" DATA**).




1
ABANDON
previous operatio
SEARCH for
the next feature
3
2
WRITE :
" End of Process
END

APPENDIX H.

APPENDIX H.1

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ***************************************************************************

 Input from                        : LSL$DATA_ROOT:[LSL.IFF]SPAVOURBAN.IFF;1
 Output to                         : LSL$DATA_ROOT:[LSL.IFF]PU1.IFF;1
 Process                           : MERGE - Feature merging.
 Layers to be processed            : 10
 Parent-feature entries?           : No.
 LITES2 command file               : LSL$LITES2CMD:ILINKMER.LCM
 FRT file                          : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0
 General shared-feature code       : 500

 ILINK LOG
 ***************************************************************************

 Aligning
        Inserting additional points for 1-1 alignment
        Finding alignment
        Checking alignment
        Moving lines identically together
        Breaking features at every node
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     0.001
        Creating node arms
 Sorting node arms and merging duplicate features
 Removing invalid 2-nodes
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ***************************************************************************

 Input features transfered      : (Point 0),  (Other 0)
 Input features processed       : (Point 113),  (Open 367),  (Closed 0)
 Processed features output      : (Point 113),  (Open 367),  (Closed 0)

 Total features in IFF input  : 480
 Total features in IFF output : 480

 Nodes found joined to 0 arms  (single point features): 113
                       1 arm   (unattached link ends) : 497
                       2 arms  (link joined to link)  : 117
                       3 arms  (link joined to links) : 1
                       4 arms  (link joined to links) : 0
                      5+ arms  (link joined to links) : 0

                                     Total        : 728
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ************************************************************************

 Input from                       : LSL$DATA_ROOT:[LSL.IFF]PU1.IFF;1
 Output to                        : LSL$DATA_ROOT:[LSL.IFF]PU2.IFF;1
 Process                          : LPJOIN - Ends with lines junction formation.
                                  : with vertex priority.
 Join tolerance                   :     1.200
 Max vector extension             :     1.200
 Min verification tolerance       :     0.001
 Layers to be processed           : 10
 LITES2 command file              : LSL$LITES2CMD:ILINKLPJ.LCM
 FRT file                         : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ************************************************************************

 Joining ends to lines
         Finding new line-end positions
         Undoing joins too close to feature ends
         Checking for negligably short loops
         Removing surplus inserted points
         Moving ends within join tolerance onto lines
         Breaking features at every node
 Creating link/node structure
         Setting up a node for each feature end
         Merging nodes separated by less than      0.001
         Creating node arms
 Sorting node arms
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ************************************************************************

 Input features transfered      : (Point 0),  (Other 0)
 Input features processed       : (Point 113),  (Open 367),  (Closed 0)
 Processed features output      : (Point 113),  (Open 367),  (Closed 0)

 Total features in IFF input  : 480
 Total features in IFF output : 480

 Nodes found joined to 0 arms  (single point features): 113
                       1 arm   (unattached link ends) : 366
                       2 arms  (link joined to link)  : 117
                       3 arms  (link joined to links) : 130
                       4 arms  (link joined to links) : 1
                      5+ arms  (link joined to links) : 0

                                        Total         : 727
 ------------------------------------------------------------------------
 Join separations over the range   0.001  to   1.200

 Range     Count | Proportion
 ----------------|-------------------------------------------------------
```

```
 0.001+      45 | ***********************
 0.121+      50 | *************************
 0.241+      15 | ********
 0.361+       6 | ***
 0.481+       2 | *
 0.601+       1 |
 0.720+       7 | ***
 0.840+       2 | *
 0.960+       0 |
 1.080+       2 | *
---------------|------------------------------------------------------------
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ************************************************************************

 Input from                     : LSL$DATA_ROOT:[LSL.IFF]PU2.IFF;1
 Output to                      : LSL$DATA_ROOT:[LSL.IFF]PU3.IFF;1
 Process                        : PPJOIN - Ends with ends junction formation.
                                : ends projected.
 Join tolerance                 :     1.200
 Max vector extension           :     1.200
 Min verification tolerance     :     0.001
 Layers to be processed         : 10
 LITES2 command file            : LSL$LITES2CMD:ILINKPPJ.LCM
 FRT file                       : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ************************************************************************

 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     1.200
        Creating node arms
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   30
344,  416.813)
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   34
453,  350.313)
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   35
219,  362.250)
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   32
078,  436.813)
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   3
384,  337.563)
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   33
656,  331.500)
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   30
016,  340.875)
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   3
844,  350.125)
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   26
054,  364.750)
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   29
797,  330.688)
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   31
224,  475.125)
%ILINK-W-DELETE, end nodes lie within /JNTOL tolerance - link deleted at (   23
701,  367.563)
 Joining ends to ends
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ************************************************************************

 Input features transfered      : (Point 0),  (Other 0)
 Input features processed       : (Point 113),  (Open 367),  (Closed 0)
 Processed features output      : (Point 113),  (Open 354),  (Closed 1)

 Total features in IFF input  : 480
 Total features in IFF output : 468
```

```
Nodes found joined to 0 arms  (single point features): 113
                      1 arm   (unattached link ends)  : 132
                      2 arms  (link joined to link)   : 179
                      3 arms  (link joined to links)  : 72
                      4 arms  (link joined to links)  : 1
                     5+ arms  (link joined to links)  : 0

                                         Total        : 437
---------------------------------------------------------------------------
Join separations over the range   0.001  to   1.200

Range     Count | Proportion
----------------|----------------------------------------------------------
 0.001-     255 | **************************************
 0.121-      67 | **********
 0.241+      40 | ******
 0.361+      15 | **
 0.481+       9 | *
 0.601+      11 | **
 0.720+       5 | *
 0.840+      11 | **
 0.960-      10 | *
 1.080+       2 |
----------------|----------------------------------------------------------
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ************************************************************************************************

 Input from                    : LSL$DATA_ROOT:[LSL.IFF]PU3.IFF;1
 Output to                     : LSL$DATA_ROOT:[LSL.IFF]PU4.IFF;1
 Process                       : BREAK - Breaking features at junctions.
 Layers to be processed        : 10
 Parent-feature entries?       : No.
 FRT file                      : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ************************************************************************************************

 Breaking features
        Inserting intersection points
        Breaking features at intersection points
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     0.001
        Creating node arms
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ************************************************************************************************

 Input features transferred     : (Point 0),  (Other 0)
 Input features processed       : (Point 113),  (Open 354),  (Closed 1)
 Processed features output      : (Point 113),  (Open 485),  (Closed 1)

 Total features in IFF input  : 468
 Total features in IFF output : 599

 Nodes found joined to 0 arms  (single point features): 113
                       1 arm   (unattached link ends) : 16
                       2 arms  (link joined to link)  : 178
                       3 arms  (link joined to links) : 188
                       4 arms  (link joined to links) : 9
                      5+ arms  (link joined to links) : 0

                                            Total     : 504
```

APPENDIX H.2

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ************************************************************************

 Input from                     : LSL$DATA_ROOT:[LSL.IFF]SPAVOEDGE.IFF;1
 Output to                      : LSL$DATA_ROOT:[LSL.IFF]ED1.IFF;1
 Process                        : BREAK - Breaking features at junctions.
 Layers to be processed         : 10
 Parent-feature entries?        : No.
 FRT file                       : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ************************************************************************

 Breaking features
        Inserting intersection points
        Breaking features at intersection points
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than    0.002
        Creating node arms
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ************************************************************************

 Input features transferred     : (Point 0),  (Other 0)
 Input features processed       : (Point 270),  (Open 864),  (Closed 4)
 Processed features output      : (Point 270),  (Open 1190),  (Closed 0)

 Total features in IFF input  : 1138
 Total features in IFF output : 1460

 Nodes found joined to 0 arms  (single point features): 269
                       1 arm   (unattached link ends) : 645
                       2 arms  (link joined to link)  : 535
                       3 arms  (link joined to links) : 15
                       4 arms  (link joined to links) : 155
                      5+ arms  (link joined to links) : 0

                                         Total        : 1619
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ******************************************************************************

 Input from                     : LSL$DATA_ROOT:[LSL.IFF]ED1.IFF;1
 Output to                      : LSL$DATA_ROOT:[LSL.IFF]ED2.IFF;1
 Process                        : LPJOIN - Ends with lines junction formation.
                                : with vertex priority.
 Join tolerance                 :     1.200
 Max vector extension           :     1.200
 Min verification tolerance     :     0.002
 Layers to be processed         : 10
 LITES2 command file            : LSL$LITES2CMD:ILINKLPJ.LCM
 FRT file                       : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ******************************************************************************

 Joining ends to lines
        Finding new line-end positions
        Undoing joins too close to feature ends
        Checking for negligably short loops
        Removing surplus inserted points
        Moving ends within join tolerance onto lines
        Breaking features at every node
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes seperated by less than     0.002
        Creating node arms
 Sorting node arms
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ******************************************************************************

 Input features transfered     : (Point 0),  (Other 0)
 Input features processed      : (Point 270),  (Open 1190),  (Closed 0)
 Processed features output     : (Point 270),  (Open 1190),  (Closed 0)

 Total features in IFF input  : 1460
 Total features in IFF output : 1460

 Nodes found joined to 0 arms  (single point features): 269
                       1 arm   (unattached link ends) : 488
                       2 arms  (link joined to link)  : 535
                       3 arms  (link joined to links) : 172
                       4 arms  (link joined to links) : 155
                      5+ arms  (link joined to links) : 0

                                     Total       : 1619
 ------------------------------------------------------------------------------
 Join separations over the range   0.002  to   1.200

 Range    Count | Proportion
 ---------------|--------------------------------------------------------------
```

```
 0.002+     47 | *******************
 0.122+     58 | ***********************
 0.242+     18 | *******
 0.362+     15 | ******
 0.481+      7 | ***
 0.601+      5 | **
 0.721+      1 |
 0.841+      4 | **
 0.960+      1 |
 1.080+      1 |
---------------|----------------------------------------------------------
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ********************************************************************************

 Input from                       : LSL$DATA_ROOT:[LSL.IFF]ED2.IFF;1
 Output to                        : LSL$DATA_ROOT:[LSL.IFF]ED3.IFF;1
 Process                          : MERGE - Feature merging.
 Layers to be processed           : 10
 Parent-feature entries?          : No.
 LITES2 command file              : LSL$LITES2CMD:ILINKMER.LCM
 FRT file                         : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0
 General shared-feature code      : 500

 ILINK LOG
 ********************************************************************************

 Aligning
        Inserting additional points for 1-1 alignment
        Forcing alignment
        Checking alignment
        Moving lines identically together
        Breaking features at every node
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     0.002
        Creating node arms
 Sorting node arms and merging duplicate features
 Removing invalid 2-nodes
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ********************************************************************************

 Input features transfered     : (Point 0),  (Other 0)
 Input features processed      : (Point 270),  (Open 1190),  (Closed 0)
 Processed features output     : (Point 270),  (Open 1191),  (Closed 0)

 Total features in IFF input  : 1460
 Total features in IFF output : 1461

 Nodes found joined to 0 arms  (single point features): 269
                       1 arm   (unattached link ends) : 640
                       2 arms  (link joined to link)  : 540
                       3 arms  (link joined to links) : 18
                       4 arms  (link joined to links) : 152
                      5+ arms  (link joined to links) : 0

                                        Total      : 1619
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ******************************************************************************

 Input from                    : LSL$DATA_ROOT:[LSL.IFF]ED3.IFF;1
 Output to                     : LSL$DATA_ROOT:[LSL.IFF]ED4.IFF;1
 Process                       : PPJOIN - Ends with ends junction formation.
                               : ends projected.
 Join tolerance                :     1.200
 Max vector extension          :     1.200
 Min verification tolerance    :     0.002
 Layers to be processed        : 10
 LITES2 command file           : LSL$LITES2CMD:ILINKPPJ.LCM
 FRT file                      : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0


 ILINK STATISTICS
 ******************************************************************************

 Input features transfered     : (Point 0),  (Other 0)
 Input features processed      : (Point 270),  (Open 1191),  (Closed 0)
 Processed features output     : (Point 270),  (Open 957),  (Closed 0)

 Total features in IFF input   : 1461
 Total features in IFF output  : 1227

 Nodes found joined to 0 arms  (single point features): 269
                       1 arm   (unattached link ends) : 162
                       2 arms  (link joined to link)  : 386
                       3 arms  (link joined to links) : 292
                       4 arms  (link joined to links) : 26
                      5+ arms  (link joined to links) : 0

                                        Total         : 1135
 ------------------------------------------------------------------------------
 Join separations over the range   0.002  to   1.200

 Range     Count | Proportion
 ----------------|-------------------------------------------------------------
  0.002+     553 | **********************************************
  0.122+     131 | **********
  0.242+      52 | ****
  0.362+      15 | *
  0.481+      21 | **
  0.601+       7 | *
  0.721+       4 |
  0.841+       5 |
  0.960+       3 |
  1.080+       0 |
 ----------------|-------------------------------------------------------------
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ************************************************************************

 Input from                      : LSL$DATA_ROOT:[LSL.IFF]ED4.IFF;1
 Output to                       : LSL$DATA_ROOT:[LSL.IFF]ED5.IFF;1
 Process                         : BREAK - Breaking features at junctions.
 Layers to be processed          : 10
 Parent-feature entries?         : No.
 FRT file                        : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ************************************************************************

 Breaking features
        Inserting intersection points
        Breaking features at intersection points
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than    0.002
        Creating node arms
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ************************************************************************

 Input features transfered     : (Point 0),  (Other 0)
 Input features processed      : (Point 270),  (Open 957),  (Closed 0)
 Processed features output     : (Point 270),  (Open 1117),  (Closed 0)

 Total features in IFF input  : 1227
 Total features in IFF output : 1387

 Nodes found joined to 0 arms  (single point features): 269
                       1 arm   (unattached link ends) : 14
                       2 arms  (link joined to link)  : 386
                       3 arms  (link joined to links) : 440
                       4 arms  (link joined to links) : 32
                      5+ arms  (link joined to links) : 0

                                       Total          : 1141
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ************************************************************************

 Input from                   : LSL$DATA_ROOT:[LSL.IFF]ED41.IFF;1
 Output to                    : LSL$DATA_ROOT:[LSL.IFF]ED42.IFF;1
 Process                      : BREAK - Breaking features at junctions.
 Layers to be processed       : 10
 Parent-feature entries?      : No.
 FRT file                     : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ************************************************************************

 Breaking features
        Inserting intersection points
        Breaking features at intersection points
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     0.002
        Creating node arms
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ************************************************************************

 Input features transfered    : (Point 1),  (Other 4)
 Input features processed     : (Point 270),  (Open 955),  (Closed 0)
 Processed features output    : (Point 270),  (Open 1115),  (Closed 0)

 Total features in IFF input  : 1230
 Total features in IFF output : 1390

 Nodes found joined to 0 arms  (single point features): 269
                       1 arm   (unattached link ends) : 15
                       2 arms  (link joined to link)  : 387
                       3 arms  (link joined to links) : 439
                       4 arms  (link joined to links) : 31
                      5+ arms  (link joined to links) : 0

                                          Total       : 1141
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ****************************************************************************

 Input from                     : LSL$DATA_ROOT:[LSL.IFF]NNED42.IFF;1
 Output to                      : LSL$DATA_ROOT:[LSL.IFF]ED43.IFF;1
 Process                        : BREAK - Breaking features at junctions.
 Layers to be processed         : 10
 Parent-feature entries?        : No.
 FRT file                       : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ****************************************************************************

 Breaking features
        Inserting intersection points
        Breaking features at intersection points
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than      0.002
        Creating node arms
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ****************************************************************************

 Input features transfered      : (Point 1),  (Other 4)
 Input features processed       : (Point 270),   (Open 1109),   (Closed 0)
 Processed features output      : (Point 270),   (Open 1114),   (Closed 0)

 Total features in IFF input   : 1384
 Total features in IFF output  : 1389

 Nodes found joined to 0 arms  (single point features): 269
                       1 arm   (unattached link ends) : 14
                       2 arms  (link joined to link)  : 390
                       3 arms  (link joined to links) : 446
                       4 arms  (link joined to links) : 24
                      5+ arms  (link joined to links) : 0

                                          Total      : 1143
```

APPENDIX H.3

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 *******************************************************************************

 Input from                   : LSL$DATA_ROOT:[LSL.IFF]T01.IFF;1
 Output to                    : LSL$DATA_ROOT:[LSL.IFF]T02.IFF;1
 Process                      : LPJOIN - Ends with lines junction formation.
                              : with no vertex priority.
 Join tolerance               :    2.000
 Max vector extension         :    2.000
 Min verification tolerance   :    0.001
 Layers to be processed       : 6
 LITES2 command file          : LSL$LITES2CMD:ILINKLPJ.LCM
 FRT file                     : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0
 FCP file                     : FCP_UNDEF_PARCELS.DAT;0
 Feature code pairs specified
             10  with  10
            342  with  10, 342
            344  with  10, 342:344

 ILINK LOG
 *******************************************************************************

 Joining ends to lines
        Finding new line-end positions
        Undoing joins too close to feature ends
        Checking for negligably short loops
        Removing surplus inserted points
        Moving ends within join tolerance onto lines
        Breaking features at every node
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than    0.001
        Creating node arms
 Sorting node arms
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 *******************************************************************************

 Input features transfered    : (Point 113),  (Other 305)
 Input features processed     : (Point 0),  (Open 0),  (Closed 35)
 Processed features output    : (Point 0),  (Open 0),  (Closed 35)

 Total features in IFF input  : 453
 Total features in IFF output : 453

 Nodes found joined to 0 arms  (single point features): 0
                       1 arm   (unattached link ends) : 0
                       2 arms  (link joined to link)  : 24
                       3 arms  (link joined to links) : 0
                       4 arms  (link joined to links) : 4
                      5+ arms  (link joined to links) : 1

                                         Total      : 29
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ******************************************************************************

 Input from                    : LSL$DATA_ROOT:[LSL.IFF]MAV02.IFF;3
 Output to                     : LSL$DATA_ROOT:[LSL.IFF]T01.IFF;1
 Process                       : LLJOIN - Feature alignment.
 Join tolerance                :     2.000
 Layers to be processed        : 6
 LITES2 command file           : LSL$LITES2CMD:ILINKLLJ.LCM
 FRT file                      : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0
 FCP file                      : FCP_UNDEF_PARCELS.DAT;0
 Feature code pairs specified
              10  with  10
             342  with  10, 342
             344  with  10, 342:344

 ILINK LOG
 ******************************************************************************

 Aligning
        Inserting additional points for 1-1 alignment
        Finding alignment
        Checking alignment
        Moving lines identically together
        Breaking features at every node
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     2.000
        Creating node arms
 Sorting node arms and merging duplicate features
 Removing invalid 2-nodes
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ******************************************************************************

 Input features transfered     : (Point 113),  (Other 305)
 Input features processed      : (Point 0),  (Open 0),  (Closed 35)
 Processed features output     : (Point 0),  (Open 0),  (Closed 35)

 Total features in IFF input   : 453
 Total features in IFF output  : 453

 Nodes found joined to 0 arms  (single point features): 0
                       1 arm   (unattached link ends) : 0
                       2 arms  (link joined to link)  : 4
                       3 arms  (link joined to links) : 42
                       4 arms  (link joined to links) : 3
                      5+ arms  (link joined to links) : 2
                                        Total        : 51
 ------------------------------------------------------------------------------
 Join separations over the range   0.001  to   2.000

 Range     Count | Proportion
 ---------------|--------------------------------------------------------------
 No joins within verification range  0.001 to  2.000
 ---------------|--------------------------------------------------------------
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ********************************************************************************

 Input from                   : LSL$DATA_ROOT:[LSL.IFF]TO2.IFF;1
 Output to                    : LSL$DATA_ROOT:[LSL.IFF]TO3.IFF;1
 Process                      : PPJOIN - Ends with ends junction formation.
                              : ends projected.
 Join tolerance               :    2.000
 Max vector extension         :    2.000
 Min verification tolerance   :    0.001
 Layers to be processed       : 6
 LITES2 command file          : LSL$LITES2CMD:ILINKPPJ.LCM
 FRT file                     : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0
 FCP file                     : FCP_UNDEF_PARCELS.DAT;0
 Feature code pairs specified
          10  with  10
         342  with  10, 342
         344  with  10, 342:344

 ILINK LOG
 ********************************************************************************

 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than    2.000
        Creating node arms
 Joining ends to ends
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ********************************************************************************

 Input features transfered    : (Point 113),  (Other 305)
 Input features processed     : (Point 0),  (Open 0),  (Closed 35)
 Processed features output    : (Point 0),  (Open 0),  (Closed 35)

 Total features in IFF input  : 453
 Total features in IFF output : 453

 Nodes found joined to 0 arms  (single point features): 0
                       1 arm   (unattached link ends) : 0
                       2 arms  (link joined to link)  : 24
                       3 arms  (link joined to links) : 0
                       4 arms  (link joined to links) : 4
                      5+ arms  (link joined to links) : 1

                                          Total       : 29
 --------------------------------------------------------------------------------
 Join separations over the range   0.001  to   2.000

 Range     Count | Proportion
 ----------------|----------------------------------------------------------------
 No joins within verification range  0.001 to  2.000
 ----------------|----------------------------------------------------------------
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ********************************************************************************

 Input from                  : LSL$DATA_ROOT:[LSL.IFF]T03.IFF;1
 Output to                   : LSL$DATA_ROOT:[LSL.IFF]T04.IFF;1
 Process                     : LLJOIN - Feature alignment.
 Join tolerance              :     0.400
 Layers to be processed      : 6
 LITES2 command file         : LSL$LITES2CMD:ILINKLLJ.LCM
 FRT file                    : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ********************************************************************************

 Aligning
        Inserting additional points for 1-1 alignment
        Finding alignment
        Checking alignment
        Moving lines identically together
        Breaking features at every node
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than    0.400
        Creating node arms
 Sorting node arms and merging duplicate features
 Removing invalid 2-nodes
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ********************************************************************************

 Input features transfered    : (Point 0),  (Other 51)
 Input features processed     : (Point 113),  (Open 8),  (Closed 281)
 Processed features output    : (Point 113),  (Open 8),  (Closed 281)

 Total features in IFF input  : 453
 Total features in IFF output : 453

 Nodes found joined to 0 arms  (single point features): 111
                       1 arm   (unattached link ends) : 1
                       2 arms  (link joined to link)  : 6
                       3 arms  (link joined to links) : 428
                       4 arms  (link joined to links) : 237
                      5+ arms  (link joined to links) : 182

                                    Total      : 965
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ******************************************************************************

 Input from                    : LSL$DATA_ROOT:[LSL.IFF]T04.IFF;1
 Output to                     : LSL$DATA_ROOT:[LSL.IFF]T05.IFF;1
 Process                       : LPJOIN - Ends with lines junction formation.
                               : with no vertex priority.
 Join tolerance                :     0.400
 Max vector extension          :     0.400
 Min verification tolerance    :     0.001
 Layers to be processed        : 6
 LITES2 command file           : LSL$LITES2CMD:ILINKLPJ.LCM
 FRT file                      : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ******************************************************************************

 Joining ends to lines
        Finding new line-end positions
        Undoing joins too close to feature ends
        Checking for negligably short loops
        Removing surplus inserted points
        Moving ends within join tolerance onto lines
        Breaking features at every node
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     0.001
        Creating node arms
 Sorting node arms
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ******************************************************************************

 Input features transfered    : (Point 0),  (Other 51)
 Input features processed     : (Point 113),  (Open 8),  (Closed 281)
 Processed features output    : (Point 113),  (Open 8),  (Closed 281)

 Total features in IFF input  : 453
 Total features in IFF output : 453

 Nodes found joined to 0 arms  (single point features): 102
                       1 arm   (unattached link ends) : 1
                       2 arms  (link joined to link)  : 190
                       3 arms  (link joined to links) : 6
                       4 arms  (link joined to links) : 41
                      5+ arms  (link joined to links) : 8

                                            Total     : 348
 ------------------------------------------------------------------------------
 Join separations over the range   0.001  to   0.400

 Range    Count | Proportion
 ---------------|--------------------------------------------------------------
```

```
0.001+      3 | ******************
0.041+      0 |
0.081+      1 | ******
0.121+      2 | ************
0.161+      0 |
0.201+      1 | ******
0.240+      0 |
0.280+      1 | ******
0.320+      1 | ******
0.360+      2 | ************
--------------|------------------------------------------------------------
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ******************************************************************************

 Input from                  : LSL$DATA_ROOT:[LSL.IFF]T05.IFF;1
 Output to                   : LSL$DATA_ROOT:[LSL.IFF]T06.IFF;1
 Process                     : PPJOIN - Ends with ends junction formation.
                             : ends projected.
 Join tolerance              :    0.400
 Max vector extension        :    0.400
 Min verification tolerance  :    0.001
 Layers to be processed      : 6
 LITES2 command file         : LSL$LITES2CMD:ILINKPPJ.LCM
 FRT file                    : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ******************************************************************************

 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     0.400
        Creating node arms
 Joining ends to ends
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ******************************************************************************

 Input features transfered    : (Point 0),  (Other 51)
 Input features processed     : (Point 113),  (Open 8),  (Closed 281)
 Processed features output    : (Point 113),  (Open 8),  (Closed 281)

 Total features in IFF input  : 453
 Total features in IFF output : 453

 Nodes found joined to 0 arms  (single point features): 113
                       1 arm   (unattached link ends) : 6
                       2 arms  (link joined to link)  : 179
                       3 arms  (link joined to links) : 2
                       4 arms  (link joined to links) : 41
                      5+ arms  (link joined to links) : 7

                                          Total       : 348
 ------------------------------------------------------------------------------
 Join separations over the range   0.001   to    0.400

 Range     Count | Proportion
 ---------------|--------------------------------------------------------------
 No joins within verification range  0.001 to  0.400
 ---------------|--------------------------------------------------------------
```

APPENDIX H.4

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ****************************************************************************

 Input from                    : LSL$DATA_ROOT:[LSL.IFF]URB_EDGE_MAVO.IFF;2
 Output to                     : LSL$DATA_ROOT:[LSL.IFF]OUT1.IFF;1
 Process                       : LLJOIN - Feature alignment.
 Join tolerance                :     2.000
 Layers to be processed        : 6
 LITES2 command file           : LSL$LITES2CMD:ILINKLLJ.LCM
 FRT file                      : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0
 FCP file                      : FCPII.DAT;0
 Feature code pairs specified
              10  with  10
             342  with  10, 342
             344  with  10, 342, 344, 411
             409  with  10, 342, 344, 409, 411
             411  with  10, 342
             413  with  10, 342, 344, 409, 411, 413
             415  with  10, 342, 344, 409, 411, 413, 415
             417  with  10, 342, 344, 409, 411, 413, 415, 417
             419  with  10, 342, 344, 409, 411, 413, 415, 417:419

 ILINK LOG
 ****************************************************************************

 Aligning
        Inserting additional points for 1-1 alignment
        Finding alignment
        Checking alignment
        Moving lines identically together
        Breaking features at every node
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     2.000
        Creating node arms
 Sorting node arms and merging duplicate features
 Removing invalid 2-nodes
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ****************************************************************************

 Input features transfered    : (Point 272),  (Other 564)
 Input features processed     : (Point 0),  (Open 4),  (Closed 20)
 Processed features output    : (Point 0),  (Open 0),  (Closed 24)

 Total features in IFF input  : 860
 Total features in IFF output : 860

 Nodes found joined to 0 arms  (single point features): 0
                       1 arm   (unattached link ends) : 0
                       2 arms  (link joined to link)  : 6
                       3 arms  (link joined to links) : 26
                       4 arms  (link joined to links) : 2
                      5+ arms  (link joined to links) : 0

                                         Total        : 34
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ****************************************************************************

 Input from                     : LSL$DATA_ROOT:[LSL.IFF]OUT1.IFF;1
 Output to                      : LSL$DATA_ROOT:[LSL.IFF]OUT2.IFF;1
 Process                        : LPJOIN - Ends with lines junction formation.
                                : with vertex priority.
 Join tolerance                 :      2.000
 Max vector extension           :      2.000
 Min verification tolerance     :      0.002
 Layers to be processed         : 6
 LITES2 command file            : LSL$LITES2CMD:ILINKLPJ.LCM
 FRT file                       : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0
 FCP file                       : FCPII.DAT;0
 Feature code pairs specified
              10  with  10
             342  with  10, 342
             344  with  10, 342, 344, 411
             409  with  10, 342, 344, 409, 411
             411  with  10, 342
             413  with  10, 342, 344, 409, 411, 413
             415  with  10, 342, 344, 409, 411, 413, 415
             417  with  10, 342, 344, 409, 411, 413, 415, 417
             419  with  10, 342, 344, 409, 411, 413, 415, 417:419

 ILINK LOG
 ****************************************************************************

 Joining ends to lines
        Finding new line-end positions
        Undoing joins too close to feature ends
        Checking for negligably short loops
        Removing surplus inserted points
        Moving ends within join tolerance onto lines
        Breaking features at every node
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than      0.002
        Creating node arms
 Sorting node arms
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ****************************************************************************

 Input features transfered      : (Point 272),  (Other 564)
 Input features processed       : (Point 0),   (Open 0),   (Closed 24)
 Processed features output      : (Point 0),   (Open 0),   (Closed 24)

 Total features in IFF input  : 860
 Total features in IFF output : 860

 Nodes found joined to 0 arms  (single point features): 0
                       1 arm   (unattached link ends) : 0
```

```
                 2 arms  (link joined to link)  : 14
                 3 arms  (link joined to links) : 0
                 4 arms  (link joined to links) : 5
                5+ arms  (link joined to links) : 0

                                   Total        : 19
---------------------------------------------------------------------------
Join separations over the range   0.002  to   2.000

Range      Count | Proportion
-----------------|---------------------------------------------------------
No joins within verification range  0.002 to  2.000
-----------------|---------------------------------------------------------
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ****************************************************************************

 Input from                       : LSL$DATA_ROOT:[LSL.IFF]OUT2.IFF;1
 Output to                        : LSL$DATA_ROOT:[LSL.IFF]OUT3.IFF;1
 Process                          : PPJOIN - Ends with ends junction formation.
                                  : ends projected.
 Join tolerance                   :     2.000
 Max vector extension             :     2.000
 Min verification tolerance       :     0.002
 Layers to be processed           : 6
 LITES2 command file              : LSL$LITES2CMD:ILINKPPJ.LCM
 FRT file                         : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0
 FCP file                         : FCPII.DAT;0
 Feature code pairs specified
              10  with  10
             342  with  10, 342
             344  with  10, 342, 344, 411
             409  with  10, 342, 344, 409, 411
             411  with  10, 342
             413  with  10, 342, 344, 409, 411, 413
             415  with  10, 342, 344, 409, 411, 413, 415
             417  with  10, 342, 344, 409, 411, 413, 415, 417
             419  with  10, 342, 344, 409, 411, 413, 415, 417:419

 ILINK LOG
 ****************************************************************************

 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than      2.000
        Creating node arms
 Joining ends to ends
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ****************************************************************************

 Input features transfered     : (Point 272),  (Other 564)
 Input features processed      : (Point 0),  (Open 0),  (Closed 24)
 Processed features output     : (Point 0),  (Open 0),  (Closed 24)

 Total features in IFF input  : 860
 Total features in IFF output : 860

 Nodes found joined to 0 arms  (single point features): 0
                       1 arm   (unattached link ends) : 0
                       2 arms  (link joined to link)  : 14
                       3 arms  (link joined to links) : 0
                       4 arms  (link joined to links) : 5
                      5+ arms  (link joined to links) : 0

                                          Total       : 19
 ----------------------------------------------------------------------------
 Join separations over the range    0.002  to    2.000

 Range     Count | Proportion
 ----------------|-----------------------------------------------------------
 No joins within verification range  0.002 to  2.000
 ----------------|-----------------------------------------------------------
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 **************************************************************************

 Input from                      : LSL$DATA_ROOT:[LSL.IFF]OUT3.IFF;1
 Output to                       : LSL$DATA_ROOT:[LSL.IFF]OUT4.IFF;1
 Process                         : LLJOIN - Feature alignment.
 Join tolerance                  :     0.500
 Layers to be processed          : 6
 LITES2 command file             : LSL$LITES2CMD:ILINKLLJ.LCM
 FRT file                        : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 **************************************************************************

 Aligning
        Inserting additional points for 1-1 alignment
        Finding alignment
        Checking alignment
        Moving lines identically together
        Breaking features at every node
 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     0.500
        Creating node arms
 Sorting node arms and merging duplicate features
 Removing invalid 2-nodes
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 **************************************************************************

 Input features transfered       : (Point 0),  (Other 57)
 Input features processed        : (Point 272),  (Open 27),  (Closed 504)
 Processed features output       : (Point 272),  (Open 8),  (Closed 523)

 Total features in IFF input  : 860
 Total features in IFF output : 860

 Nodes found joined to 0 arms  (single point features): 272
                       1 arm   (unattached link ends) : 6
                       2 arms  (link joined to link)  : 68
                       3 arms  (link joined to links) : 794
                       4 arms  (link joined to links) : 301
                      5+ arms  (link joined to links) : 135

                                         Total        : 1576
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ****************************************************************************

 Input from                      : LSL$DATA_ROOT:[LSL.IFF]OUT4.IFF;1
 Output to                       : LSL$DATA_ROOT:[LSL.IFF]OUT5.IFF;1
 Process                          LPJOIN - Ends with lines junction formation.
                                 : with vertex priority.
 Join tolerance                  :     0.500
 Max vector extension            :     0.500
 Min verification tolerance      :     0.002
 Layers to be processed          : 6
 LITES2 command file             : LSL$LITES2CMD:ILINKLPJ.COM
 FRT file                        : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ****************************************************************************

 Joining ends to lines
         Finding new line-end positions
         Undoing joins too close to feature ends
         Checking for negligibly short loops
         Removing surplus inserted points
         Moving ends within join tolerance onto lines
         Breaking features at every node
 Creating link/node structure
         Setting up a node for each feature end
         Merging nodes separated by less than     0.002
         Creating node arms
 Sorting node arms
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ****************************************************************************

 Input features transfered      : (Point 0),  (Other 57)
 Input features processed       : (Point 272),  (Open 9),  (Closed 522)
 Processed features output      : (Point 272),  (Open 8),  (Closed 523)

 Total features in IFF input  : 860
 Total features in IFF output : 860

 Nodes found joined to 0 arms  (single point features): 256
                       1 arm   (unattached link ends) : 4
                       2 arms  (link joined to link)  : 397
                       3 arms  (link joined to links) : 11
                       4 arms  (link joined to links) : 65
                      5+ arms  (link joined to links) : 4

                                         Total       : 737
 ----------------------------------------------------------------------------
 Join separations over the range   0.002  to   0.500

 Range     Count | Proportion
 ----------------|-----------------------------------------------------------
```

```
 0.002+        1 | ***
 0.052+        3 | **********
 0.102+        1 | ***
 0.152+        3 | **********
 0.201+        1 | ***
 0.251+        2 | *******
 0.301+        2 | *******
 0.351+        2 | *******
 0.400+        4 | *************
 0.450+        0 |
---------------|------------------------------------------------------------
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 ***************************************************************************

 Input from                     : LSL$DATA_ROOT:[LSL.IFF]OUT5.IFF;1
 Output to                      : LSL$DATA_ROOT:[LSL.IFF]OUT6.IFF;1
 Process                        : PPJOIN - Ends with ends junction formation.
                                : ends projected.
 Join tolerance                 :    0.500
 Max vector extension           :    0.500
 Min verification tolerance     :    0.002
 Layers to be processed         : 6
 LITES2 command file            : LSL$LITES2CMD:ILINKPPJ.LCM
 FRT file                       : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 ***************************************************************************

 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     0.500
        Creating node arms
 Joining ends to ends
 Writing to IFF output
 Counting arms-per-node

 ILINK STATISTICS
 ***************************************************************************

 Input features transfered     : (Point 0),  (Other 57)
 Input features processed      : (Point 272),  (Open 8),  (Closed 523)
 Processed features output     : (Point 272),  (Open 8),  (Closed 523)

 Total features in IFF input  : 860
 Total features in IFF output : 860

 Nodes found joined to 0 arms  (single point features): 272
                       1 arm   (unattached link ends) : 12
                       2 arms  (link joined to link)  : 382
                       3 arms  (link joined to links) : 4
                       4 arms  (link joined to links) : 64
                      5+ arms  (link joined to links) : 3

                                            Total      : 737
 ---------------------------------------------------------------------------
 Join separations over the range   0.002   to    0.500

 Range     Count | Proportion
 ---------------|-----------------------------------------------------------
 No joins within verification range  0.002 to   0.500
 ---------------|-----------------------------------------------------------
```

APPENDIX I.

APPENDIX I.1

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 *************************************************************************

 Input from                    : LSL$DATA_ROOT:[LSL.IFF]PU41.IFF;1
 Output to                     : LSL$DATA_ROOT:[LSL.IFF]PU5.IFJ;1
 Process                       : STRUCTURE - Junction Structure formation.
 Layers to be processed        : 10
 Report free-end nodes         : No.
 FRT file                      : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 *************************************************************************

 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     0.001
        Creating node arms
 Writing to IFF output
        Writing node-to-link pointers
        Writing link-to-node pointers

 ILINK STATISTICS
 *************************************************************************

 Input features deselected     : (Point 0),  (Other 0)
 Input features processed      : (Point 113),  (Open 482),  (Closed 1)
 Processed features output     : (Point 113),  (Open 482),  (Closed 1)

 Total features in IFF input  : 596
 Total features in IFF output : 596

 Nodes found joined to 0 arms  (single point features): 113
                       1 arm   (unattached link ends) : 13
                       2 arms  (link joined to link)  : 178
                       3 arms  (link joined to links) : 191
                       4 arms  (link joined to links) : 6
                      5+ arms  (link joined to links) : 0

                                        Total         : 501
```

APPENDIX I.2

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input

 ILINK COMMAND INTERPRETATION
 *****************************************************************************

 Input from                      : LSL$DATA_ROOT:[LSL.IFF]ED51.IFF;1
 Output to                       : LSL$DATA_ROOT:[LSL.IFF]ED6.IFJ;1
 Process                         : STRUCTURE - Junction Structure formation.
 Layers to be processed          : 10
 Report free-end nodes           : No.
 FRT file                        : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 *****************************************************************************

 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than     0.002
        Creating node arms
 Writing to IFF output
        Writing node-to-link pointers
        Writing link-to-node pointers

 ILINK STATISTICS
 *****************************************************************************

 Input features deselected     : (Point 0),  (Other 0)
 Input features processed      : (Point 270),  (Open 1113),  (Closed 0)
 Processed features output     : (Point 270),  (Open 1113),  (Closed 0)

 Total features in IFF input  : 1383*
 Total features in IFF output : 1383

 Nodes found joined to 0 arms  (single point features): 269
                       1 arm   (unattached link ends) : 13
                       2 arms  (link joined to link)  : 385
                       3 arms  (link joined to links) : 445
                       4 arms  (link joined to links) : 27
                      5+ arms  (link joined to links) : 0

                                      Total      : 1139
```

```
ILINK Version 4.2 of 17:37:18  4-APR-89
 Scanning IFF file for dynamic memory allocation
 Reading data from IFF input
%ILINK-W-BADFTR, input feature with FSN 1462 (1) in layer 1 rejected
%ILINK-W-BADFTR, input feature with FSN 1463 (2) in layer 1 rejected
%ILINK-W-BADFTR, input feature with FSN 1464 (3) in layer 1 rejected
%ILINK-W-BADFTR, input feature with FSN 1465 (4) in layer 1 rejected
%ILINK-W-BADFTR, input feature with FSN 1466 (5) in layer 1 rejected

 ILINK COMMAND INTERPRETATION
 **********************************************************************

 Input from                    : LSL$DATA_ROOT:[LSL.IFF]PRO1.IFF;1
 Output to                     : LSL$DATA_ROOT:[LSL.IFF]ED6.IFJ;1
 Process                       : STRUCTURE - Junction Structure formation.
 Layers to be processed        : 10
 Report free-end nodes         : No.
 FRT file                      : LSL$SITE_ROOT:[GIOTIS]GIOTIS.FRT;0

 ILINK LOG
 **********************************************************************

 Creating link/node structure
        Setting up a node for each feature end
        Merging nodes separated by less than      0.002
        Creating node arms
 Writing to IFF output
        Writing node-to-link pointers
        Writing link-to-node pointers

 ILINK STATISTICS
 **********************************************************************

 Input features deselected     : (Point 0),  (Other 0)
 Input features processed      : (Point 270),  (Open 1109),  (Closed 0)
 Processed features output     : (Point 270),  (Open 1109),  (Closed 0)

 Total features in IFF input  : 1384
 Total features in IFF output : 1379

 Nodes found joined to 0 arms  (single point features): 269
                       1 arm   (unattached link ends) : 17
                       2 arms  (link joined to link)  : 392
                       3 arms  (link joined to links) : 443
                       4 arms  (link joined to links) : 22
                      5+ arms  (link joined to links) : 0

                                     Total      : 1143
```

APPENDIX I.3

```
============================== I P O L Y G O N ==============================

IPOLYGON invoked by GIOTIS using terminal WTA2: at 10-AUG-1989 22:08:55.55

Command line:

$ IPOLYGON/SEED=(USE:FSN,FC:321)/POLYGONS=(LABEL,FC:500)/OPTIONS=AREA/LIST=POI
/ASCII=LABEL ED6

=============================================================================


+---------------------------------------------------------------+
|                                                               |
|                  Building IFF Address Tables                  |
|                                                               |
+---------------------------------------------------------------+

Number of IFF segment feature addresses tabulated ... 1113
Segment coordinate range is:
X-min .............................................    -46.985
X-max .............................................    674.141
Y-min .............................................    -52.874
Y-max .............................................   1125.750


+---------------------------------------------------------------+
|                                                               |
|                      Checking Seed Points                     |
|                                                               |
+---------------------------------------------------------------+

Number of seed point feature addresses tabulated ... 270


+---------------------------------------------------------------+
|                                                               |
|                        Forming Polygons                       |
|                                                               |
+---------------------------------------------------------------+

Suspected coincident segments near features with FSN 385 and 387
Suspected coincident segments near features with FSN 950 and 959
```

```
=============================== I P O L Y G O N ==============================

IPOLYGON invoked by GIOTIS using terminal WTA2: at 10-AUG-1989 23:51:19.20

Command line:

$ IPOLYGON/SEED=(USE:FSN,FC:321)/POLYGONS=(LABEL,FC:500)/OPTIONS=AREA/LIST=POL
/ASCII=LABEL ED6

==============================================================================


+-----------------------------------------------------------------+
|                                                                 |
|                   Building IFF Address Tables                   |
|                                                                 |
+-----------------------------------------------------------------+

Number of IFF segment feature addresses tabulated ... 1111
Segment coordinate range is:
X-min ..............................................     -46.985
X-max ..............................................     674.141
Y-min ..............................................     -52.874
Y-max ..............................................    1125.750


+-----------------------------------------------------------------+
|                                                                 |
|                       Checking Seed Points                      |
|                                                                 |
+-----------------------------------------------------------------+

Number of seed point feature addresses tabulated ... 270


+-----------------------------------------------------------------+
|                                                                 |
|                        Forming Polygons                         |
|                                                                 |
+-----------------------------------------------------------------+

Suspected coincident segments near features with FSN 390 and 392
Suspected coincident segments near features with FSN 953 and 962
```

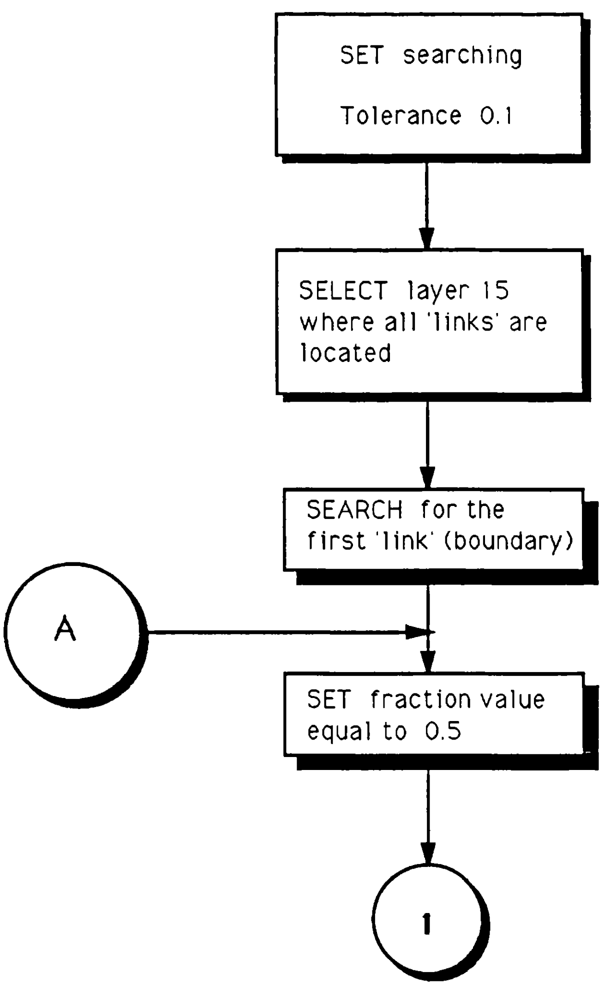
APPENDIX J.

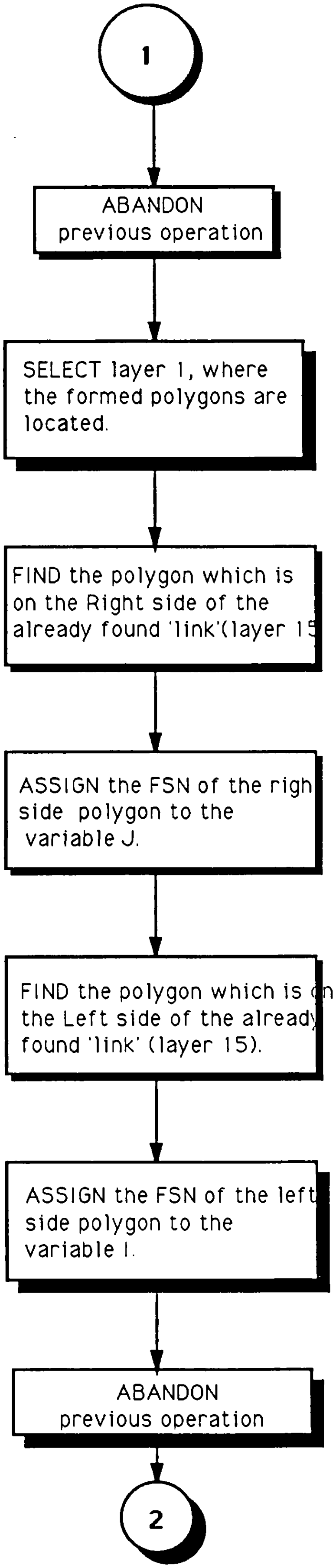
APPENDIX J.1.

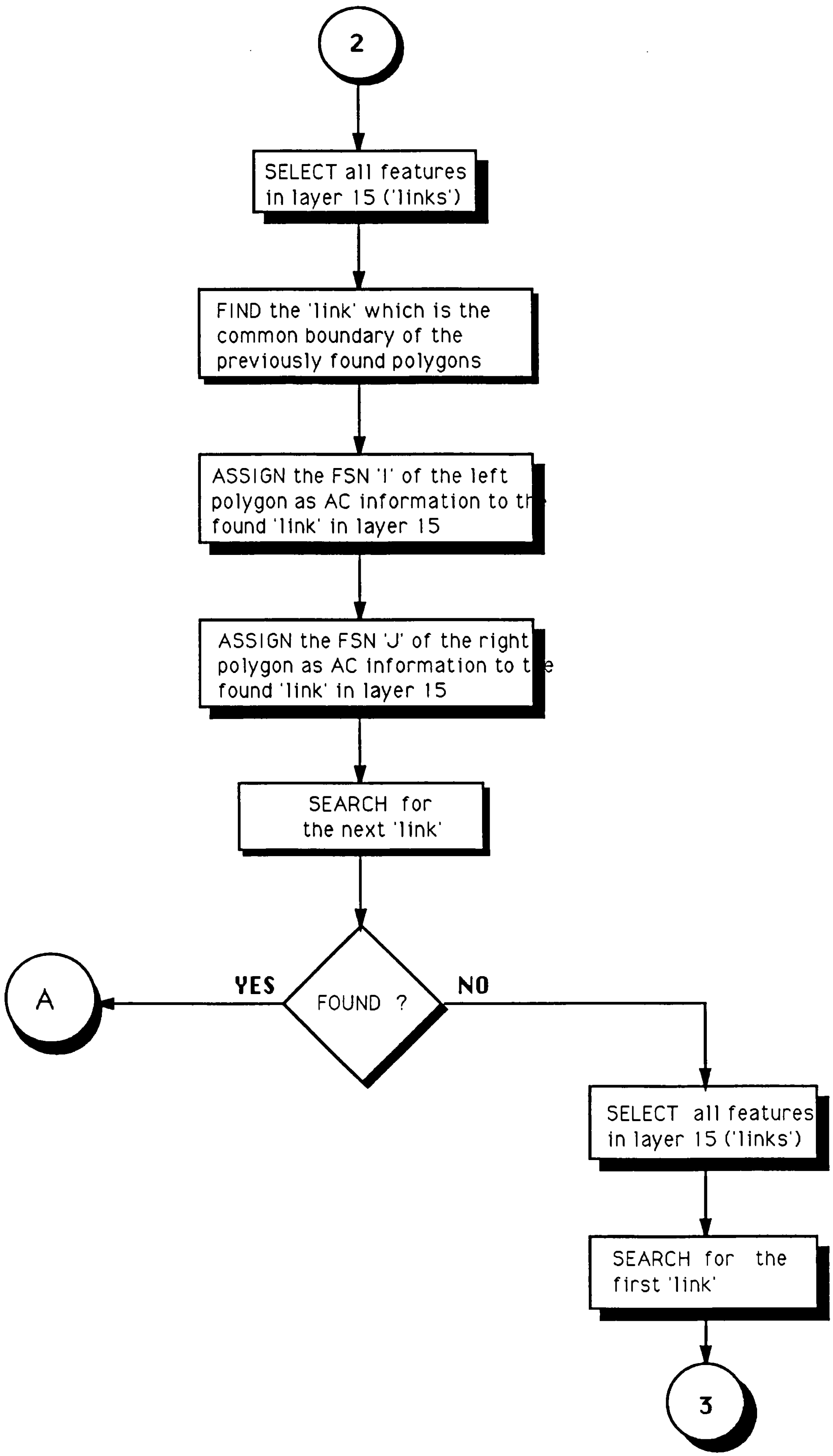
Problem Definition : Create the topological relationship ADJACENCY, where there is a polygon to left and the right of a link. Define the LENGTH of this link (boundary).

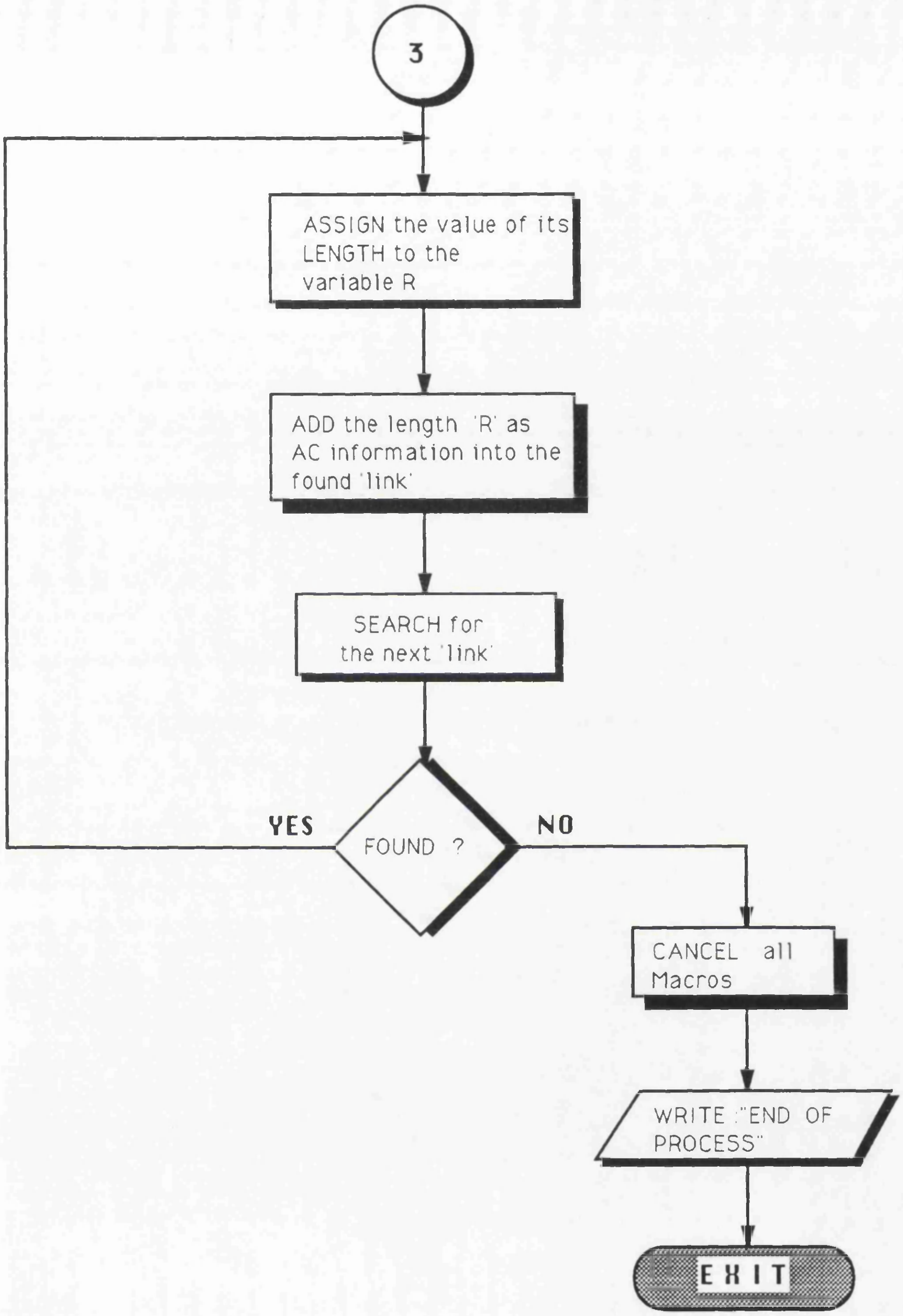
Needed Output : Features specifying parcel boundaries having as Ancillary Code (AC) information the following :
1- FSN of the RH polygon
2- FSN of the LH polygon
3- Its length, in metres.

Needed Input : The input is to be the result of overlaying the output from ILINK/SRUCTURE process (but without the centroids) with the output from the IPOLYGON module.




1
ABANDON
previous operation
SELECT layer 1, where
the formed polygons are
located.
FIND the polygon which is
on the Right side of the
already found 'link'(layer 15
ASSIGN the FSN of the righ
side polygon to the
variable J.
FIND the polygon which is on
the Left side of the already
found 'link' (layer 15).
ASSIGN the FSN of the left
side polygon to the
variable I.
ABANDON
previous operation
2


2
SELECT all features in layer 15 ('links')
FIND the 'link' which is the common boundary of the previously found polygons
ASSIGN the FSN 'I' of the left polygon as AC information to the found 'link' in layer 15
ASSIGN the FSN 'J' of the right polygon as AC information to the found 'link' in layer 15
SEARCH for the next 'link'
FOUND ?
YES
NO
A
SELECT all features in layer 15 ('links')
SEARCH for the first 'link'
3

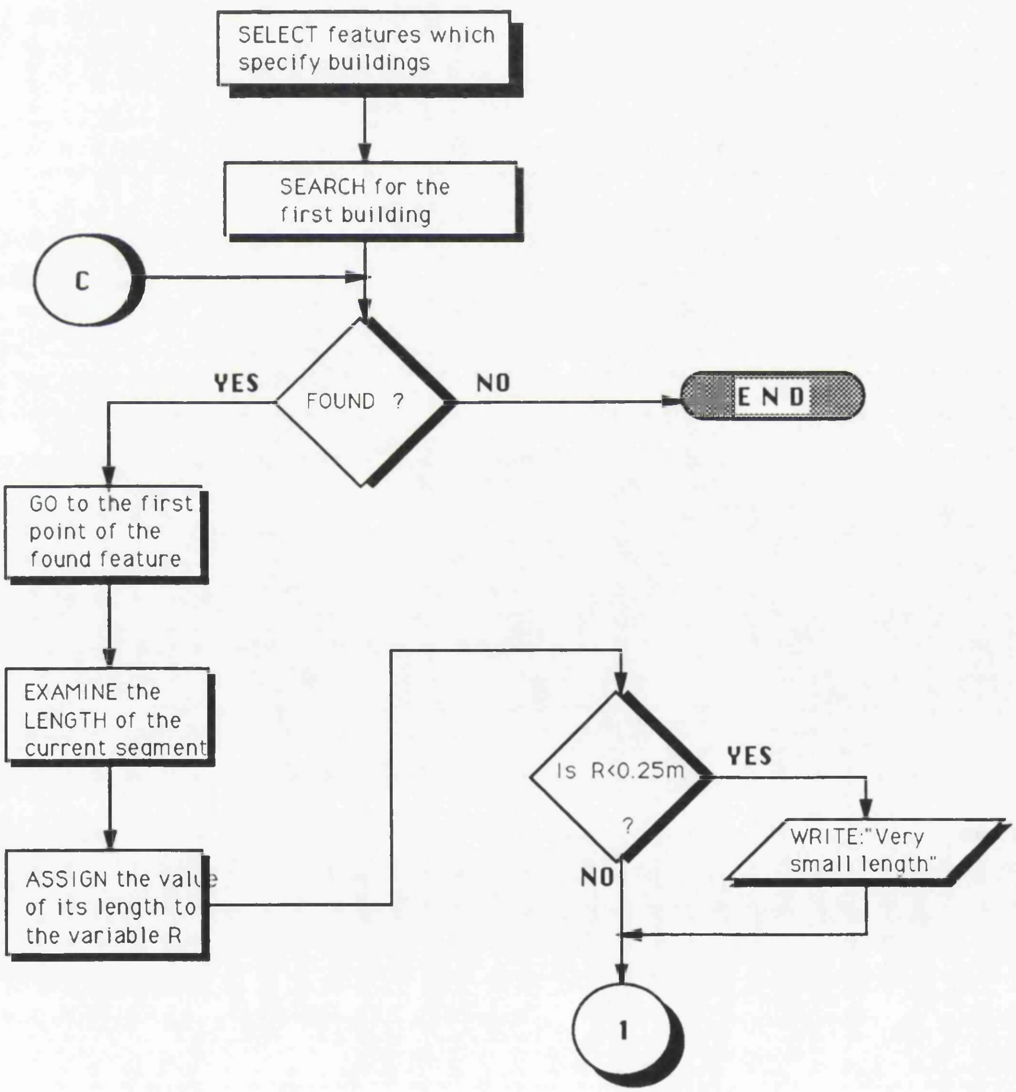

3
ASSIGN the value of its LENGTH to the variable R
ADD the length 'R' as AC information into the found 'link'
SEARCH for the next 'link'
FOUND ?
YES
NO
CANCEL all Macros
WRITE :"END OF PROCESS"
EXIT

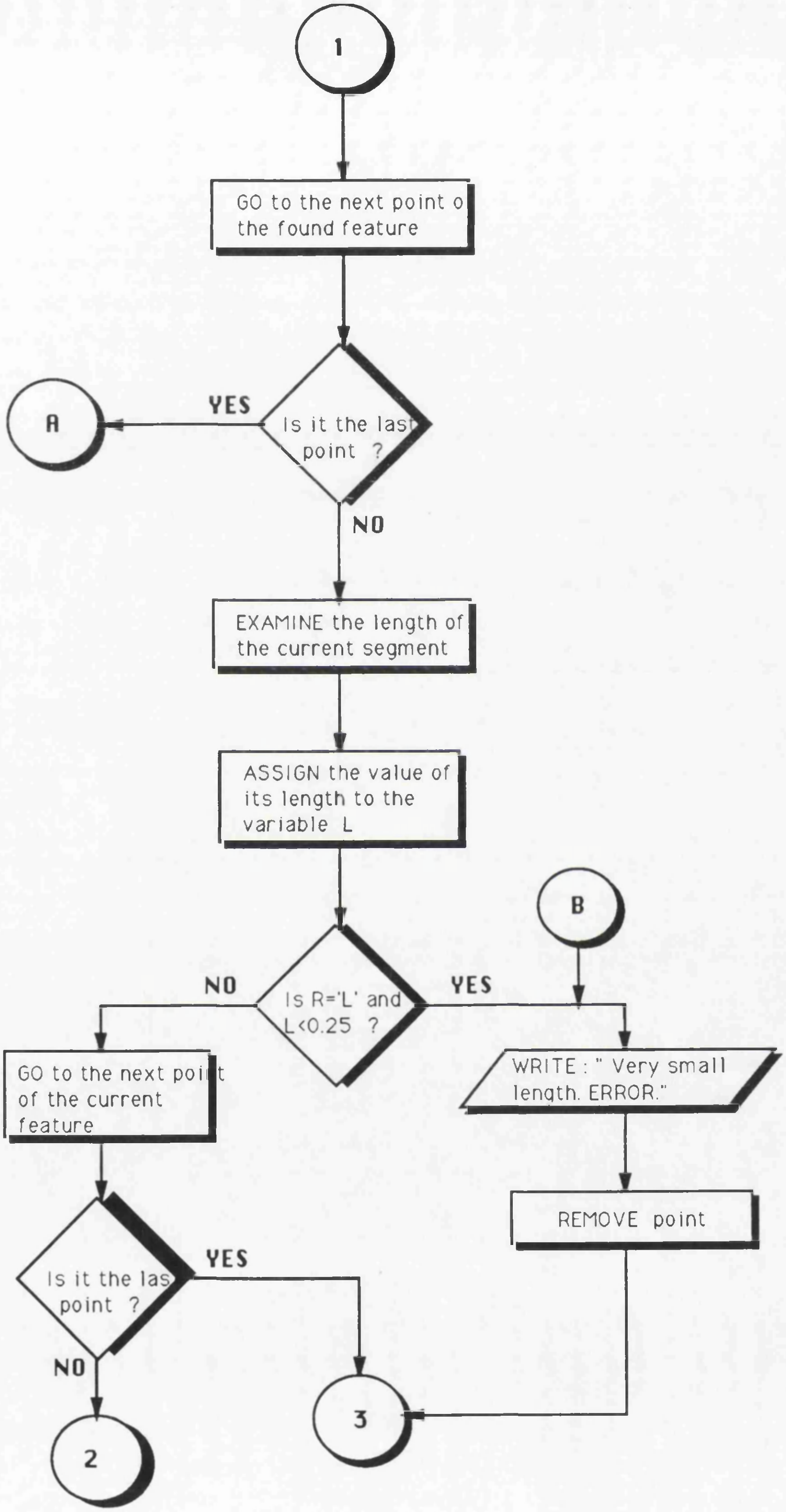
APPENDIX J.2

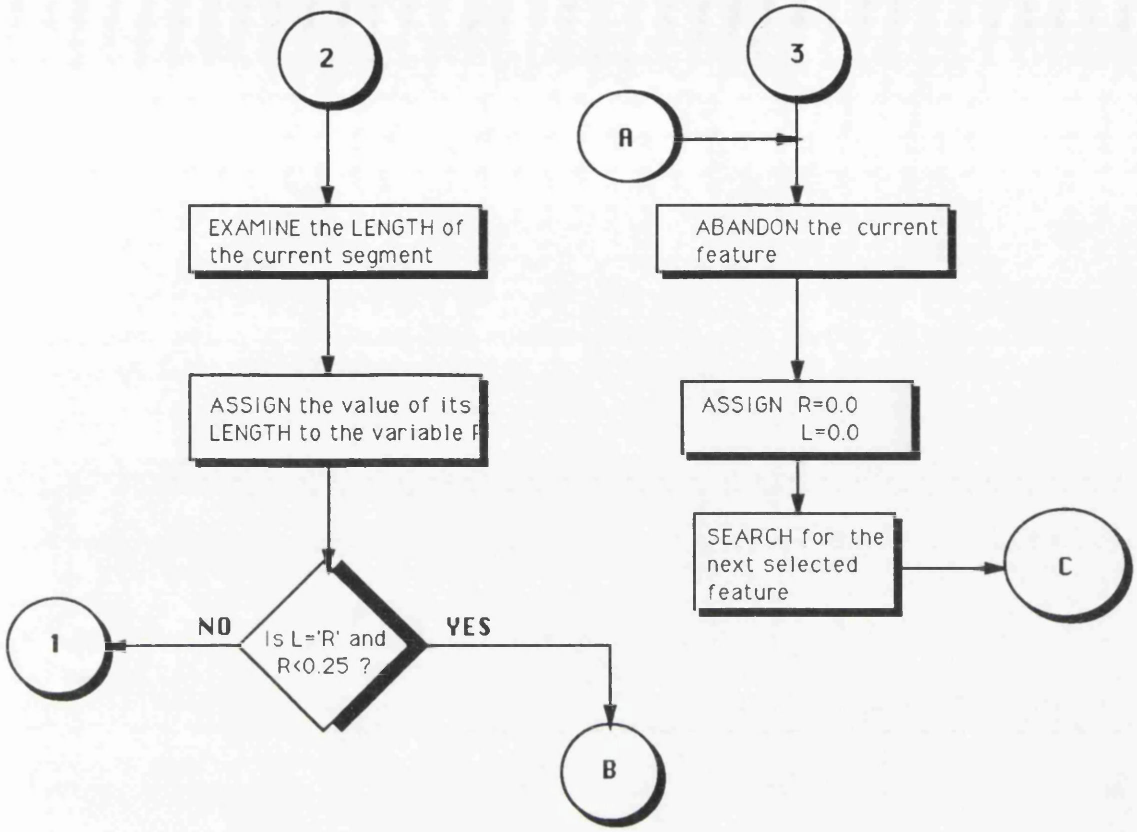
Problem Definition : Delete segments of building features which their length is smaller than 0.25m. These segments have been created during the ILINK process, they are double recorded and usually they are appeared outside of the parcel.

Needed Output : Buildings released from duplicated segments with length smaller than 0.25m

Needed Input : The input is to be the output of the STEP-2 (ILINK) of the editing stage.




1
GO to the next point o
the found feature
Is it the last
point ?
YES
A
NO
EXAMINE the length of
the current segment
ASSIGN the value of
its length to the
variable L
B
Is R='L' and
L<0.25 ?
NO
YES
GO to the next point
of the current
feature
WRITE : " Very small
length. ERROR."
REMOVE point
Is it the las
point ?
YES
NO
2
3

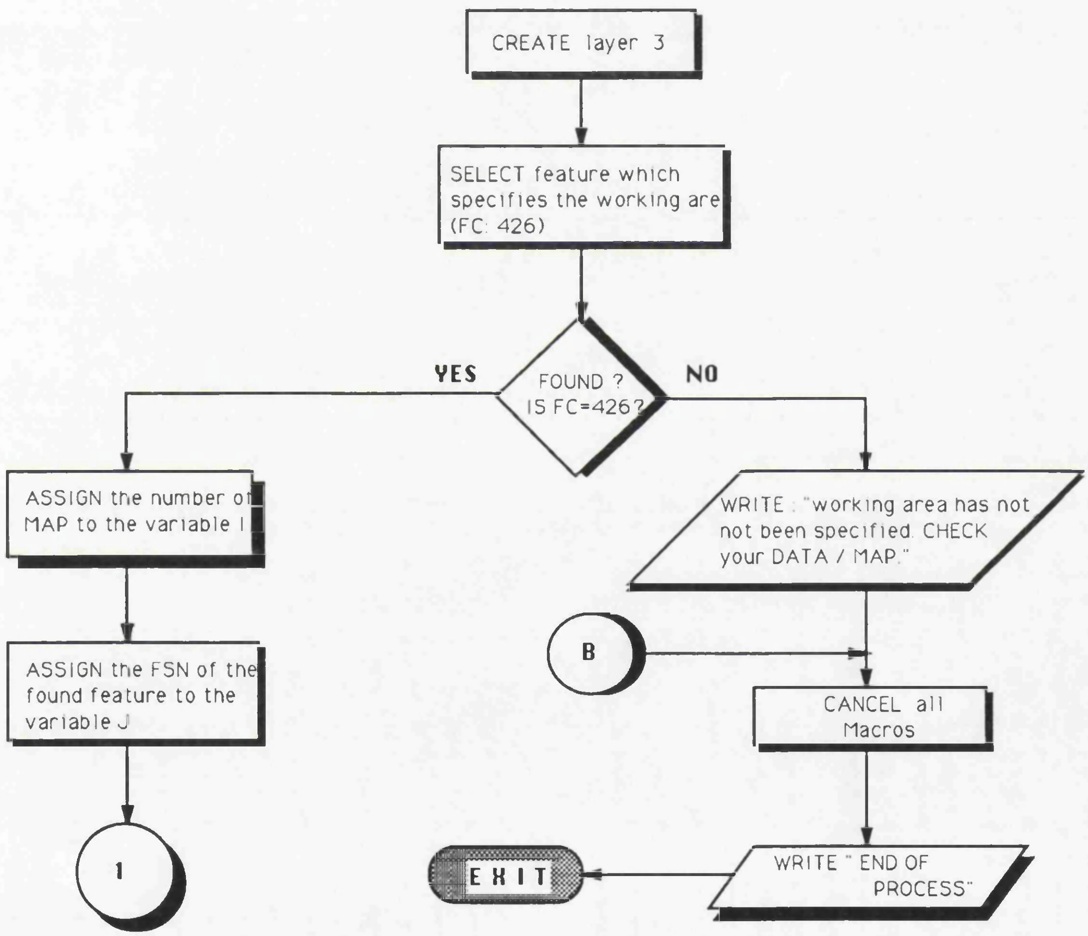

2
3
A
EXAMINE the LENGTH of the current segment
ABANDON the current feature
ASSIGN the value of its LENGTH to the variable R
ASSIGN R=0.0 L=0.0
SEARCH for the next selected feature
C
NO
Is L='R' and R<0.25 ?
YES
1
B

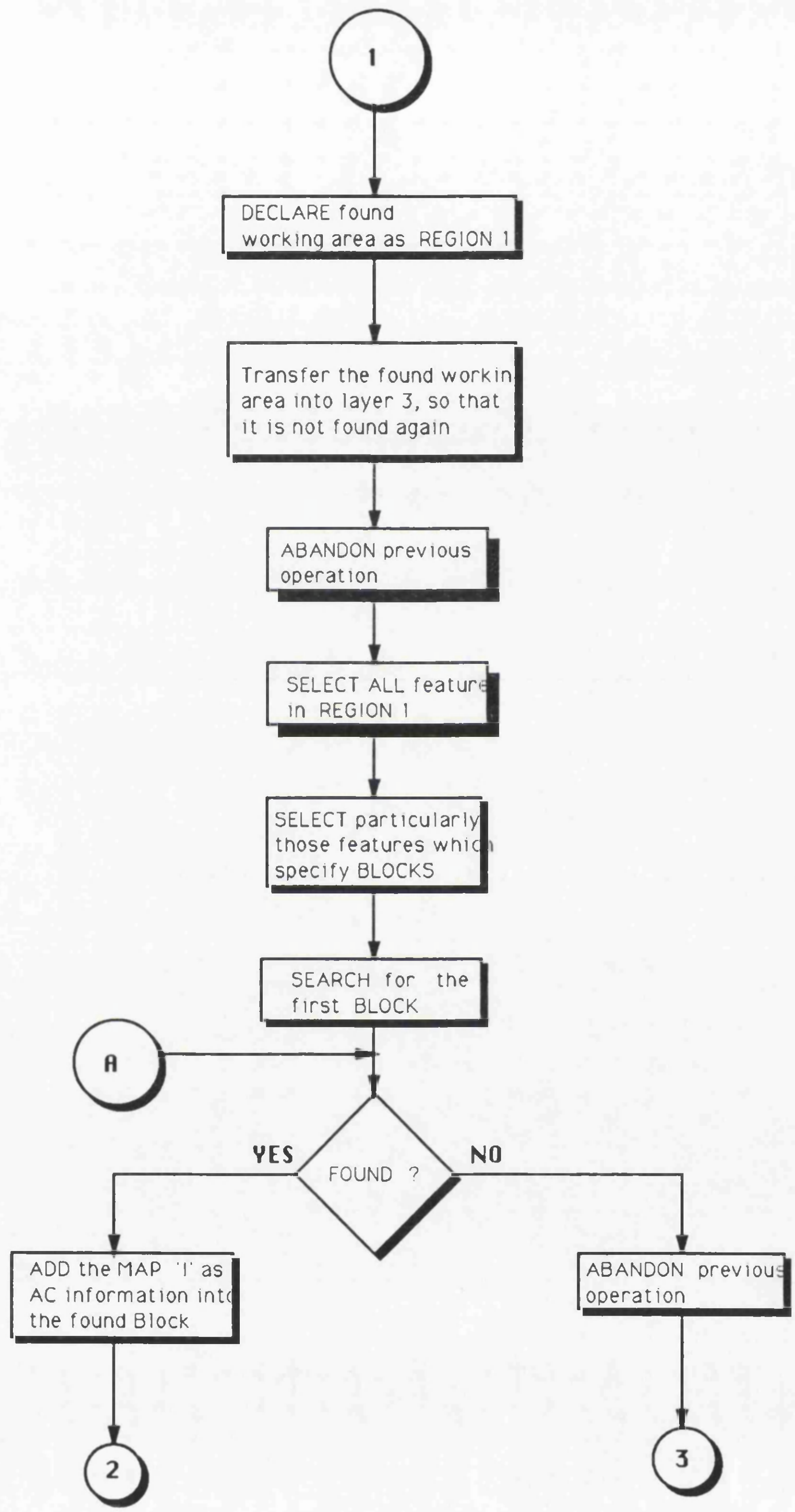
APPENDIX J.3.1

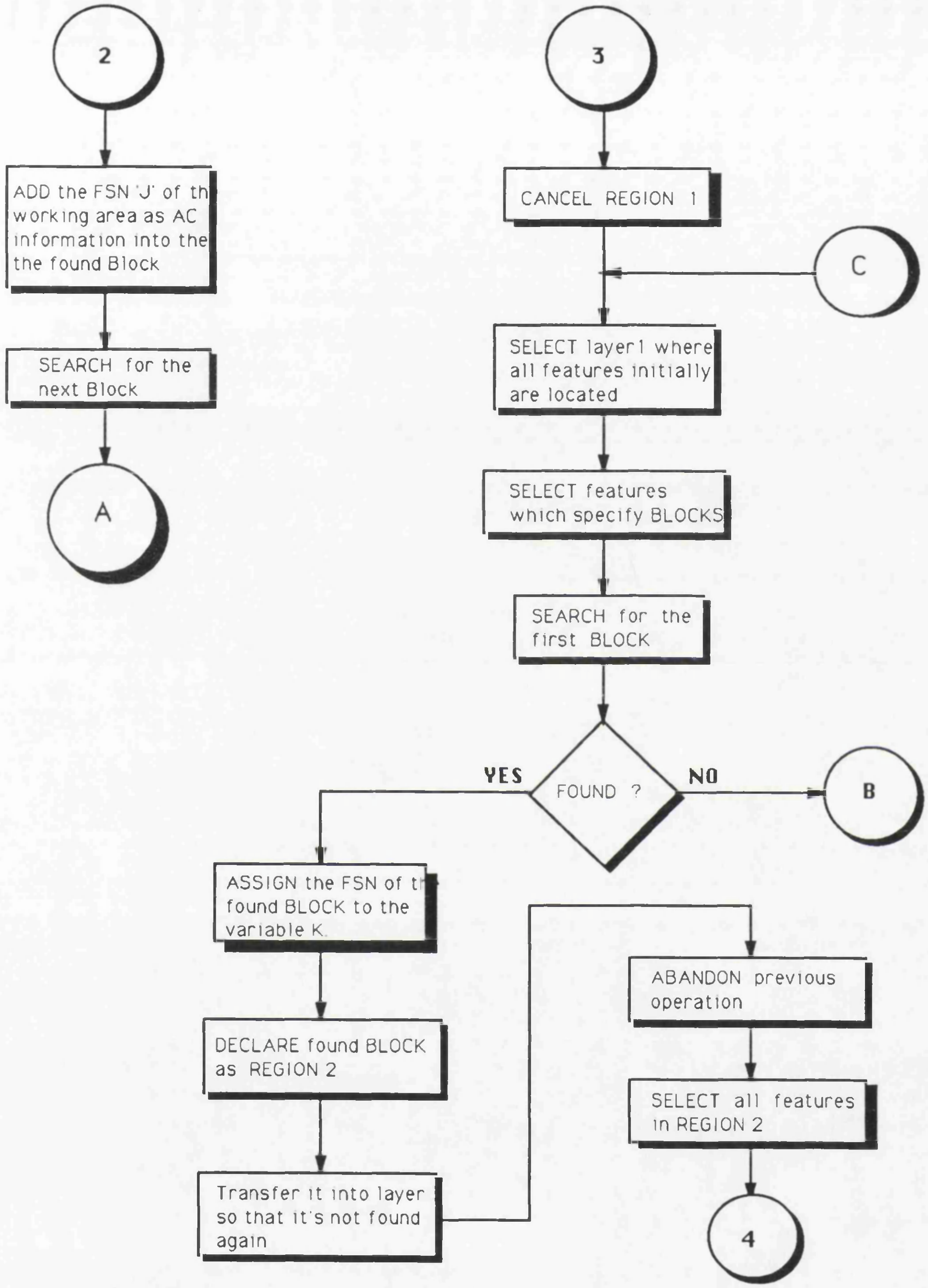
Problem Definition : Add the FSN of the working area into Blocks and the FSN of a Block into parcels and buildings lying within this Block as AC information

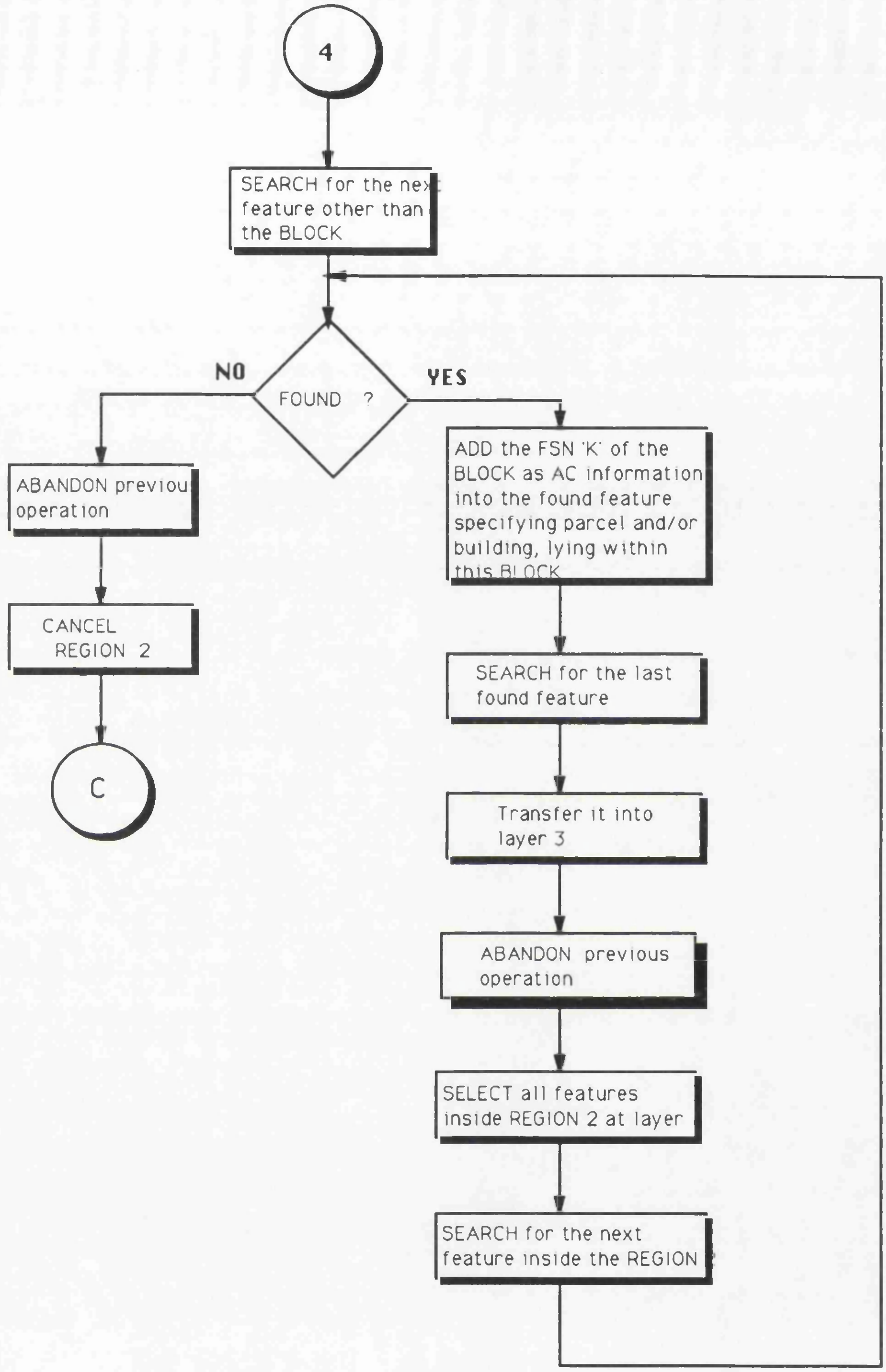
Needed Output : Features specifying Blocks will have the FSN of working area as AC information, and parcels and buildings will have as AC the FSN of the Block.

Needed Input : The input is to be the whole output of editing stage WITH buildings released from duplicated features with length smaller than 0.25m though (Appen. J.2)




1
DECLARE found working area as REGION 1
Transfer the found workin area into layer 3, so that it is not found again
ABANDON previous operation
SELECT ALL feature in REGION 1
SELECT particularly those features which specify BLOCKS
SEARCH for the first BLOCK
A
FOUND ?
YES
NO
ADD the MAP '1' as AC information into the found Block
ABANDON previous operation
2
3


2
ADD the FSN 'J' of th working area as AC information into the the found Block
SEARCH for the next Block
A
3
CANCEL REGION 1
C
SELECT layer1 where all features initially are located
SELECT features which specify BLOCKS
SEARCH for the first BLOCK
FOUND ?
YES
NO
B
ASSIGN the FSN of th found BLOCK to the variable K.
DECLARE found BLOCK as REGION 2
Transfer it into layer so that it's not found again
ABANDON previous operation
SELECT all features in REGION 2
4

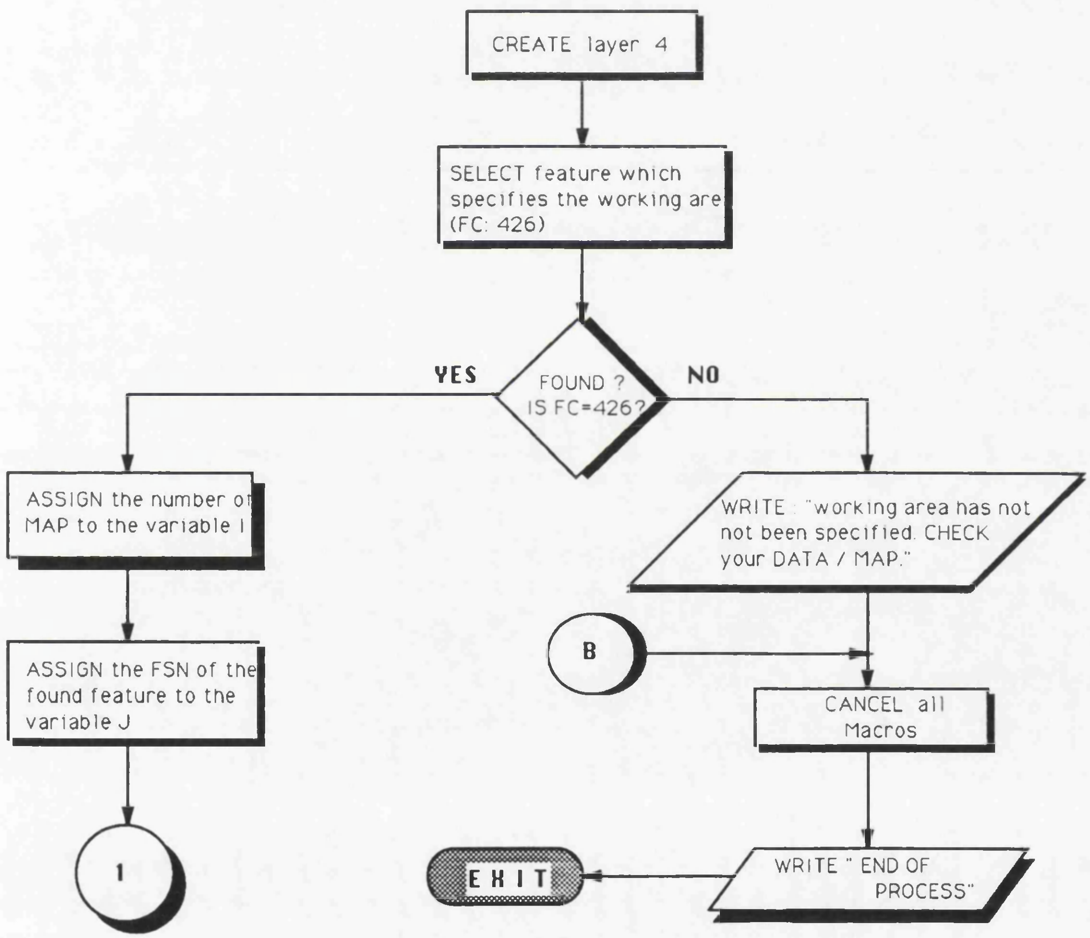

4
SEARCH for the next feature other than the BLOCK
FOUND ?
NO
YES
ABANDON previous operation
CANCEL REGION 2
C
ADD the FSN 'K' of the BLOCK as AC information into the found feature specifying parcel and/or building, lying within this BLOCK
SEARCH for the last found feature
Transfer it into layer 3
ABANDON previous operation
SELECT all features inside REGION 2 at layer
SEARCH for the next feature inside the REGION 2

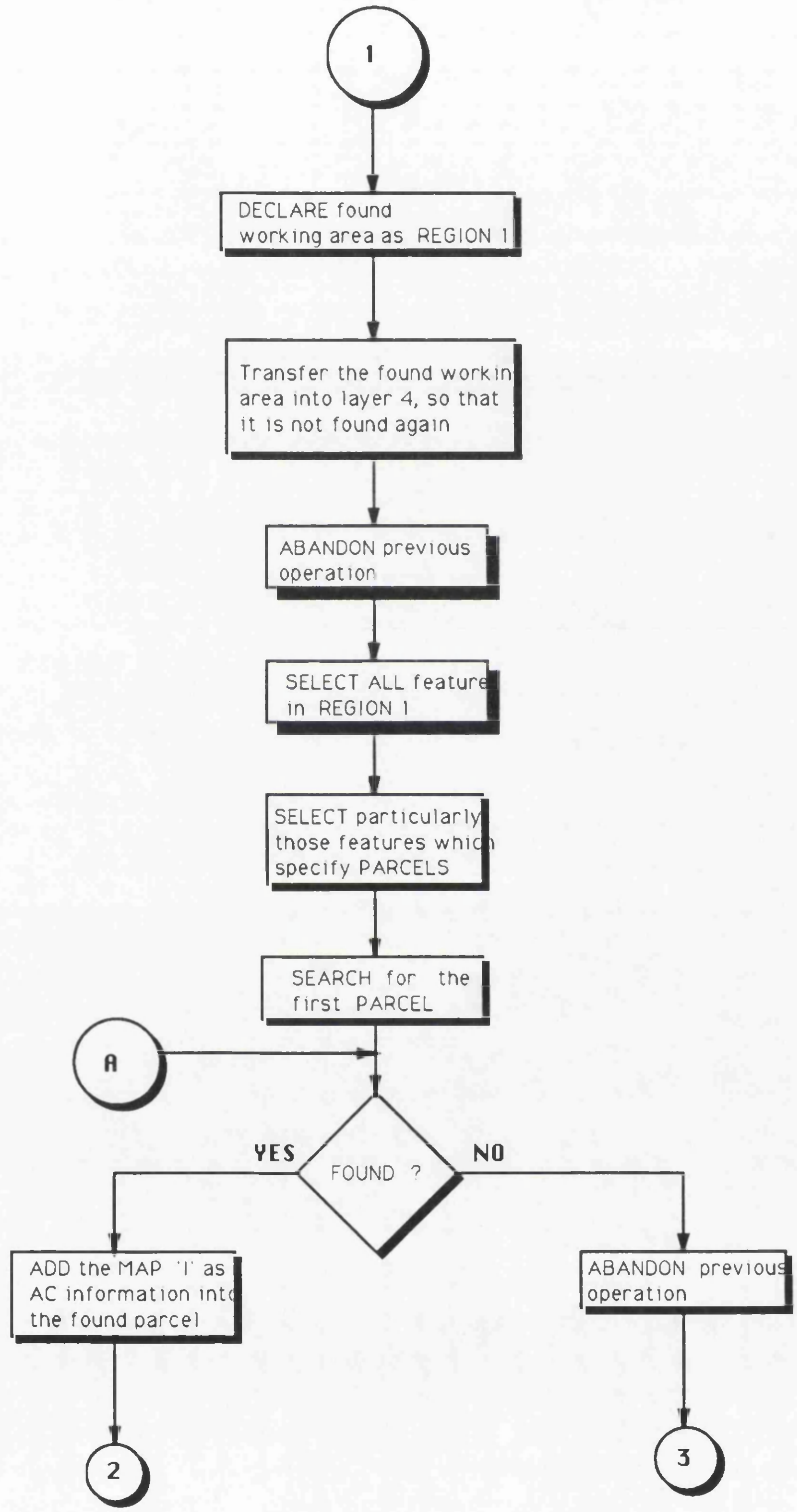
APPENDIX J.3.2

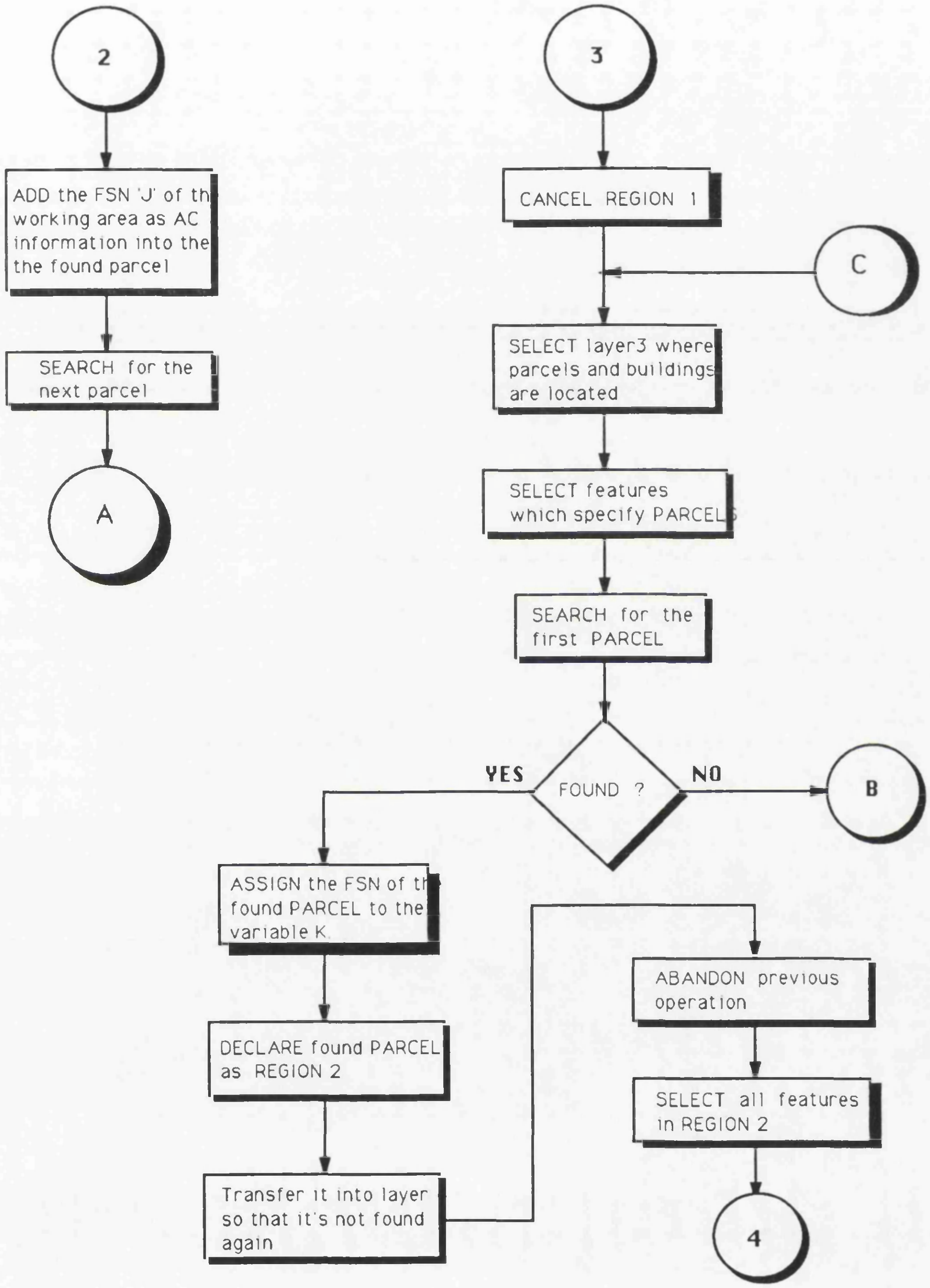
Problem Definition : Add the FSN of the working area into parcels and the FSN of a parcel into buildings lying within this parcel.

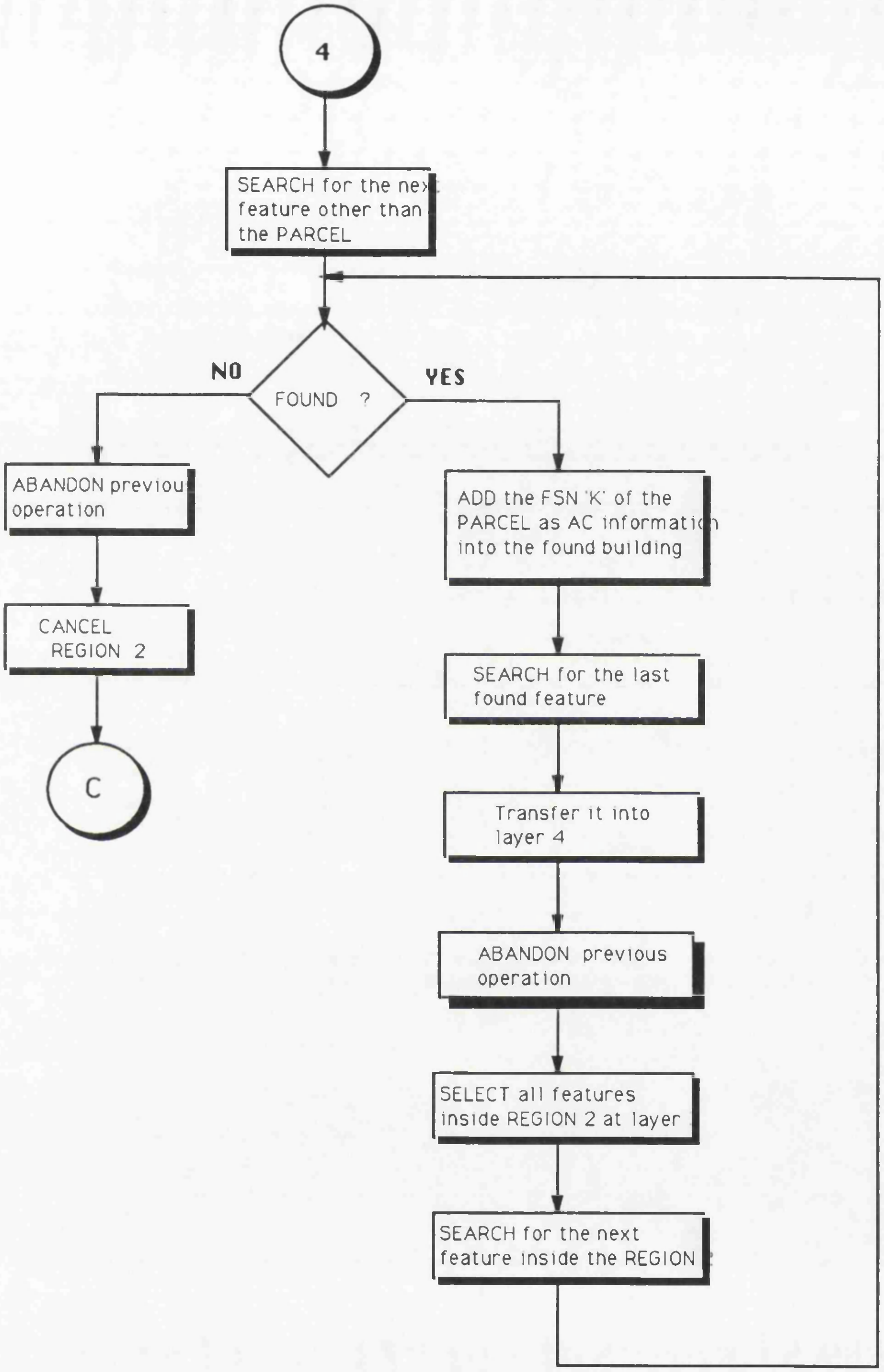
Needed Output : Features specifying buildings will have the FSN of parcel, in which they belong to, as AC information.

Needed Input : The input is to be the output from the Macro program which handles the FSNs of working areas and Blocks. (see Appendix J.3.1.).




1
DECLARE found working area as REGION 1
Transfer the found workin area into layer 4, so that it is not found again
ABANDON previous operation
SELECT ALL feature in REGION 1
SELECT particularly those features whic specify PARCELS
SEARCH for the first PARCEL
A
YES
FOUND ?
NO
ADD the MAP 'I' as AC information int the found parcel
ABANDON previou operation
2
3


2
ADD the FSN 'J' of th working area as AC information into the the found parcel
SEARCH for the next parcel
A
3
CANCEL REGION 1
C
SELECT layer3 where parcels and buildings are located
SELECT features which specify PARCELS
SEARCH for the first PARCEL
FOUND ?
YES
NO
B
ASSIGN the FSN of the found PARCEL to the variable K
DECLARE found PARCEL as REGION 2
Transfer it into layer so that it's not found again
ABANDON previous operation
SELECT all features in REGION 2
4


4
SEARCH for the next feature other than the PARCEL
FOUND ?
NO
YES
ABANDON previous operation
CANCEL REGION 2
C
ADD the FSN 'K' of the PARCEL as AC information into the found building
SEARCH for the last found feature
Transfer it into layer 4
ABANDON previous operation
SELECT all features inside REGION 2 at layer
SEARCH for the next feature inside the REGION

APPENDIX K.

APPENDIX K.1

The Accuracy of the Area of a polygon determined by the coordinates of its vertices.

It is know that the Area of a polygon can be determined by the following forms :

$$[I] \qquad E = \frac{1}{2}\sum_{1}^{v} x_i \left(y_{i-1} - y_{i+1}\right)$$

$$[II] \qquad E = \frac{1}{2}\sum_{1}^{v} y_i \left(x_{i+1} - x_{i-1}\right)$$

Assuming that $dx_i = dx$

$dy_i = dy$

which represent the errors of determination of X and Y coordinates of the polygon vertices and taking the (I) form and, according to the theory of errors we will have :

$$dE^2 = \frac{1}{2}\sum_{1}^{n}\left[\left(\frac{\partial\left(x\left(y_{i-1} - y_{i+1}\right)\right)}{\partial x_i}\right)^2 dx^2 + \left(\frac{\partial\left(x\left(y_{i-1} - y_{i+1}\right)\right)}{\partial y_{i-1}}\right)^2 dy^2 + \left(\frac{\partial\left(x\left(y_{i-1} - y_{i+1}\right)\right)}{\partial y_{i+1}}\right)^2 dy^2\right] =$$

$$= \frac{1}{2}\sum_{1}^{n}\left[\left(y_{i-1} - y_{i+1}\right)^2 dx^2 + x_i^2 dy^2 - x_i^2 dy^2\right] \Rightarrow$$

$$dE^2 = \frac{1}{2}\sum_{1}^{n}(y_{i-1} - y_{i+1})^2 dx^2 \qquad [I.1]$$

Similar result will also be for the (II) form :

$$dE^2 = \frac{1}{2}\sum_{1}^{n}(x_{i+1} - x_{i-1})^2 dy^2 \qquad [II.1]$$

Generalizing the above forms it will be :

$dE^2 = c\ dx^2$ [I.2]

$dE^2 = a\ dy^2$ [II.2]

Thus, it becomes evident that the error of Area of a polygon it is proportional of the error during the determination of the coordinates of its vertices.

APPENDIX K.2

List of Program which translates the IFF format into rows and columns. (An example-"Spaghetti").

```
program  test_oracle(inpf2,outpf);

{**     It translates the output file from the structuring process
        in SPAGHETTI technique (IFF format) to a form of rows
        and columns. (RELATION of Table 1(Fig.8.2)-Chapter 8).

        IFF1 :  output file from structuring process, in IFF format,
                which is to be the input file in the current program.

        OUT1 :  output file in the form of rows and columns.    **}


    var
            inpf2,          { input file name in IFF format }
            outpf
                                                        : text;


            RH_b,
            fsn,
            code,
```

```
LH_b,
 ii              { dummy integer }
                                          : integer;


Length
                                          :  real;



      AC,          { Dummy  Ancillary  Code }
        CH,      { It controls  new features input }
       FS      { Dummy  Feature  Serial  Number }
                                   : array [1..2]of char;


BEGIN
          writeln ('It is going to read from input file');
        reset (inpf2, 'IFF1');
        rewrite(outpf ,'OUT1' );
     WHILE  NOT  EOF(inpf2) DO
      begin
            WRITELN (' inside the first loop');
           read(inpf2,CH[1],CH[2]);
          writeln  (CH[1],CH[2]);
          IF (CH[1]='E') AND (CH[2]='F') THEN
          READLN(INPF2)
          ELSE
            READLN(INPF2,fsn);
           while (CH[1]= 'N') and (CH[2]='F') do
            begin
```

```
WRITELN(' inside the second loop');
  readln (inpf2,FS[1],FS[2], code);
  writeln(FS[1],FS[2]);
  read(inpf2,AC[1],AC[2]);
  writeln(AC[1],AC[2]);
  readln(inpf2, ii, LH_b);
  read(inpf2,AC[1],AC[2]);
  writeln(AC[1],AC[2]);
  readln(inpf2, ii, RH_b);
  read(inpf2,AC[1],AC[2]);
  writeln(AC[1],AC[2]);
  readln(inpf2, ii, Length);
  write (outpf,fsn,'  ');
  write (outpf,code,'  ');
  write (outpf,LH_b,'  ');
  write (outpf,RH_b,'  ');
  writeln (outpf,Length:9:3);
CH[1]:='s';CH[2]:='s';
end;
  writeln('just got out');
END;
  close (inpf2);
  close (outpf);
  write(' press RETURN to EXIT');
  readln;
END.
```