CHAPTER 5

SOFTWARE DEVELOPMENT :
The development of LARES (LAnd REadjustment System)

5.1 Introduction

As outlined in Chapter 3, the value-based approach to land readjustment is a complex process which requires spatial data analysis. Especially, when many land valuation factors are involved in the process, it is almost impossible to analyse these factors by conventional manual methods. While dealing with a large amount of information, to fulfil all necessary calculations, land distribution is difficult to perform manually. Therefore, current computing technology should be introduced to the land readjustment process in order to increase the speed of data and to manage information effectively.

In this chapter, the automation of the proposed model is described. A prototype land readjustment model which is to be referred as **LARES** (**LA**nd **RE**adjustment **S**ystem) was designed and developed using GIS. The development stages of the model are outlined, including the used GIS package and its associated modules. As a GIS tool, the functionality of ARC/INFO was used during the prototype development. A menu-driven system which is easy to use for the user has been created. Arc Macro Language (AML) and FORTRAN77 programming languages were used for the programming requirements.

5.2   Integration of land readjustment with GIS

A value-based land readjustment approach certainly requires an effective information management system in order to accomplish the whole process in a successful way. Land valuation analysis, for example, deals with many land valuation factors which should be spatially examined in a defined geographical unit. In addition, data input, basic calculations, data extraction, manipulation and providing all necessary information should be done precisely in a short period of time. Querying and display of any graphical or textual information is also an important for user requirements. Therefore, the integration of the value-based land readjustment with a spatial information system such as a GIS is essential.

However, as explained in Chapter 4, GIS is a system to collect, store, manipulate, use and analyse spatial information. It has the capabilities to handle all required graphical and textual data within a computer system so that any desired new information can be reached and derived from that which exists. GIS also provides great functionality to deal with complex spatial data analysis that the value-based land readjustment requires.

Due to its great functionality, the use of GIS is vital to develop a value-based land readjustment prototype model. Using the capability of GIS, the main analysis requirements of the proposed model were developed. Based on Figure 5.1, some main algorithms such as land subdivision, land valuation factor analysis, and land distribution were designed and performed. The following sections however give more details about the development of these algorithms, including the GIS tool used and the other data procedures throughout the prototype LARES.
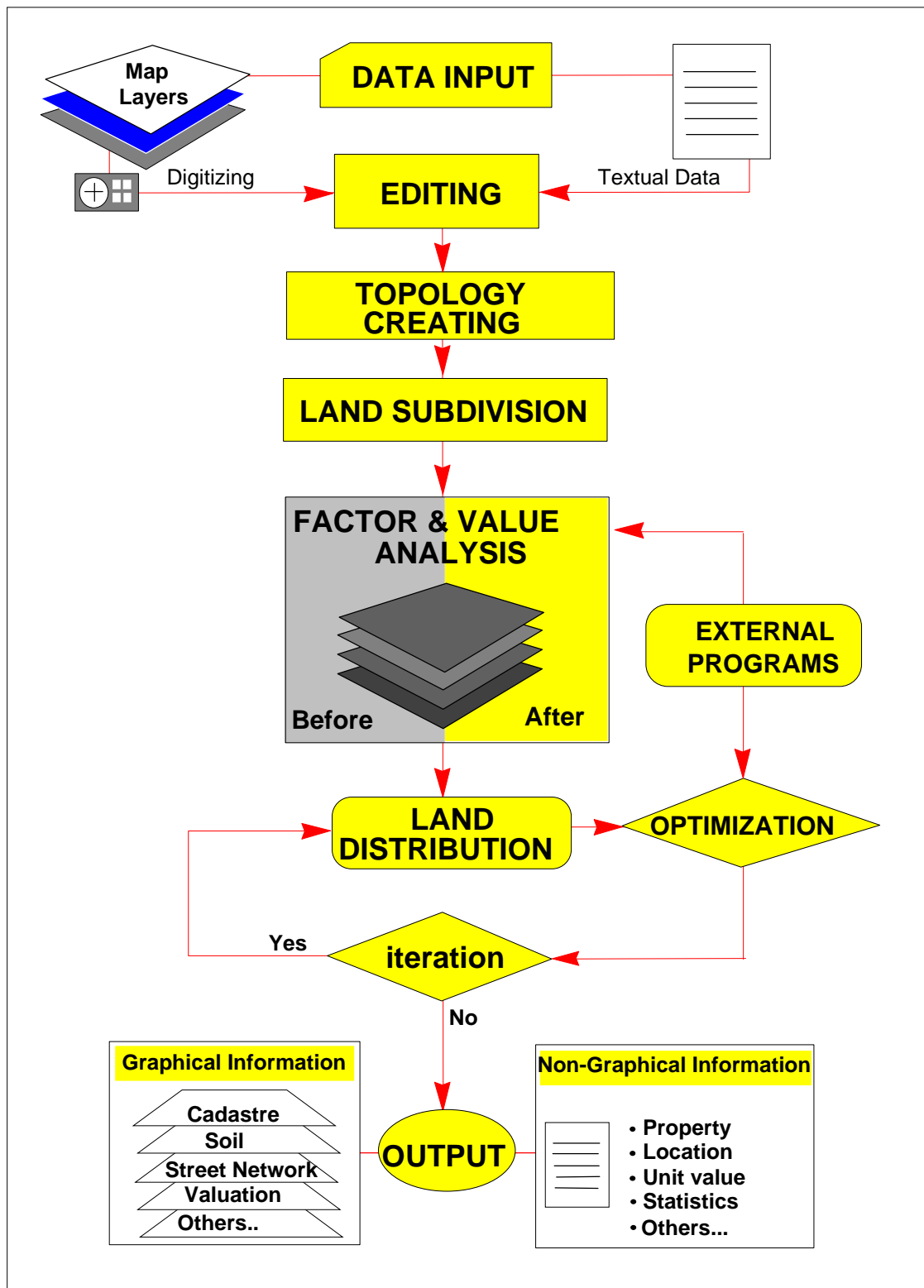
Figure 5.1   An overview of LARES

5.3   Choice of a GIS tool

To execute the required spatial data analysis for the value-based land readjustment model, the use of a GIS system is essential. Therefore, the GIS systems which would perform the requirements of the proposed model were examined. The details about different GIS tools are reviewed by Parker (1990), Taylor (1991), Bakker and Toppen (1993).

Due to its availability in the Surveying Department, ARC/ INFO GIS software was selected and used for the development of the proposed model. ARC/ INFO was selected because it is a world-wide used vector based GIS system which is suitable for the large scale applications. It has a number of vector process modules that the value-based land readjustment model requires. Such processes include polygon overlay, buffering, 3-D views and network analysis. ARC/INFO also has its own programming language which allows the user to develop independent algorithms and user interface environments for a particular application. The linkage with other external files is also possible with ARC/ INFO. However, more details on ARC/ INFO GIS system is given in Appendix G.

5.4   Software organisation

In order to design and develop the prototype model LARES, the following considerations were taken into account during the software development;

• the prototype LARES should be designed as a single model which deals with all data processing within that model,

- the required spatial data analysis should be performed by the designed model,

- an interactive user environment should be created for data extracting, editing, and displaying requirements,

- the main applications such as land subdivision, land valuation, and land distribution algorithms should be designed as different modules,

- when the query of information is required both graphical and non-graphical data should be provided quickly,

- a user friendly menu-driven interface should be designed,

- the model should allow the modification of a land valuation factor including the adding of a new valuation factor,

- all kinds of data should be stored in suitable formats for further use.

Using ARC/ INFO GIS system, the above considerations were accomplished. One of the main advantages of ARC/ INFO is to communicate to external programs via AML. AML enables users to define sets of ARC/ INFO command sequences and to be stored in files for both interactive and non-interactive use. It also provides various functions and directives for accessing ASCII data files and executing user-defined external programs. Therefore, AML and FORTRAN77 programming languages were used for the algorithm requirements.

5.4.1   Data processing

The main tasks of the software are illustrated in Figure 5.2. According to Figure 5.2, firstly, the required data is derived from the property, zoning, thematic, topographical maps, and from the other related textual records. These maps are considered as the input coverages.
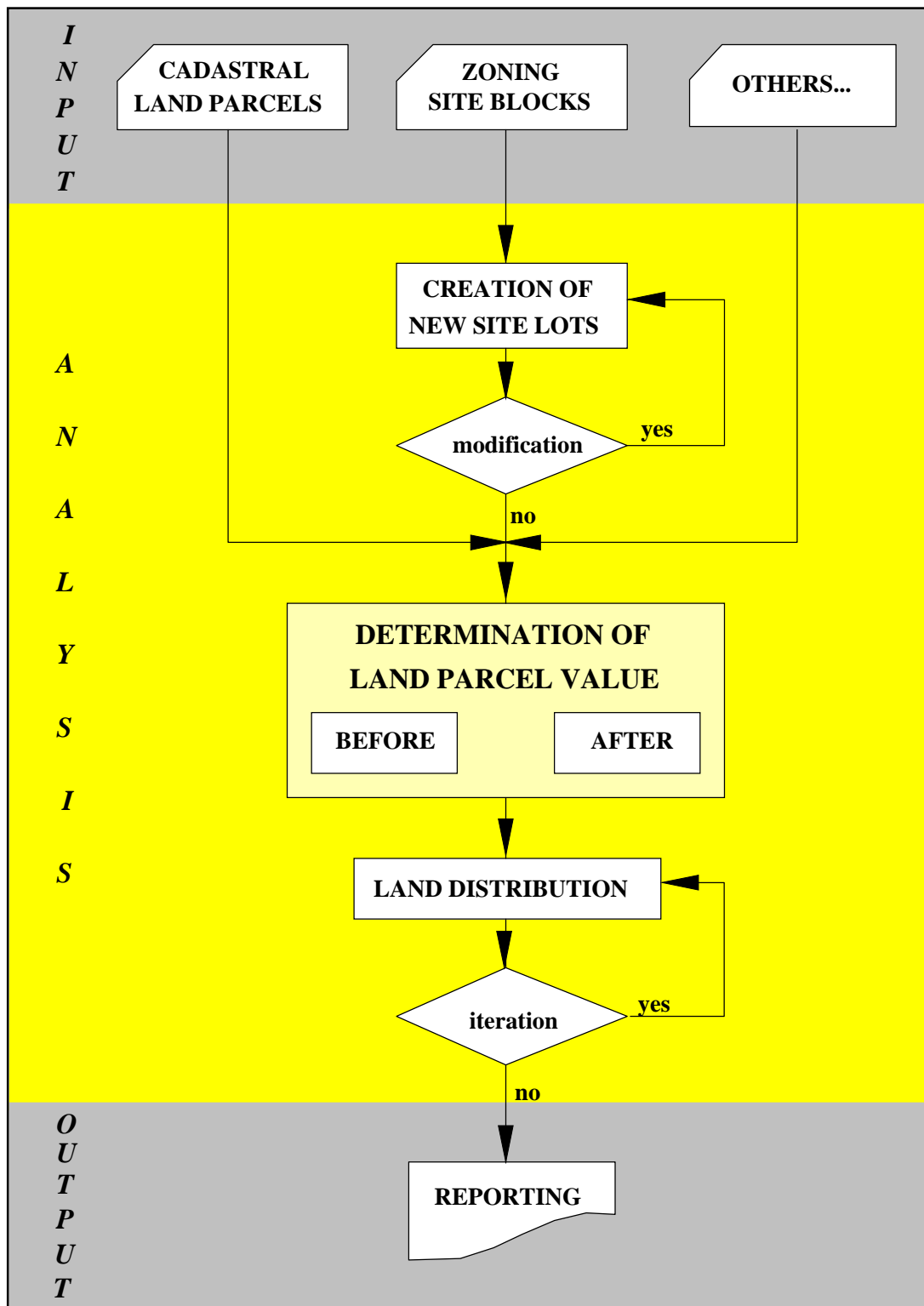
Figure 5.2   The main tasks which undertaken during the software
                  development

Then, site blocks on zoning plans are subdivided into new land parcels with respect to detailed zoning codes. Following the subdivision process, cadastral and newly created land parcels are individually analysed by the selected land valuation factors. Using the required equations, each land parcel value is determined before and after. Land distribution is then performed. Based on the calculated valuation figures, each cadastral land parcel is finally reallocated within the new lots.

In order to carry out these operations, a number of algorithms were developed. The main operations such as land subdivision, land valuation analysis, land distribution, and query of information were designed as individual modules. The development of these modules is detailed in the following sections including data storage.

5.4.2   Customisation

Throughout the data processing, many tasks are performed by different commands. Most of them are the ARC/ INFO commands which are executed very often. To avoid repeating of these commands, data processing is automated and simplified for frequently performed actions by AML macros and menus. However, the AML macros were used to organise a sequence of ARC/ INFO commands into easily performed, sophisticated data processing operations. The menus were used to develop menu-driven user interfaces to meet the needs of particular applications. The menu system of the prototype model is explained in Chapter 6.

5.4.3   Storage of data

There are two types of data to input. These are graphical and non-graphical data. The graphical data was digitised and stored as a series of coordinates which identify the locations of the digitised entities. In ARC/ INFO, this locational data is used to build topology which identifies points, arcs and polygons, so that map features are represented by sets of arcs and label points and topological relationships between connected lines and points. This spatial data is linked by common feature numbers to the non-graphical data in a relational DBMS by Arc Attribute Tables (AAT) and Polygon Attribute Tables (PAT).

Area features such as land parcels, and zoning blocks, are defined by polygons which are outlined by a list of arcs. Arcs are stored as an ordered series of *x,y* coordinates. They have unique user-IDs and all the arcs in a coverage are sequentially numbered. An arc consists of two nodes. These nodes are also sequentially numbered in ARC/ INFO. The internal arc number and the related node numbers with from- and to-node are stored in AAT.

Non-graphical data is stored in feature attribute tables. A relational database structure is used to store numerical and alpha-numerical data. Using AAT and PAT tables, the feature attribute tables are also linked to graphical data tables. The relational DBMS which forms the second half of ARC/INFO allows the user to associate and interrelate information from several files by matching selected codes which are common to each file. As illustrated in Figure 5.3, a lot-ID can be associated with each land parcel, it can be then be related to a file containing information on ownership, zoning etc. of the parcel.
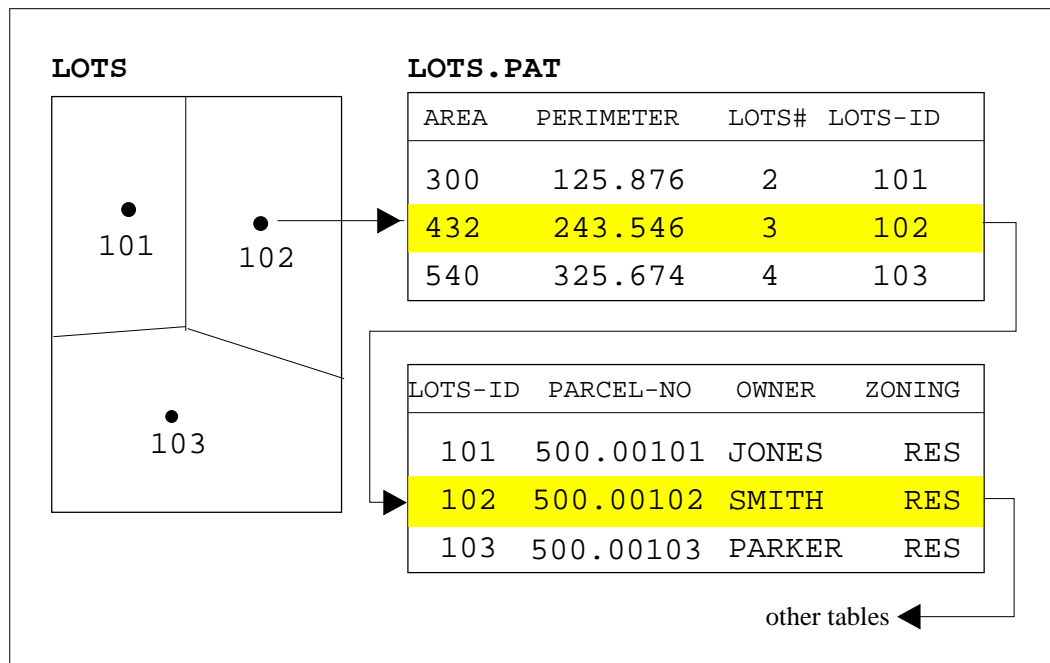
LOTS

LOTS.PAT

AREA	PERIMETER	LOTS#	LOTS-ID
300	125.876	2	101
432	243.546	3	102
540	325.674	4	103

LOTS-ID	PARCEL-NO	OWNER	ZONING
101	500.00101	JONES	RES
102	500.00102	SMITH	RES
103	500.00103	PARKER	RES

other tables

Figure 5.3   Graphic and tabular integration

5.4.4   Data check and correction

Due to digitising errors the input data must be checked before implementation. In order to make spatial analysis, the input data should be free of errors and topologically correct. This is accomplished by establishing the existing spatial relationships, identifying errors, correcting them, and reconstructing the topology. Some of the common errors that topology construction can identify are;

- Arcs that do not connect to other arcs
- Polygons that are not closed
- Polygons that have no label point or too many label points

Once data are put in ARC/INFO, the system provides two commands to create topology automatically. These commands are BUILD and CLEAN.

Although both are used to construct topology and create feature attribute tables, they differ somewhat. `BUILD` processes points, lines and polygons, whereas `CLEAN` processes only lines and polygons. However, when these commands are issued, digitising errors can be listed and display. Using the `ARCEDIT` environment, these errors are edited and corrected. Then, topology is reconstructed. This process is repeated until the spatial relationships are satisfied within a given tolerances (Figure 5.4).
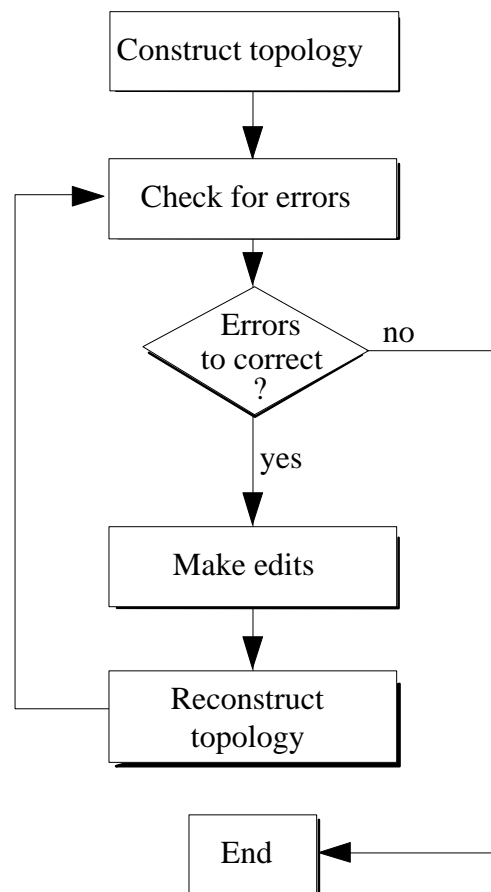

Figure 5.4 Reconstruction of topology

5.4.5 The sequence of polygon segments

In a land readjustment process, the polygons such as land parcel and site blocks are mostly dealt with as a geometrical feature. A polygon is digitised

corner by corner rather than as a continuous line. In this case, several digitised arcs make a polygon. As illustrated in Figure 5.5, an arc can also consist of several line segments as vertex between two nodes.

In ARC/INFO, line segments are stored in accordance with the digitising direction of an arc. Therefore, line segments can be stored in non-sequence form (Figure 5.6.a). This creates a problem when there is a need to know what particular parcel side follows the which one. On the other hand, the verteces are not considered as an arc in AAT tables. The verteces are represented with pseudo-nodes. However, in the cadastral process each broken line should be identified with its real-nodes and considered as a single geometrical feature.
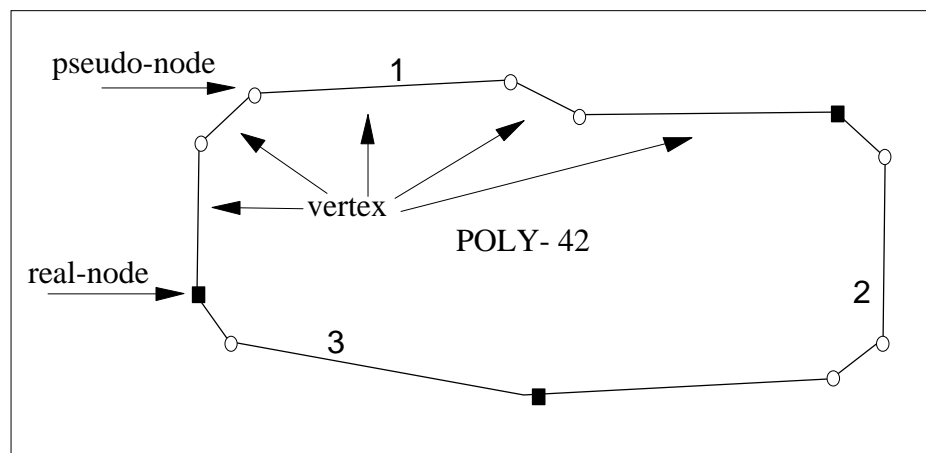

Figure 5.5 A polygon digitised with three arcs

In order to solve this problem, all pseudo-nodes were converted to real nodes and the new line segments are re-stored in a sequence form for a polygon. As a result, all corners of a land parcel were identified and the following parcel sided were re-arranged in the same direction with respect to from-to-node numbers (Figure 5.6.b).
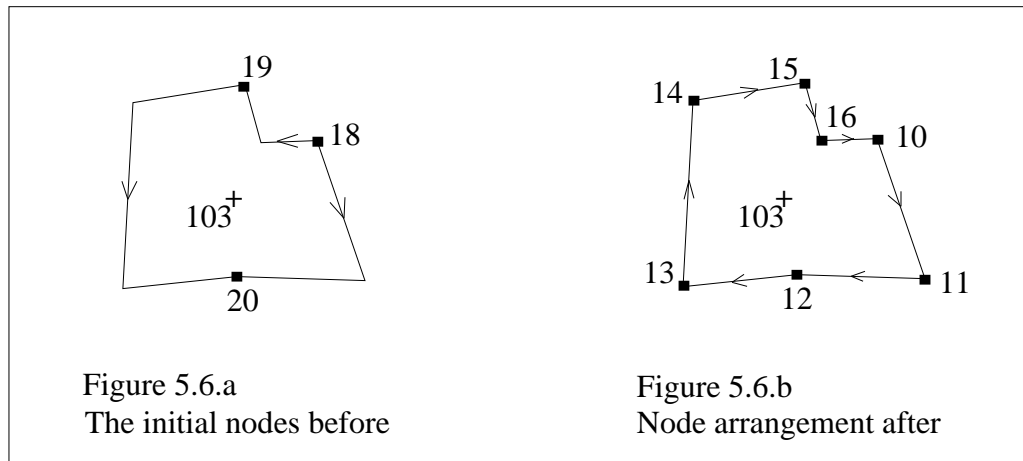
Figure 5.6.a
The initial nodes before

Figure 5.6.b
Node arrangement after

Figure 5.6 Node re-arrangement

5.5   The modular design of LARES

The single modules which perform particular tasks for the requirement of the proposed land readjustment process are explained in the following sections.

5.5.1   Land subdivision: The creation of new lots

In a land readjustment project there are two main input coverages. These are cadastral parcels and zoning site blocks. The property map which consists of cadastral parcels represents the current land-use condition in the project area. On the other hand, zoning plans represent the newly designed land patterns that aim to be applied to the land. In this plan, rather than individual new lots, only the site blocks are given, with the necessary zoning codes. So, before the project site lots do not exist on the zoning plan.   The land subdivision process is usually carried out by land surveyors during the plan implementation stage.

In the proposed model, to compare the land parcels before and after, the new lots should be created with respect to zoning details. For this purpose an algorithm was written and linked with the ARC/ INFO environment. The flowchart of this and subdivision algorithm is given in Figure 5.7.

The land subdivision programme, first, reads the AAT and PAT tables of the input zoning coverages. In the AAT table, there is the re-organised line segments with their internal node numbers and coordinates of these nodes. On the other hand, PAT tables hold the attribute records of the zoning plan with the associated zoning codes. Following the data reading, site lots are created block by block.

Once a site block is taken, the algorithm determines the corner positions of the block then finds out two reference points on the long sides of the block. These are called upper and lower points (Figure 5.8.a). Based on both these reference points and minimum street frontage, the top corner of the new lot is positioned (Figure 5.8.b). Then, the other corner of the new lot is positioned with the aim to create a lot with a square shape (Figure 5.8.c). When a lot is created its area is calculated and compared with the given minimum area. If the created lot area is smaller than given area, the previous street frontage is increased and process is repeated. When a new lots is successful with the given zoning area, then the other lots are created using the same procedure.

If a site block has a very complex geometrical shape, after a certain number of iterations of the process, the subdivision program stops subdividing that block and gives a warning message to the user that editing is needed. Therefore, after the execution of the land subdivision program, some editing would be required.
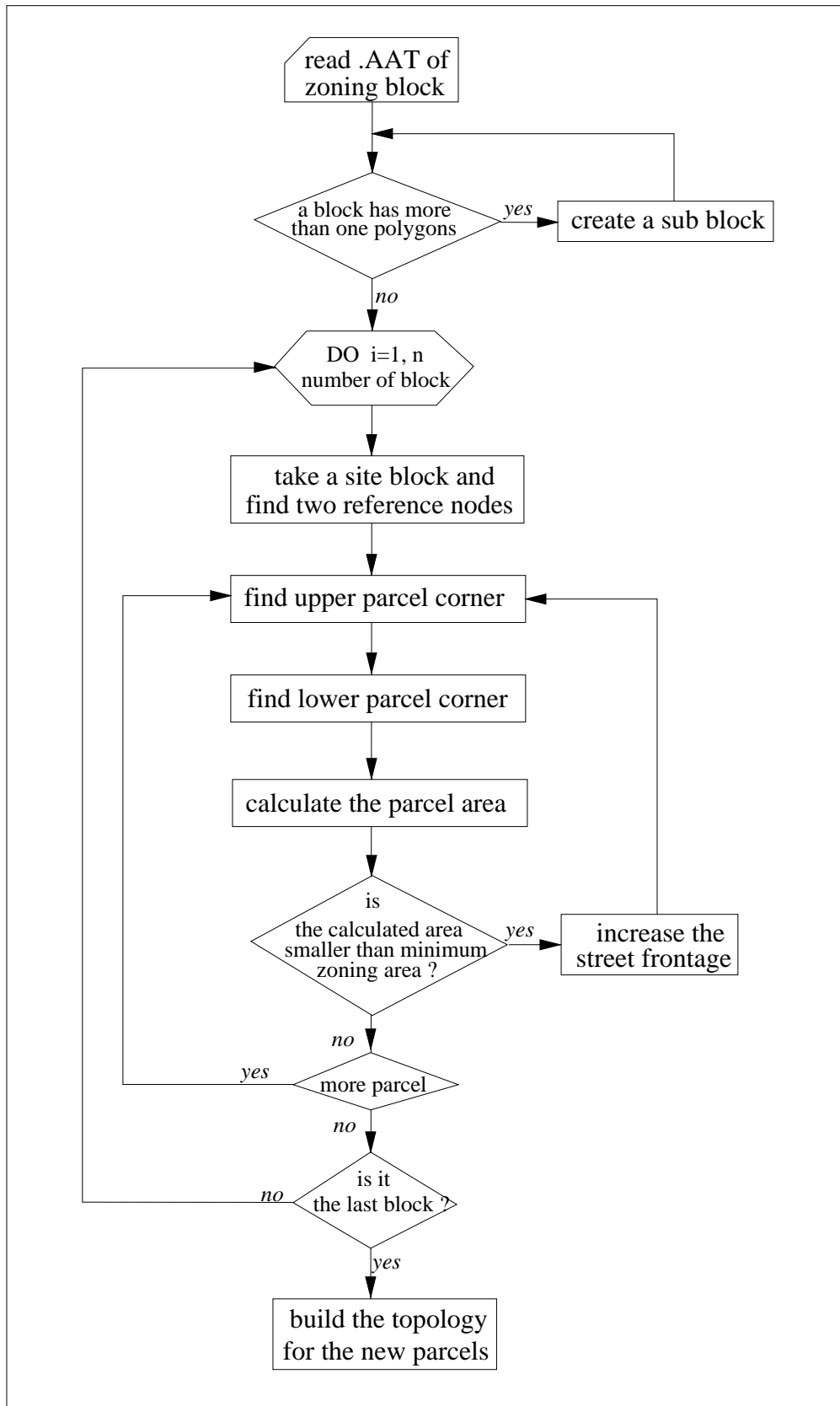
Figure 5.7 The flowchart of land subdivision algorithm

A user may also wish to change a produced lot shape. In these cases, the `ARCEDIT` environment is used to complete the subdivision process. When the subdivision of the site block is fully completed, then the final check is done automatically regarding the zoning requirements. The topology of new lots are then created for further use.
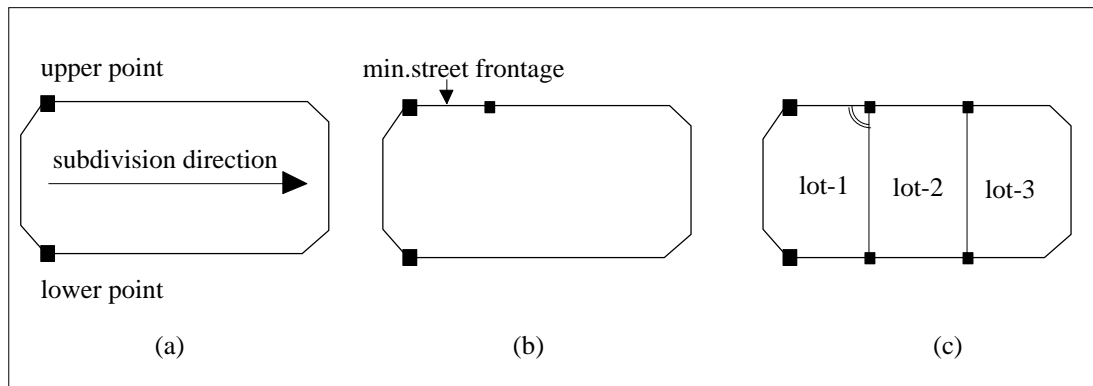

Figure 5.8   Parcel creation

5.5.2   Land valuation factor analysis

Following the land subdivision process, land valuation factor analysis is carried out for both cadastral parcels and the produced new lots. In this stage, land valuation factors are individually selected and related factor formulas applied. To determine a land parcel value, the algorithms were designed for each land valuation factor. The design and development of these algorithms is discussed in the following sections:

(a)   **Determination of topographic factor value:**

Formula [3.3] is used to calculate this factor value. According to this formula, the corresponding slope values of a land parcel should be examined. Therefore, the input coverage which contains the contours was considered. Using the contour lines with their attached heights, a slope coverage was

created by the `TIN` module of ARC/INFO. This coverage represents the slope polygons which includes the slope percentages. This slope coverage was then overlaid on the cadastral and lot coverages. The slope values of the corresponding areas were considered to determine the total value of a land parcel. In the determination, the surface area of a land parcel is used rather than its flat area. Figure 5.9 illustrates the calculation of topographic factor value of a land parcel.
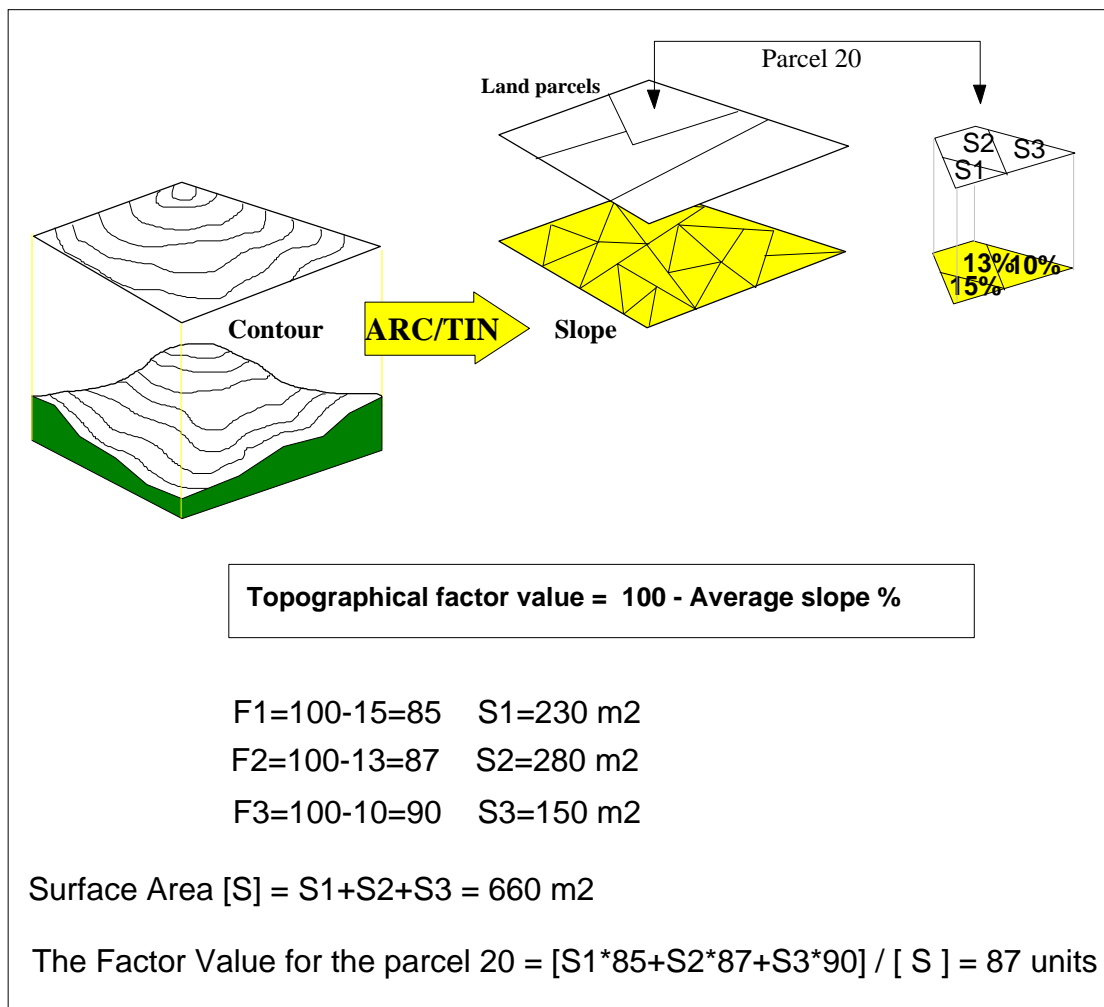

Figure 5.9 Topographic factor value analysis

(b)   Determination of factor value for environment, soil condition and usable area:

Due to their similar formulation these three factors are calculated in the same way. The related map coverage is overlaid with the land parcel's coverage. Then, based on the combination of these coverages, the factor value is determined. Basically, this overlaying process is done through `UNION` command of ARC/INFO. The process is illustrated in Figure 5.10.

Surface area of the parcel 32 = S = S1 + S2 + S3 = 230 + 110 + 85 = 425 m2

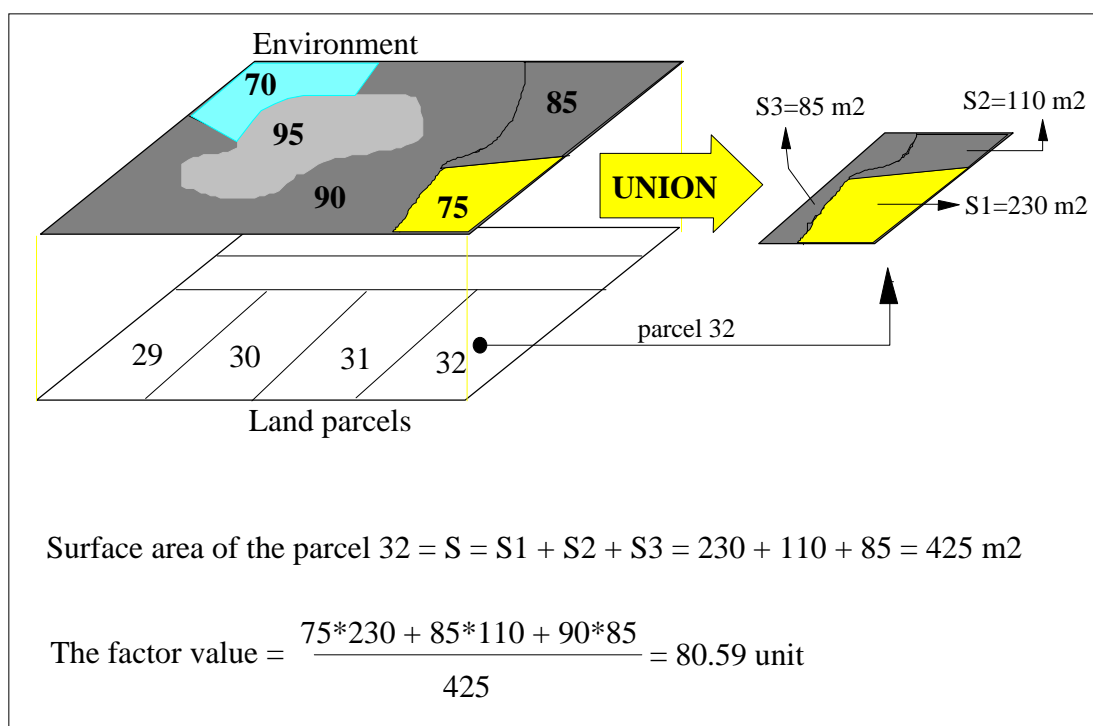The factor value $= \dfrac{75*230 + 85*110 + 90*85}{425} = 80.59$ unit

Figure 5.10 Environmental factor value analysis

(c)   Noise and nuisances:

To determine the noise and nuisance effects, the road coverage is basically examined with the land parcels. The roads are considered as the main noise resources due to traffic movement. Besides, a coverage which includes some other noise and nuisance places such as airport, entertainment places, are also combined with the road coverage and a new layer is created. On this new coverage, buffer zones are created around the roads and the noise places. The

roads are classified in accordance with their width. The direct distances from the centroid point of parcel to the closest point of noise or nuisance buffer zones are calculated. Then, based on the illustration in the Figure 3.8, these factor values are determined for a land parcel.

(d)   Shape:

The shape factor is determined by examining the number of parcel corners and distance between these corners. The coordinates of parcel corner are read from the input coverages and based on the formula [3.4], the shape factor is calculated. An algorithm which calculates the shape factor value is illustrated in Figure 5.11.

(e)   Street frontage and access to street:

For the street frontage, land parcel coverage is overlaid on a coverage which contains the block outlines only. When a block outline and a parcel boundary share the same arc then the total length of these shared arcs or line segments are taken into account in the value calculation. An example for the calculation of street frontage value is illustrated in Figure 5.12. During this operation, if a parcel shares any boundary with a block outline, then the parcel is considered as an accessible parcel from the road and assigned with 100 value. Otherwise it is considered as non-accessible parcel and assigned with 0 value.

(f)   Location within site block:

A site block and related land parcels are examined. Within the same block, the distance from the centroid point of a block to the centroid points of land parcels are calculated. The most far off parcel from the block centre is taken as the most valuable parcel inside the block. Then, using the formula [3.8], factor values is determined for the other parcels within the block.
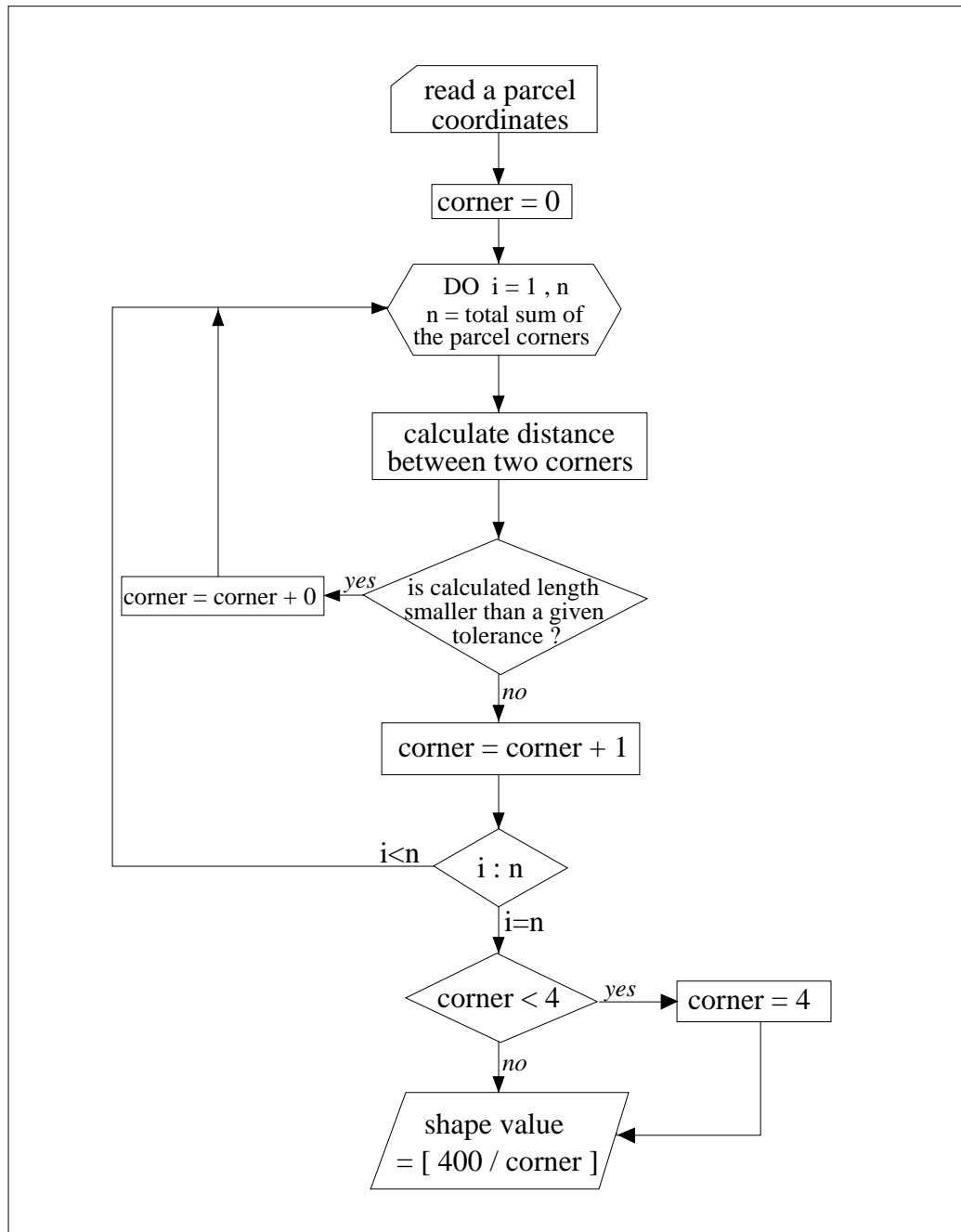
Figure 5.11   The flowchart of parcel's shape calculation

(g)   <u>Permitted number of floors, construction areas:</u>

These factors are only considered for the new site lots because of the new zoning requirements. The factors are determined by the aid of zoning feature attribute tables and the required formulas. Information about these factors are included in the zoning PAT table as descriptive data. This PAT table is linked with the new lots and the corresponding data is examined for a lot.
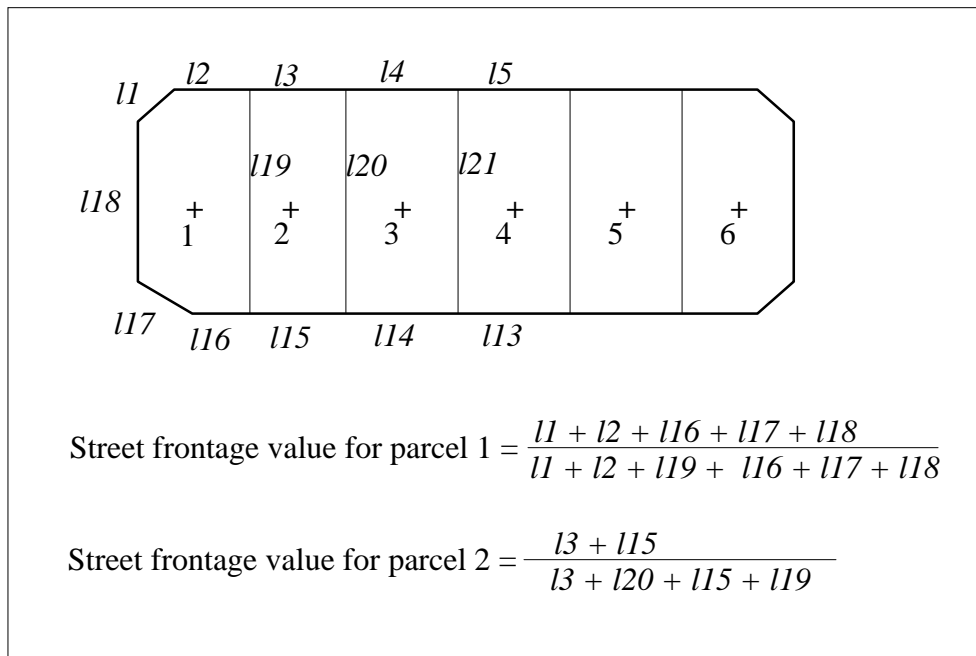
Street frontage value for parcel 1 $= \dfrac{l1 + l2 + l16 + l17 + l18}{l1 + l2 + l19 + l16 + l17 + l18}$

Street frontage value for parcel 2 $= \dfrac{l3 + l15}{l3 + l20 + l15 + l19}$

Figure 5.12   Analysis of the street frontage factor value

(h)   Supplied services and available utilities:

These factors are also given as the input data and stored in PAT tables. Using these tables, both cadastral and new site parcels are examined with respect to the related formulas.

(i)   Proximity to shopping areas, health services, educational places, play gardens, recreational areas, religious places, city centre, car park, fire station, police station, access to highway, railway and waterways:

For the proximity analysis, first, a street network coverage is created. The parcel coverages and road coverages are combined together to build an input coverage for this process. On this new coverage, the parcel centroid points are linked to road axes. In the linkage process, a parcel centroid point is connected to the closest street frontage segment. So, a node is marked on the frontage segment. Then, this node is linked to the closest road segment. Finally, the shortest path from the centroid point of parcel to road segment is

defined and road-parcel connection is accomplished. This connection process also applies for the target points. The target points can be considered such as library, hospital, shops, metro station, city centre. The connection of an hospital building to the closest road segment is geometrically identified. At the end of the road-parcel and road-target linkage process, a new line coverage which represents the street network is created for both the cadastral and the new land parcels (Figure 5.13).

Using the created network coverage, the shortest paths from a parcel to a target point is calculated and factor value is determined. Along the path, the 3-D surface is considered. Therefore, surface distance is used for the length unit, rather than planimetric distance.

In the street network coverage, ARC/ INFO `TIN` modules were first used to determine the surface length along the line segments. Then, to find out the shortest path between the given two nodes, these lengths and from-to nodes were loaded into the `ROUTE`modules of ARC/INFO.

Sometimes more than one factor target may exist. For example, in a project area, a few shopping centres, schools etc. could be located. The algorithm also examines these conditions and takes the closest target point for the land parcel.

Figure 5.13   The street networks for old and new land parcels
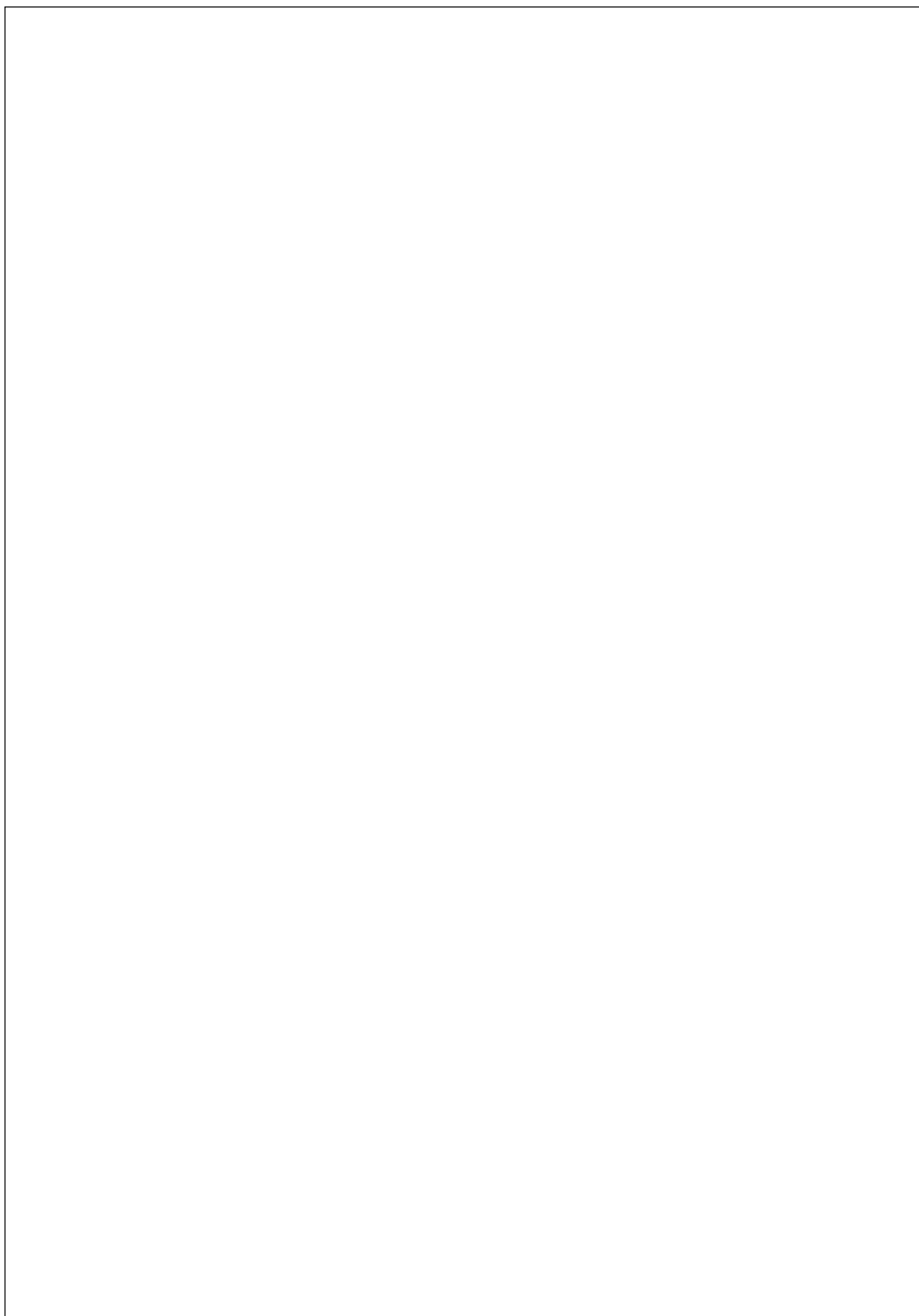
(j)   View:

On a topographic surface, two points are defined as inter-visible if it is possible to connect the two points with a straight line segment without intersecting any part of the surface. For the analyses of visibility between land parcels first a TIN model is created.   Then, a visibility region is determined by a circle. Using ARC/ INFO `visibility` function, land parcels are examined individually.   `Visibility` uses a lattice file to determine visibility by calculating the number of times an area is seen from viewpoint. If the two points are inter-visible view value is taken as, $V = 1$. If the two points are not inter-visible $V = 0$. (Figure 5.14). During the visibility analysis, instead of using the ground elevations of viewpoints, new elevations are defined for the land parcels with respect to building's heights.
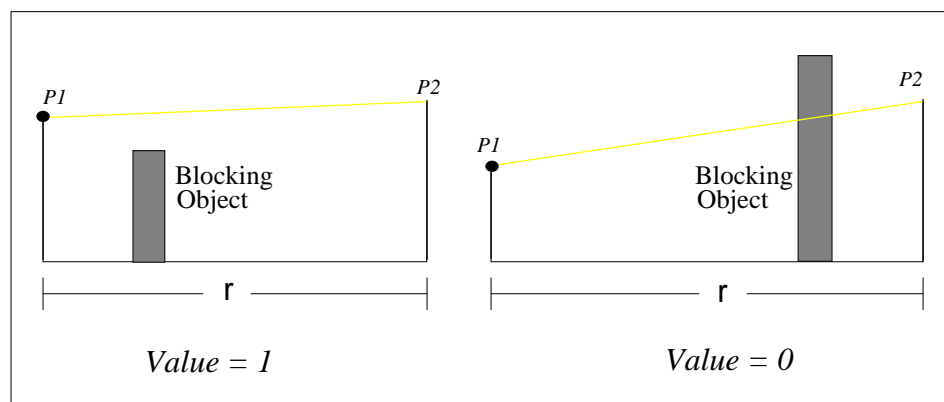

Figure 5.14   Inter-visibility and blocking object

5.5.3   Calculation of parcel values

Following the determination of each factor value, the parcel values are calculated by the equation [3.2]. This equation is applied to both the old and new land parcels. Then, the individual land parcel valuation results are used in the determination of the total values of the project area, before and after. As explained in section 3.3.2.3, these total values should be equal in the value-based land readjustment model. This is provided by equation [3.15]. At the end of all the calculation procedures, the final land parcel values which are subject to reallocation are stored for the land distribution process.

5.5.4   Parcel distribution

Land distribution is carried out block by block. First, the cadastral and new parcel coverages are combined. Then, the cadastral parcels which match a zoning block are grouped and reallocated within the same block in accordance with their old location and the input value. In this process, the total value of the grouped cadastral parcels are compared with the total value of the new lots within the block. If the total value of the cadastral parcels is not sufficient for the zoning block, than the closest parcel or parcels to the block are included in the cadastral parcel's group. The main idea here is to fill a zoning block with the corresponding cadastral parcels regarding the value and their original location. When sufficient value is provided for the block, then land distribution is accomplished in that parcel base. A simple example for the distribution process is basically illustrated in Figure 5.15.

Figure 5.15 An example for land distribution

After land distribution, some of the new land parcels can be shared between more than one cadastral parcel. This occurs because the limits of a new parcel size are given by the zoning plan that must be followed. However, the number of shared parcels can be decreased by giving a tolerance value. This tolerance is considered during the comparison of old and new parcel values. When the new parcel needs more value to fill it up, then the required value is compared with the given tolerance. If the needed value is less than the given tolerance, the required value can be ignored for the new parcel. The determination of the tolerance value depends on the value accuracy which the user is expected to provide. So, the involvement of tolerance value for the process is optional.

5.5.5 Outputs

After the whole calculations and spatial analysis, all results, input and output information both graphical and textual, including land valuation maps with 3D visualisations, street networks, ownership records, and land distribution tables are stored for the display at user's request. Using the `ARCPLOT` facilities, a query modules which provides the above information was designed for LARES. More details on the data presentation and query modules are given in Chapter 6 under section 6.4.5 and 6.5.

5.6 Modification of LARES

The modification of the prototype model allows for further development of LARES. When some changes are required on the existing modules, the user

should follow the AML and FORTRAN files to do these changes. Modification may be needed for the following procedures.

5.6.1   Valuation factors

In the LARES, each land valuation factor has a single algorithm which was developed in accordance with its own valuation formula. Each of these valuation factors was also assigned a unique factor code. These codes are used to link a valuation factor with its related written algorithms. When a user wants to modify a valuation algorithm, the valuation codes should be considered (Figure 5.16). These codes are also assigned with some of the other files which are related. For example, for a land valuation factor, a coverage file and its input and output files are represented with the same factor ID. Although each land valuation factor is designed separately, the modification of factor does not affect the other valuation factors. On the other hand, a new valuation factor would also be attached to the model by following the same procedures.
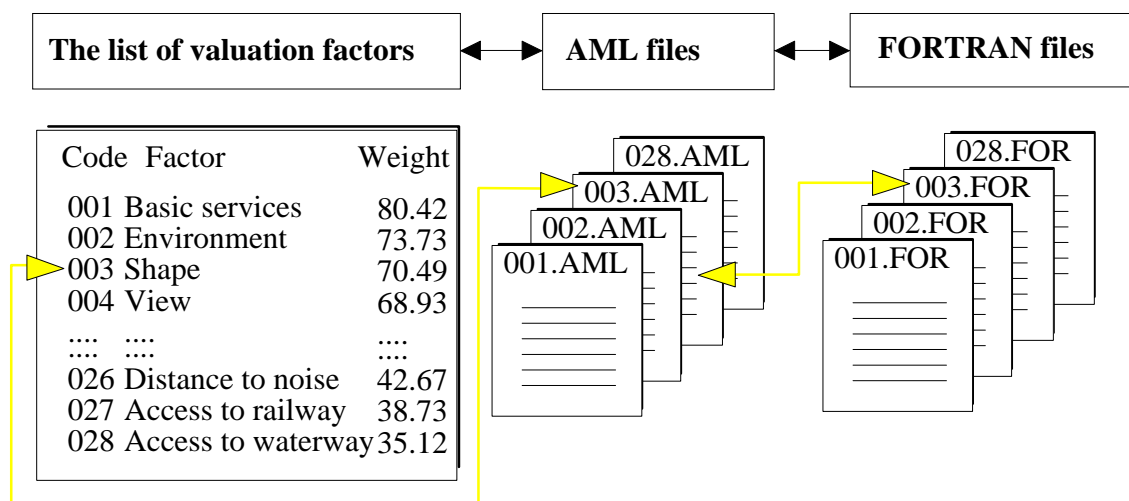

Figure 5.16   The linkage of valuation factor, AML and FORTRAN files

5.6.2   Factor weights

If a weight change is required for a particular land valuation factor, this can be done in the factor valuation file. Within the weight column of the file, only the factor weight data is changed. As illustrated in Figure 5.16, the data format should be same as before.

5.6.3   Menu changes

The whole process is customised by AML. Using the functionality of ARC/ INFO AML, a menu-driven system has been established. This menu system provides an easy-to-use interface employing a mouse to select desired menu choices. The menu system consists of some main menus such as *valuation* and sub-menus such as *factor-selection* under the *valuation* menu (Figure 5.17). A user can perform the ARC/ INFO commands without leaving the menu-driven system. A particular application can also be included in the main menu and run through it. In order to improve the functionality of the LARES menu, the menu design can be modified in a various ways. Based on the user's requirements, these changes are done via *.MENU files.
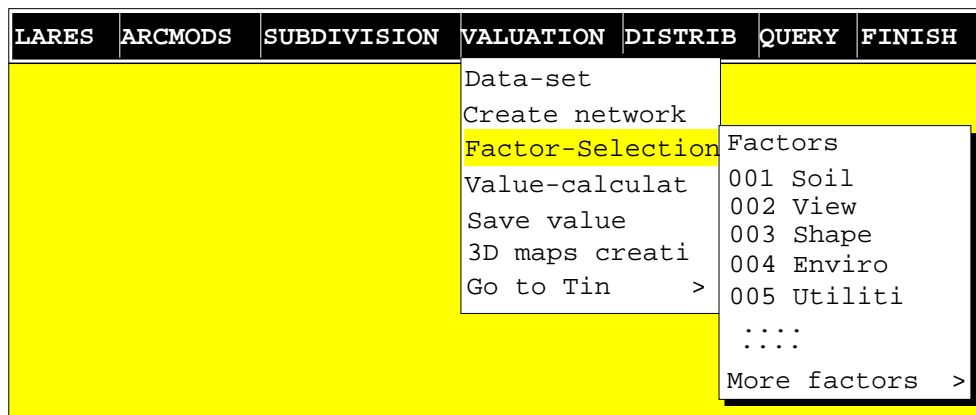
```
LARES  ARCMODS  SUBDIVISION  VALUATION  DISTRIB  QUERY  FINISH
                             Data-set
                             Create network
                             Factor-Selection  Factors
                             Value-calculat    001 Soil
                             Save value        002 View
                             3D maps creati    003 Shape
                             Go to Tin      >  004 Enviro
                                               005 Utiliti
                                                ....
                                                ....
                                               More factors  >
```

Figure 5.17   The view of land valuation menus

5.7   Chapter summary

In this chapter the software design and development for a value-based land readjustment model were described. The integration of land readjustment with GIS was followed by the development of a prototype model. This prototype model which has been referred as LARES was designed to perform all computing requests of the value-based land readjustment process in a single computing environment.

ARC/ INFO software has been used as a GIS tool for the spatial analysis and data management requirements. Using the functionality of ARC/ INFO, the algorithms which deal with the land valuation factors were developed. The main operations such as land subdivision, land valuation analysis, and the distribution of land parcels were designed and developed as different modules. However, LARES was designed to combine all these operations within a single model to manage the data process effectively. To perform any required task easily, menu-driven system was also created for the user. This menu system including the modules of LARES will be described in the following chapter.