Integration of GIS and Multivariable Analysis in Urban Planning

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Abstract— **Multivariable analysis contributes mainly to the scientific establishment of traditional approaches concerning the description, comprehension and projection of cities' structure. Geographic Information Systems (GIS) technology has undoubtedly a crucial role in this process. The present paper focuses on the systematic retrieval and import to a GIS system as well as elaboration of data with regard to the urban characteristics of the Old Town of Xanthi, in Greece. The paper also includes the identification and evaluation of the aforementioned data with the combined use of Correspondence and Hierarchical Cluster Analysis. The application of the methods allowed for drawing complex results about the degree of differentiation or similarity of the prevailing conditions of the research area's micro scale which are not revealed by traditional urban analysis.**

Keywords—Urban Planning, GIS, Multivariable Statistical Analysis, Correspondence and Hierarchical Cluster Analysis

I. INTRODUCTION

The interpretation of the special social, economic and functional cities' profile, as well as of their internal composition and operation may be the scope of multivariable classifications [1]. Multivariable analysis contributes mainly to the scientific establishment of traditional approaches concerning the description, comprehension and projection of cities' structure and refers to the differentiation of individual characteristics of their regions, as basic components for creating urban space. Geographic Information Systems (GIS) technology has undoubtedly a crucial role in this process, by contributing to the acquisition, collection, updating, elaboration and illustration of the large data volume and also in supporting decision making through specialized applications [2] [3] [4] [5] [6].

The present paper focuses on the systematic retrieval, import to a GIS system as well as elaboration of data with regard to the urban characteristics of the Old Town of Xanthi, which is a modern city of almost 60.000 inhabitants in Northern Greece. Moreover, the paper includes the identification and evaluation of the aforementioned data with the combined use of Correspondence and Hierarchical Cluster Analysis.

The advantages of these methods, which have experienced rapid development mainly in France, after 1970, include the following: processing of large tables that contain heterogeneous data, elaboration of qualitative data, identification of the existence of both linear and non-linear relationships among variables, depending on the data used. Both methods are used in cases where the researchers' objective is to reveal the secret structure of a dataset, without distinguishing the variables in dependent and independent and without the existence of strict a priori assumptions or conditions [7].

The application of the methods allowed for drawing complex results about the degree of differentiation or similarity of the prevailing conditions of the research area's micro scale which are not revealed by traditional urban analysis. The use of the integrated GIS system improves the quality of research and gives the opportunity of constantly providing up to date information and monitoring the factors which play a key role in the implementation of development policies [8].

II. AREA OF RESEARCH

The Old Town of Xanthi is Located in the heart of modern Xanthi, one of the most important urban centers in the northern part of Greece, with nearly 60.000 inhabitants. The Old Town was founded in the middle of 19th century and it is the first city centre, the creation of which was, almost exclusively, due to activities associated with tobacco cultivation, production and manufacturing. These activities have characterised, with their rise and fall the evolution of its physiognomy.

Old Xanthi covers an area of 31 Ha, occupying 1/7 of the total city's area. It extends along the foothills of Xanthi, bounded by a thick forest to the west, a river valley to the east and by the centre of the modern city to the south. The different ground grades, sharper in the northern part and smoother in the southern one, influence the form of the urban tissue and separate the settlement in areas. Narrow irregular streets define a variety of block shapes; some of them with continuous building facades and some with free-standing buildings intermingled with courtyards and gardens. Urban indexes such as lot size, property pattern, building heights and volumes, form a unique urban setting, which could not be duplicated by modern development.

In the context of dynamic city's development, the southern part of the Old Town is connected to the wider area of the

modern city's centre, where a penetration trend by service and entertainment uses is reported; sometimes this is desirable but in some cases it causes deterioration of the settlement's traditional character. For the aforementioned reason, a part of the modern city's centre is also included in this research; the transition zone that surrounds every traditional core and where usually the majority of conflicts take place (Fig. 1).

Fig. 1.   Research area

III. DATA CHOICE

Qualitative and quantitative data recording was based on a primary, detailed fieldwork that took place in the context of the "Plan and Program for the reservation – restoration and growth of Old Town" [9]. Moreover, a sampling survey took place by distributing a questionnaire to a 10% of the total population for recording data concerning housing conditions as well as certain demographic and socioeconomic characteristics of the residents. The full dataset resulting from this study was used to create an electronic database which served as feedback for a GIS system.

The variables that were chosen for this specific application refer to the structure of the urban tissue (blocks' shape and size), the built environment (existing coverage percentage, existing building coefficient), land use allocation and to some main characteristics of the population (change of households' number and size). The land uses were grouped in general categories such as: residential, manufacturing, commercial, offices-administration-banks, education-welfare-culture-sports and entertainment – tourism. There are also some singular uses such as: empty residential property, empty store, building under construction or reconstruction, ruined building, auxiliary building, parking space. Data analysis and elaboration were performed using aggregation per land use category without taking into account their storey allocation.

The research unit that was considered suitable for the purposes of this study is the block, because it is the cell of the organization, classification and differentiation of the characteristics of the settlement. The dimensions of the database (20x94) derived from the number 20 of the chosen variables and the number 94 of the analysis' objects (blocks).

IV. DATA ANALYSIS AND RESULTS

The cartographic representation of several of the chosen variables through the production of thematic maps using GIS technology (ArcGIS) conducts a first approach of identifying the basic characteristics of the urban environment and contributes to achieving a complete overview of it (Fig. 2 - 7).

PRAXITELIS program [10] is a software package which utilizes data analysis techniques and it is mostly oriented to the application of Multivariable Analysis methods. In this case, it is used to apply Correspondence and Hierarchical Cluster Analysis. The program can elaborate both qualitative and quantitative variables and provides the user with the potential to homogenize the data using many options and therefore the final dataset describes more closely the real situation of the phenomenon which it attempts to interpret.

With the aid of Correspondence Analysis, a first identification of groups of interrelated variables takes place, while at the same time the data that are going to be used by the Hierarchical Cluster Analysis are prepared. The method leads to the creation of a series of explanatory factor axes which are extracted sequentially based on their importance and each one of them is represented by an eigenvalue, in proportion with its interpretative capacity. The program gives the opportunity to create graphs of the projection of objects or variables (or both) to one or more pairs of axes that are predefined by the user in order to examine the existing relationships or differences with respect to each pair.

In this application, the participation of variables in the creation of the first three factor axes, which interpret a significant part of the requested information (35,235%), showed that the first factor correlates the entertainment with the personal services land use and the commercial with the manufacturing land use. The second factor indicates a correlation between the high building coefficient, the small blocks and the noteworthy decrease of households' number, while the third factor shows that the low coverage with the low building coefficient are associated.

Hierarchical Cluster Analysis groups the objects and variables in a limited number of homogeneous clusters. The program proceeds to the data elaboration and displays: a) the classification in the form of neighboring pairs (for each data pair the hierarchy nodes appear, with their corresponding weight and connection level) and b) the hierarchy in the form of a tree diagram where all different binding levels of data analysis are expressed. This specific application of the method revealed four distinct groups of variables that are analyzed in the following part (Fig. 8).

- Group A includes small sized blocks, elongated or trapezoid, with low building coefficient and coverage and exclusively of residential use.

Fig. 2.   Built environment
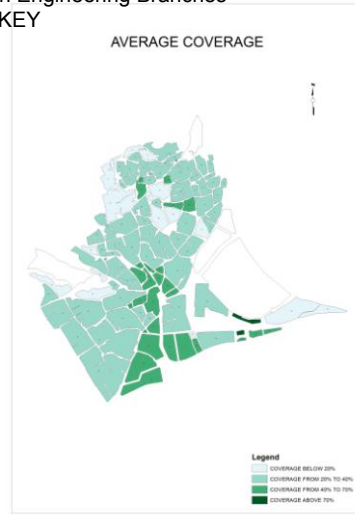

Fig. 5.   Average Coverage
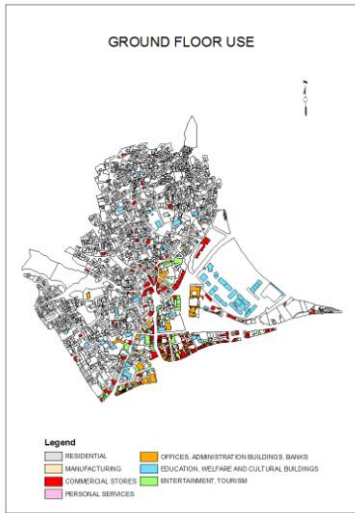

Fig. 3.   Ground floor use
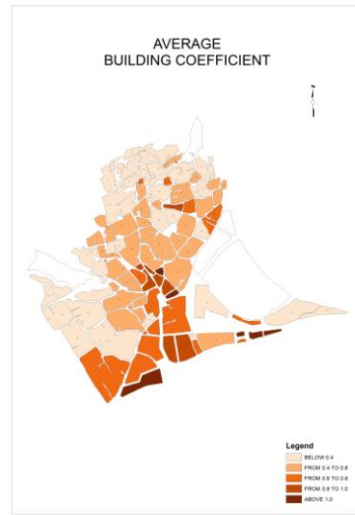

Fig. 6.   Average Building Coefficient
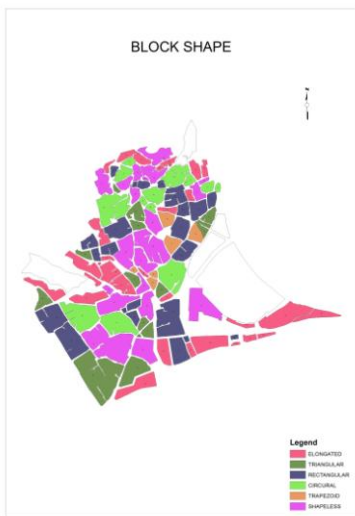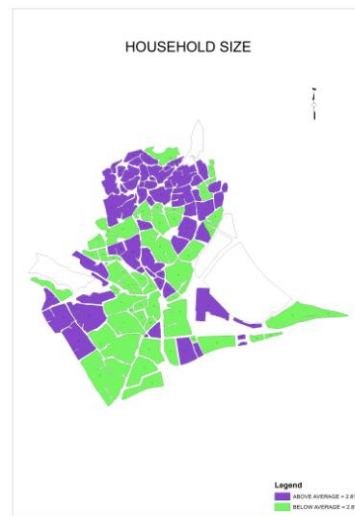

Fig. 4.   Block shape

Fig. 7.   Household size

The majority of households have many members and the values of the demographic indexes are critical, possibly due to the fact that a part of the population is moving to other parts of the city, with the aim of finding better housing conditions.

- Group B involves medium sized blocks, of triangular, square or circular shape with medium building coefficient and coverage. Residential use dominates this group as well, but not exclusively as in Group A; it is accompanied by low concentrations of other uses (mostly commercial stores, food stores and welfare facilities) around certain cores which form the basic local neighborhoods' centres. The dominance of medium – sized households is evident, and so are the numerous auxiliary buildings next to the main residential ones. The demographical indexes appear to be constant.

- Group C is characterized by blocks of large size and shapeless. Commercial activity is more intense within the boundaries of this group; there is also a significant number of ruined buildings and some small private parking spaces.

- Group D includes blocks with high coverage and building coefficient which are not characterized by a specific shape or form. This group is home for several activities of the city centre, which have replaced residential uses. A concentration of administration, education and entertainment services is observed, and the manufacturing activities that are located in this group are directly associated with the commercial uses. The majority of households are of small size and the demographic indexes are particularly dynamic.

The blocks of Group A are situated across the perimeter of the Old Town, mainly at its northern part and also at characteristic spots of its entry. The majority of Old Town's area is occupied by blocks of Group B. The 5 local centres that are created have the following common characteristics: they are allocated either on principle road axes' intersections either next to squares or in close proximity to public spaces or neighborhoods' landmarks. The blocks which belong to Group C are mainly located at the southern part of the Old Town, where intense pressures for reconstruction and central commercial activities occur. Finally, the blocks of Group D are situated exclusively at the southeastern part of the research area, with clear boundaries. The transition zone belongs almost totally to this Group, while a linear penetration is visible on the surrounding southern entry of the Old Town.

V. CONCLUSIONS

The complexity and interaction of information issues posed by modern urban planning needs require the use of Geographical Information Systems technology and Multivariable Statistical Analysis.

Fig. 8.   Blocks' clustering

In urban analysis, Multivariable methods contribute to the establishment of earlier approaches concerning the description, interpretation and prediction of urban centers' urban structure. The relationships among the research's objects are examined in terms of their homogeneity or heterogeneity, in terms of their hierarchical spatial organization or their general dependence on each other. Moreover, GIS technology is the core of an integrated environment of information, decision making and planning processes. The advantages and opportunities offered by this technology pose a challenge to the traditional institutional structures, functional roles and planning and management practices of the urban environment.

In the present application this integration gave the opportunity for the:

- Identification of the data which mark the local attributes that create the microenvironments of the Old Town and define its character

- Comprehension of the neighborhoods' function and their relationship with the city centre

- Emergence of the data which are significant for the final choices and of the correlations that contributed to the safe determination of the final proposals

- Validation of separated activity domains of a potential intervention

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