UTILIZING GIS FOR THE ASSESSMENT OF HISTORICAL STRATIFICATION IN BERGAMA (PERGAMON) AS A SUPPORT FOR CONSERVATION DECISION-MAKING PROCESS

A. G. Bilgin Altınöz

METU, Faculty of Architecture, Department of Architecture, İnönü Blv., 06531 Ankara, Turkey – bilgin@arch.metu.edu.tr

KEY WORDS: Multitemporal, Method, Decision Support, GIS, Heritage Information Management, Urban Conservation, Multi-layered Towns, Bergama (Pergamon)

ABSTRACT:

Bergama is a *multi-layered Anatolian town*, which possesses the traces and material remains of different eras within its contemporary urban form. In order to sustain the multi-layered character of Bergama, the *multitemporal spatial data* concerning historical stratification should be considered as an integral part of *conservation decision-making process*. Hence, a *decision supporting study*, in which *GIS* is considered as the main tool, has been accomplished. In this paper, the main phases of the study are defined, together with the results provided through them. Considering the outcomes of the case of Bergama, the paper concludes with a discussion on the pros and cons of the GIS based assessment method in formation of a heritage information system to support the conservation decision-making process in multi-layered Anatolian towns.

1. INTRODUCTION

Being subject to continuous inhabitancy beginning from early ages onwards, majority of the towns in Anatolia possess physical traces of different eras as different layers within their historical development processes, thus denoting them as *multi-layered towns*. In multi-layered towns, it is the admixture of different layers and their relation with each other what contribute to urban identity through diversity and specificity. Hence, conservation and management studies should prominently consider their multi-layered character.

Today, most of the multi-layered Anatolian towns are faced with the danger of losing their multi-layered character and resulting in one-dimensional areas. Along with many other causes, one of the main reason for this, is the incompatibility of conservation decisions and interventions with the physical structure and historical stratification of the town. Comprehensive, correct and utilizable information about historical stratification of the multi-layered town should support the conservation decision-making process so as to sustain the town's multi-layered character. This calls for processing complex and huge amounts of data coming from various sources in various formats.

Developments in information technology have been providing invaluable tools for handling complex and huge amounts of data, among which GIS have a special concern for dealing with spatial ones. GIS offer a medium compatible with multi-dimensional dynamic nature of multi-layered towns and allow for the integration of various data concerning different layers of the town.

In the view of these considerations, an *information based* assessment method has been built up for structuring, analysing and evaluating the multitemporal data about historical stratification as a decision support in multi-layered towns by using GIS[*]. In order to provide terminological, syntactic and structural standards, the elemental phases to be followed, terminology, format and means of providing, documenting and presenting data and system of rules in relating and questioning them are defined.

Following is the implementation of this method on the case of Bergama (Pergamon), which is an outstanding representative of multi-layered Anatolian towns.

2. ASSESSMENT OF HISTORICAL STRATIFICATION IN BERGAMA

Bergama possesses a distinguishable multi-layered character as a result of continuous occupancy since early ages onwards. The inhabitation in and around the town is considered to be dating back to Prehistoric ages, although the earliest material remains which exist today belong to Geometric and Archaic Eras (Radt 2002: 21-23). In the contemporary town of Bergama, it is possible to visualize traces and remains of Hellenistic, Roman, Principalities, Ottoman and Turkish Republican Eras as different layers constituting the urban form.

Inspite of the multiplicity of layers belonging to different periods, the town is –unfortunately- faced with the danger of losing its multi-layered character in the near future. Major reason for this problem is the deficient consideration of the data concerning multi-layeredness in the urban conservation management and conservation decision-making processes. Being common to most of the multi-layered Anatolian towns, this problem has been studied through the case of Bergama as an important representative of such towns.

The execution of the study required various softwares among which GIS played the major role. The basic softwares utilized are Adobe Photoshop 5.0, AutoCAD R14, and ArcViewGIS 3.2. The major system properties of the PCs utilized during this

[*] This study was carried on as a part of the Ph.D. Thesis of the author (Bilgin Altınöz 2003).

study are Pentium III – 750 with 250 MB RAM, 20 GB HDD, 16 MB Graphic Card.

2.1 General Structure and Content of the Assessment Method

In building up the assessment method, specification of the context, objectives of the study and competencies of the tool are considered prominently as the three major components of the study.

As the basic specification of the context, *multi-layeredness*, has been effective in determining the elemental phases of the study and in defining the means of dealing with data of *spatiotemporal / multitemporal* character. Accordingly, the common concepts and methods used by disciplines for which stratification is of major concern, namely archaeology and geology, and the models developed for the conception of time / space relationship by cartography, contributed to the formation of the method of this study.

Conserving, sustaining, enhancing the material remains and traces constituting the multi-layered character of the urban form is the aim of this study. Thus, allowing efficient and sufficient integration of the data concerning historical stratification into conservation decision-making process is defined as the main objective. Consequently, the elements of urban form of different periods and the information necessary for identifying, understanding, evaluating them for conservation decision-making played an important role in the configuration of the method and its content.

Last but not least, GIS as the main tool of the study, has been influential both in defining the major steps to be followed and in determining the data types, format and structural scheme of the method.

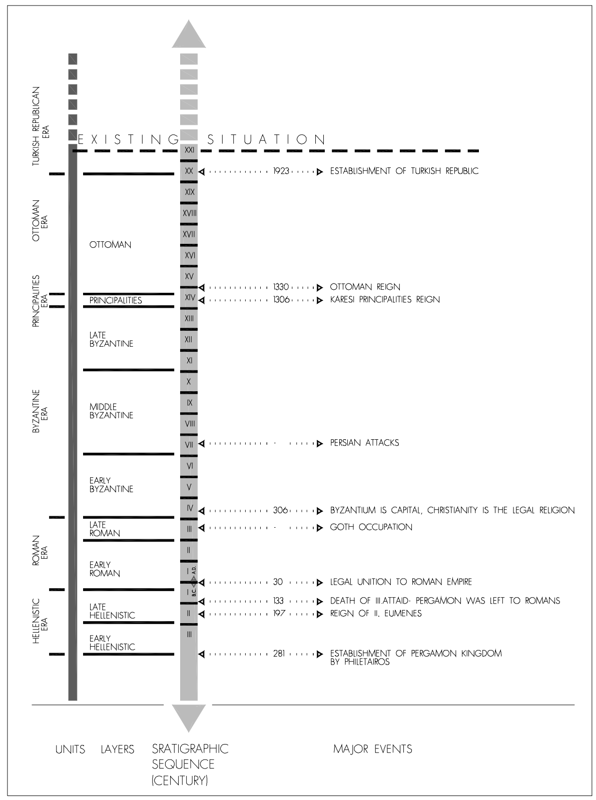
Accordingly, the major phases of the study, which are achieved through a thorough study and evaluation of stratigraphic studies and GIS based ones, are (Bilgin Altınöz 2002: 134):

- Identification of layers, determination of stratigraphic units and their stratigraphic sequences
- Stratigraphic recording and representation:
  - Data collection, entry and correction
    - Collection and classification of raw data
    - Conversion of raw data into digital data
  - Data storage, structuring and retrieval: Constitution of GIS data model
    - Spatial data structure
    - Attribute data structure
- Stratigraphic correlation, analysis and evaluation: Data manipulation and analysis
- Presentation of results: Data visualization, output and reporting

2.1.1 Identification of Layers, Determination of the Stratigraphic Units and Stratigraphic Sequence: The layers of historical stratification in Bergama are identified considering the interfacial changes, which correspond to major events reflected in the physical structure of the town, and the major periods defined for Bergama in literature. Accordingly, the layers constituting the historical stratification in Bergama come out to be Early Hellenistic (Philetarian town – 3$^{\text{rd}}$ century B.C.), Late Hellenistic (Eumenes' extension – 2$^{\text{nd}}$ century B.C.), Early Roman (1st century B.C. - 2nd century A.D.), Late Roman (3rd century A.D.), Early Byzantine (4th - 6th centuries), Middle Byzantine (7th - 10th centuries), Late Byzantine (11th - 13th centuries), Karesi Principality (1300 – 1330), Ottoman (1330 and 1923), Turkish Republican (1923 onwards) periods.

Even though these periods form up the layers of the town, like it is in every kind of stratigraphic studies, they do not directly correspond to the *units* of the *decision supporting study*. The units of the study are decided upon the divergences and similarities of the urban and architectural properties. Thereupon, for this study, the units are determined as Hellenistic, Roman, Byzantine, Principalities, Ottoman Periods and Existing town, considering the differentiation in architecture and / or urban form, as well as the existence of data about them (figure 1).

Figure 1. The major events, layers and units in relation to stratigraphic sequence in Bergama (Bilgin Altınöz 2002: 162).



2.1.2 Stratigraphic Recording and Representation: In recording and representing multitemporal / spatiotemporal data, models developed for the conception of time / space relationship, the methods of representation used by disciplines dealing with stratification, and the structure and data model of GIS are considered with regards to the objectives and content of the study.

Information about historical stratification necessitates comprehensive information about the urban form of each stratigraphic unit and their relation with each other. Therefore, among various models developed for the conception of time / space relationship, *sequent snapshots model*, which reflects the state of layers at the interfaces, is found to be the most proper model for recording and representing multitemporal spatial data concerning historical stratification. Although, this model is not mentioned as the most efficient model for GIS based studies due to indirect indication of changes and production of redundant data (Langran 1993: 37-43), it is the most common method in stratification based studies, where the layers necessitate to be studied first separately and then altogether, so as to understand each layer together with their position within the whole. Thereupon, in this study, the components making up the urban form of each phase are documented as they appear at the interface and studied separately, which are then put all together to form up the whole information system.

Keeping this basic guiding principle in mind, stratigraphic recording and representation phase is handled in two steps, which are common to all GIS based studies. Those are, data collection, entry and correction and data storage, structuring and retrieval.

Data Collection, Entry and Correction: The first step of this phase is to collect and classify the raw data concerning the predefined units of the study. For this, an extensive literature, archival and site survey had been carried on so as to provide data about the urban form of Bergama in different periods. Basic data sources of this study have been, historic maps, engravings, old drawings and photographs, drawings produced during archaeological excavations, plans concerning different periods of the town, existing maps, contemporary photos, aerial photos and satellite images, travelers' books, reports of plans and projects, reports of archaeological excavations, articles and books concerning different aspects of the urban form, inventories of the registered buildings. Besides these basic sources of data, site survey is always the most important data source concerning the existing situation of the remains and traces belonging to different periods.

The quantity and context of data concerning the urban form are not homogeneous for all the units defined for the study. There are intensive and directly utilizable data about the urban form and architectural components of Hellenistic and Roman Pergamon, owing to the lately prepared studies of Dr. Ulrike Wulf-Rheidt (1994) and Prof. Dr. Wolfgang Radt (2002; 1993; 1988; 1984), which are built upon the results of excavations and researches carried by the German archaeologists since the 19th century onwards. Whereas, the data concerning the urban form of Byzantine era, for which also the main data source is archaeological excavation (AVP XV2 1991), are not as extensive and directly utilizable as those concerning the Hellenistic and Roman eras. Among all, Principalities era is the most disadvantageous one with respect to the data sources, as there are very few documents or existing remains belonging to this period from which data about the urban structure can be provided. There is a variety of historic and contemporary visual and written sources concerning the Ottoman era, most of which provide data about single structures, mainly the monumental buildings, such as mosques, khans, and market places. However, the main data source, which provides data concerning the whole Ottoman urban tissue, is 1904 map of the town prepared by German cartographer Otto Berlet (AVP I 1913). Besides, site survey is an important data source for Ottoman era, owing to the still standing structures belonging to this period.

The data concerning the existing situation of the urban form come from various plans and maps, among which 1/1000, 1/5000 and 1/25000 existing maps set up the basis. However, as these maps are dating from 1960 and have not been revised since then, site survey had to be carried on to update the main features. Besides, during the site survey traces remains referring to the historical stratification that can be observed within the contemporary town are also documented.

Collection of raw data is followed by their classification according to the defined units of the study and conversion into digital format. For digital data production, AutoCAD R14 is used instead of direct entry to GIS, mainly because such a study requires detailed drawings which are not so easy, and even sometimes impossible, with the less drawing and editing capabilities of GIS when compared with CAD softwares (Bilgin Altınöz 2002: 46-50; Bilgin Altınöz, Erder 2000: 43-49). Therefore, all the visual raw data sources have been transferred into the computer environment by scanning and then transferred as raster image into AutoCAD R14, so as to be converted into vector format by on-screen digitizing.

Prior to vectorization process, the elements of analysis, which will be represented as spatial data in GIS data structure, should be determined. The elements of analysis are determined both according to the main components of urban form, which are common to settlement patterns of different eras and in relation to differing levels of geographic space. Topographical features, such as sea, lake, river, hill, mountain, plain, woods, break in the terrain and contours and inclination of the terrain, are the elements of analysis which are necessary to understand the urban form in all the levels of geographic space. *Level of territorial organization* comprises the other urban and rural settlements within the territory of the town and the territorial network constituting of roads, railways, paths, etc., between them. *Level of settlement layout organization* concerns with the settled areas of the town, their extent, characteristics, boundaries and the entrances to them. *Level of intra-settlement organization* embraces streets and building blocks, their extent, outline and axis. In the *level of building block organization*, the extent and outline of edifices, walls and remains are considered.

Besides the components of urban form, there are other elements of analysis, regarding the provision of legal and operational basis for conservation decisions and implementations, such as areas designated for different types and degrees of 'sites', elements related with references used in existing maps (coordinate system, topographical measurement points, texts etc.), administrative boundaries (municipal boundary, contiguous area boundary, etc.), built-up areas, separators, sidewalks and the like.

According to the defined elements of analysis and the type of geometry (area, line, point) to represent them, the digitizing process is carried on so as to prepare the spatial objects of the information system. During this process,

The digital data production has been carried on primarily for the existing situation of the town through the different scaled existing maps. For this, first of all, an existing digital map of Bergama is obtained, by vectorizing 1/1000, 1/5000 and 1/25000 maps reflecting the existing situation and georeferencing them all. Taking the digital existing map as the basis, required elements of analysis for different stratigraphic units of the study are produced in vector format as different layers, by using various data sources. As a result, a (*.dwg*) file for each of the stratigraphic unit as well as the existing situation have been obtained, which are then combined so as to control the correctness of all the geographic relation between them.

The major difficulty during this phase has been the unification of raw data coming from various sources in different format, detail and accuracy, so as to provide a single spatial data set for each of the stratigraphic unit.

Data Storage, Structuring and Retrieval: Constitution of GIS Data Model: Following the data collection, entry and correction phase, data storage, structuring and retrieval are realized as a result of which the GIS data model of the study is set up. In structuring the GIS data model of the study, elements of analysis concerning each stratigraphic unit correspond to spatial data, while, information types concerning each element of analysis refer to attribute data, which altogether comprises the geographical objects.

When the requirements of spatiotemporal data representation model and GIS data model are considered together, the requirement of a *time and object oriented* data structure occurs.

Hence, in the GIS data model of this study, each element of analysis for each stratigraphic unit is handled as a single layer and presented in vector format so as to allow accurate spatial analysis. Raster data format is only used when an additional image, such as scanned photos or inventory forms, are to be hyperlinked to the geographical object or when only the visualization of the image at the background of the vector data is necessary. Thereupon, the data produced in each layer in each AutoCAD file are transferred to a GIS project file (*.apr*) as shape files (*.shp*) in connection with database files (*.dbs*), each defining a geographical object with a unique spatial object group definition and are added to the *views* as separate layers called *themes* in ArcView 3.2. Different views are created for topographical features, elements of analysis reflecting the existing situation and those reflecting the urban form of different historic periods, in which legend and theme properties are defined, including minimum and maximum display scales according to the level of geographical space. Even though they can be presented in different views, the utilization of the same projection and coordinate system for all the themes allow them to be geographically referenced with each other. Just like the vector data, raster-formatted images forming the background of the spatial data, such as aerial photos, plans and drawings, are also placed in their exact geographical position and saved in georeferenced file format.

The other component of GIS data structure is the attribute data, which are descriptive data stored in tables concerning the geographical objects. Each geographical object belonging to a layer is represented as a record, and each category of information is represented as a field in the attribute tables. In order to define the categories, the information types for the study are defined. With the aim to inform identity, reveal sensitivity and resolve continuity about the urban form and its components, for this study, necessary information types are defined as, *information for identification*, *information for characterizing historical stratification* and *information for decision-making*. Information for identification consists of record number, type, name, address information, current legal status and the sources of information concerning the element of analysis. Drawings, photographs, legal documents like registration and inventory forms concerning the element of analysis also supplement information for identification when necessary. Information for characterizing historical stratification encompasses period of settlement / construction, date of construction, provisional / known minimum and maximum altitudes with respect to current ground level, and geometric information concerning the element of analysis. Last but not least is the information for decision-making, which is the information required for conservation decisions and described within the legal structure of the country in concern. For the case of Turkey, even though the criteria for decision-making are not defined explicitly, laws, principles and decisions made by the conservation councils reveal that information for decision-making should cover position and perception, state of survival and degree of knowledge on existence. Following the constitution of GIS data model, the attribute data entry is made for each geographical object as different records, as a result of which the information system becomes ready for different data manipulation and analysis functions.

2.1.3 Stratigraphic Correlation, Analysis and Evaluation: Data Manipulation and Analysis: Stratigraphic correlation is the direct outcome of geographically referenced data model designed for Bergama. Hence, it is possible to visualize spatial data both in *time* oriented correlation and in *object* oriented correlation. Time oriented correlation allows visualization of data in sequent snapshots model, whereas, object oriented correlation allows visualization of relation between the same elements of analysis in different periods. The stratigraphic correlations are also visualized over the 3-dimensional *digital terrain model (DTM)* with vectoral and image coverages (figure 2).

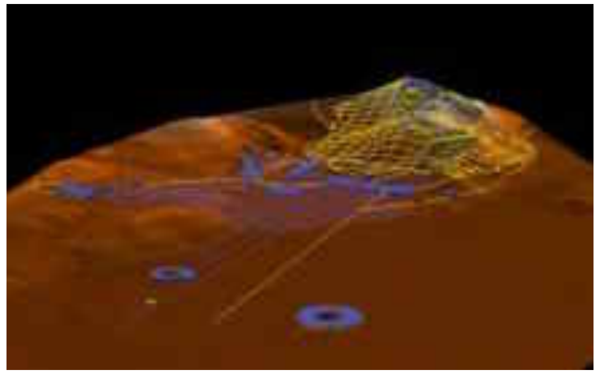


Figure 2. DTM of Bergama with vector coverages, which represents the time oriented correlation of the geographical objects belonging to urban form of Hellenistic and Roman eras.

Stratigraphic analyses are realized through the spatial and attribute data concerning geographical objects through the *data analysis and manipulation functions* of GIS. There are mainly three groups of analysis by using the three main operation types of data analysis and manipulation functions. Those are:

- Overlay operation, which allows overlaying different geographical objects to provide a new layer with new attribute data table. In Bergama this analysis is carried on for:
  - Settled areas of different historic periods and existing town as a result of which different sensitivity zones in the contemporary town with different stratification and different degrees of knowledge on existence, state of survival, and position and perception are provided.
  - Components of the urban form including the edifices and street axis as a result of which streets, blocks and edifices with different stratification options are determined.
- Comparison and search operations, by which attributes of geographical objects are compared with each other and the ones fitting the defined criteria are selected among them. In Bergama, there was a strict grid-iron system in Hellenistic and Roman eras according to the specialists of these periods. The angle of the assumed grid-iron system is still traceable in the streets and built up areas of the contemporary town, which may indicate material existence or trace continuity and sensitivity concerning these periods below the contemporary tissue. Hence, angles of street axes and outlines of built up areas are analyzed through the attribute data that store the angle information. Making an allowance for possible deformations of the grid-iron system in time, an angle range is defined which is then compared with the angles of existing street axes and the built up area outlines stored in attribute tables. The geographical objects having outline or axis angles within the defined range are selected and converted into a new theme as a result of this analysis (figure 3).
- Connectivity and neighbourhood operations, which provide spatial analysis about proximity and buffering around the geographical objects. In Bergama, this operation is realized

for the main street axis and edifices of different historic periods in order to find out the structures neighbouring them in the contemporary town. The elements of contemporary town falling into the buffer zone require special care due to the possibility of material existence of their continuation beneath the contemporary tissue or just due to being closed to the important axis or edifices of different historic periods. (figure 3).

Presentation of Results: Data Visualization, Output and Reporting: Although hard copy of the results of the analysis and evaluations can be provided in the form of maps, charts, reports and tables easily, this study is primarily designed to be used in the digital environment over the existing maps by the decision-makers. In this choice the aim is not to allow undervaluing the outcome of this study by treating them as simple analysis sheets and by forgetting that it is a system that should be managed and updated continuously. Therefore, data coming from the assessment of historical stratification are integrated into the attribute table of the related geographical objects of the contemporary urban form. Thereupon, *a heritage information system*, which contains all the necessary information for identification, for characterizing historical stratification and for conservation decision-making is provided.

It is also possible to present and share the results with the end users over Internet, which has not yet been realized for the case of Bergama.

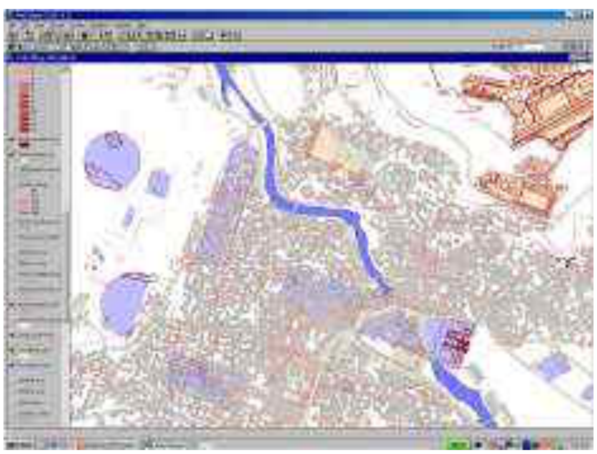


Figure 3. Results of the assessment of historical stratification showing the sensitivity areas and traces over the existing map of Bergama.

3. CONCLUSION

The decision supporting study prepared for Bergama provides comprehensive information about the historical stratification of the town, which should be considered in various levels of the conservation decision-making process. In order to achieve this information, GIS based assessment method of the study utilizes huge amounts of data in various formats, scales and details concerning all the layers making up the contemporary town.

Various analyses provided over these complex data show that their integration into the conservation decision-making process is essential, or otherwise the decisions made are not in accordance with the historical stratification of the town. The best proof of this is the comparison of the current conservation areas with the historical stratification of the town (figure 4). Their comparison reveals that, the areas having the same stratification are subject to different conservation regulations, which causes the destruction of the existing historical stratification instead of its conservation (Bilgin Altınöz, Erder 1999).

Besides the study also shows that, the data about the historical stratification differ at every point of the multi-layered town. Hence, it is recognized more apparently that in a multi-layered town like Bergama, it is not possible to make decisions over generalized information. Thereupon, area-based conservation decisions are not sufficient for multi-layered towns. The decisions should be built upon the Area-based information, which is supplemented with more detailed information concerning the stratification of the components of urban form.

This study also made obvious that, with conventional techniques it is not possible to accomplish such a complex study which requires altogether utilization of huge amounts of data in various formats, details and scales. Besides, information on historical stratification is dynamic, as it changes according to the results of new scientific researches and excavations concerning different historic periods, as well as according to the changes occurring in time within the contemporary town. Therefore, coping with data concerning historical stratification necessitates a flexible, dynamic, and continuous system. When prepared with conventional techniques and tools, it becomes a project once prepared, while with GIS it becomes a system continuously managed.

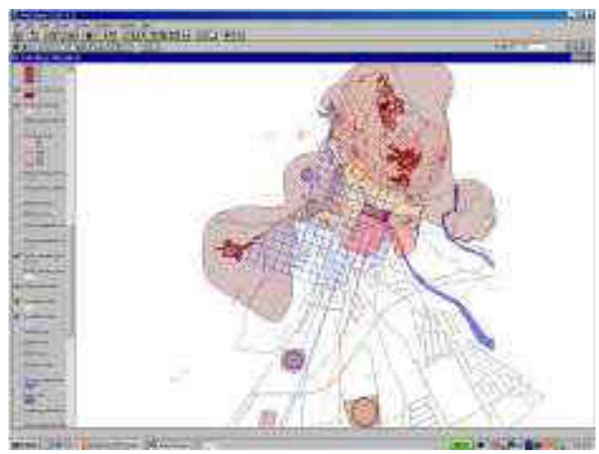


Figure 4. Comparison of the current conservation areas with the historical stratification of the town.

Hence, this study proved that GIS is an appropriate tool to realize such a system. GIS have many advantages and potentials to be utilized as an integral part of such an assessment method, whereas, they have also some shortcomings as they are not softwares especially produced or enhanced according to the requirements of such a study. The important advantages of GIS, which are recognized through this study, can be summarized as:

- the ability to integrate different types and formats of data,
- allowing the classification of complex data to obtain their easy and effective utilization,
- providing analysis over both spatial and attribute data,
- presenting an integrated environment where data produced in other softwares can be used,
- offering a highly precise environment.

As mentioned before, there are also some difficulties concerning GIS which are faced with during this study, such as:

- incompatibility of the precision of the utilized data sources with the precision provided by GIS,

- impossibility of querying more than two spatial data at a time, as a result of which the procedures of analysis increase due to repeating the same analysis many times,
- not having advanced drawing and editing capabilities as such a detailed study requires.

To conclude, it is possible to state that assessment of historical stratification by using GIS will support the conservation decision-making process and consequently will contribute to the conservation of multi-layered towns. GIS, defined as the major tool, are considerably compatible with such a study. However, standard GIS softwares reveal some problems, which need to be studied further and solved in association with GIS analysts and programmers.

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Acknowledgements:

Special thanks are due to Prof. Dr. Cevat Erder, for his constitutive, insightful comments and long term support as the supervisor of this study.

Thanks are due to 'İŞLEM Geographic Information Systems and Engineering Limited', for sponsoring ArcView GIS and for providing continuous technical support.