A System for Monitoring Environmental Quality of Urban Road Network and for Supporting Decision Makers

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Abstract: - This paper presents the attempt to design and create a database system for monitoring the environmental quality of urban road network and for supporting the decision making process of local authorities. The factors that determine and affect the environmental quality of urban roads are researched and indices are designed to quantify these factors. These factors are categorized into 20 sub-categories and grouped into 8 main categories such as urban planning and architectural factors, traffic patterns, recorded roadside land uses, recorded road equipment, or even financial ones. On the whole, 124 indices are designed, and examined on a pre-selected part of the town of Chania, which is found to be characteristic for the urban complex. A geodatabase is created, which is based on the data that was collected for every index, and this geodatabase is directly connected with a Geographical Information System (GIS). Within this GIS the potential for processing, analyzing and presenting quantitative data, is examined. The aim of this geodatabase is to constitute a useful tool for the local authorities for a continual monitoring of the environmental quality of urban roads and in their decision making on issues concerning the management of the urban environment.

Key-Words: urban roads, environmental quality, database, GIS, urban planning, decision making

1 Introduction

A great deal of conversation takes place nowadays, concerning mechanisms and systems of continuous monitoring of spatial phenomena, and the supporting of necessary decisions [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17].

Nowadays, 80% of Europeans live in urban areas, facing a continuous degrading of the quality of the urban environment. The development of economy has reached high levels during the last decades, followed by an increase in the mobility of people around the city, the excessive use of passenger cars, and the concession of a substantial part of the city's vital space to the development of the public transportation network [18, 19, 20, 21, 22]. The consequences of this policy and of the citizens' attitude are apparent, especially in the central city areas, which constitute a focal point of the transportation network, because of the density of the population in them and the diversity of their functions. Furthermore, it is observed that increasingly frequent occurrences such as conditions of traffic congestion during rush hours, parking problems, accidents, noise, environmental pollution, functions, and visual obstructions of the central arterial routes, lower the citizens' quality of life and consist the major causes of a tendency to decentralize, thus creating the need for further expansion [23, 24, 25, 26, 27].

Although an effort to deal with the existing problems is being made by the local authorities, it is usually inconsistent, while a basic awareness of the overall problem and of the researched area is non existent [28].

It is therefore considered essential to design a database in a GIS, where environmental quality indices are developed [13, 15]. This database enables us to provide a specific and detailed description and analysis of the environmental parameters of the urban roads. Also it will become a convenient tool in the hands of specialists and of the representatives of the state authorities, by facilitating their decision making on a number of issues concerning measures and interventions in the urban web. At the same time it will enable continuous observation and updating of the urban environment. Local communities which lack such a tool can attempt only occasional interventions which are difficult to evaluate as far as their effectiveness is concerned.

The present research is conducted in the context of a basic research project in the Department of Environmental Engineering of the Technical University of Crete.

It attempts an approach of those factors which define and affect the environmental quality of urban streets and creates a database in a GIS, using

a pre-selected area of the Municipality of Chania as area for the research.

The methodology followed is divided into four steps:

1) Research of the factors and indices which describe the environmental quality of the streets.
2) Obtain data and record the values of the indices on the selected research area.
3) Design and create the geodatabase and the system.
4) Investigate the potential for processing and analyzing through this system.

2 Factors and Indices for the Environmental Quality of Urban Roads

The factors and indices that are used to evaluate the environmental quality of the roads are selected and designed after research into related bibliography, on site visits and interviews with representatives of the local authorities [1 - 32].

A. URBAN PLANNING AND ARCHITECTURAL INDICES
1. Urban planning indices
2. Architectural indices
3. Road geometry
B. CONSTRUCTION MATERIALS INDICES
4. Road surface materials
5. Paving materials
C. ROAD EQUIPMENT INDICES
6. Street equipment
7. Street facilities
D. ROAD TRAFFIC INDICES
8. Static road traffic indices
9. Dynamic road traffic indices
E. LAND USES
10. Commercial uses
11. Services
12. Communal spaces
13. Other uses
F. POLLUTION INDICES
14. Air pollution indices
15. Noise pollution indices
16. Visual pollution indices
G. CLIMATIC INDICES
17. Climatic indices
H. OTHER INDICES
18. Economic indices
19. Hygiene indices
20. Other indices

Table 1: Categories and Sub-categories of the Selected Parameters

On the whole, 124 indices are selected, concerning the urban planning, the geometry of the roads, construction materials, road equipment as well as traffic, climatic, financial, and parameters that concern the use of land, pollution and hygiene [29, 30].

The urban planning and architectural indices are selected to describe the building volume of the area and its development in relation to the road network. These include; the building permit limit, the plot coverage percentage, the building system, the existence of green elements, the length of building blocks, the height of buildings, the hypsometrical arrangement of the buildings, the surface area of the building blocks, the existence of arcades, building construction dates, the shape and colour of them, as well as their façade details [15].

A number of indices has also been selected, concerning the width of roads, their orientation and inclination, roadside construction materials, road surface condition, artificial lighting, surface rainwater drainage grids, the power and telecommunications network, waste bins and wastebaskets, telephone booths, benches and canopies at bus stations [5, 6, 21].

The traffic indices include one/two way streets, parking patterns, pedestrian crossings, ramps, cycle lanes, scheduled itineraries of public transportation vehicles, the number of accidents, and the traffic load [19].

A. URBAN PLANNING AND ARCHITECTURAL INDICES
1. URBAN PLANNING INDICES
Building permit limit
Plot coverage percentage
Building system
Entrance Gardens
Length of building blocks
Maximum permissible height of buildings
Existing minimum floor number
Existing maximum floor number
Surface area of building blocks
Arcades (in parallel or across streets)
2. ARCHITECTURAL INDICES
Level of enclosure
Number of Listed Buildings
Hypsometric distribution of buildings
First year of building construction
Newest year of building construction
Average year of construction
Subterranean domiciles / semi-subterranean domiciles
Building shape
Building color
Façade details
3. ROAD GEOMETRY
Pavement width
Road width
Road orientation
Road gradient
Multi-level footpath

Table 2: First Category (URBAN PLANNING AND ARCHITECTURAL INDICES) and its three sub-categories

Further indices are selected, concerning roadside land uses (commerce, public services, common use spaces in buildings), climatic conditions (temperature, wind speed, rainfall, humidity, etc), air pollution (gas concentration, odours, etc), noise pollution, visual disturbance (advertising posts and signs, graffiti, etc), the value of land, the level of cleanliness and the level of the citizens' conforming to the regulations [1, 2, 5, 6, 31, 32].

3 Research Area and Collection of Data

3.1 Research Area

The Municipality of Chania is the largest in population in the Prefecture of Chania, with 53373 inhabitants, (2001 population census) and has an expanse of ~7000 hectares. This one-division municipality borders with the municipality of Nea Kydonia, Akrotiri, Souda, and Eleftheriou Venizelou. Figures 1 and 2 are maps which depict the urban complex of Chania. The municipality is divided into five urban units which diversify in terms of their building permit, building density, building system, height of buildings, their distance from the city centre and the different uses of land. There are further diversifications as to the morphology of the ground, and the geometrical, functional, financial and traffic characteristics of the roads.

Figure 1: Urban complex of Chania (source: Google Earth)

In order to record the parameters which contribute to the environmental quality of roads, especially those of the urban complex of the municipality of Chania, a part of the city of approximately ~500 hectares is selected, including parts from sections I, II, III, IV (Figures 3, 4). Of these, some are part of the city centre (sec.I, II), others border the city centre (sec.III), while sec.IV represents a more remote part of the city.

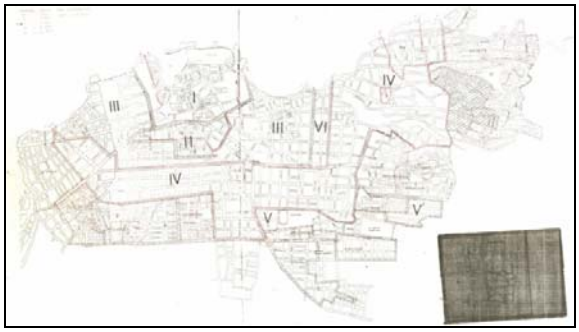

Figure 2: Urban complex of Chania

Figure 3: Research Area (source: Google Earth)

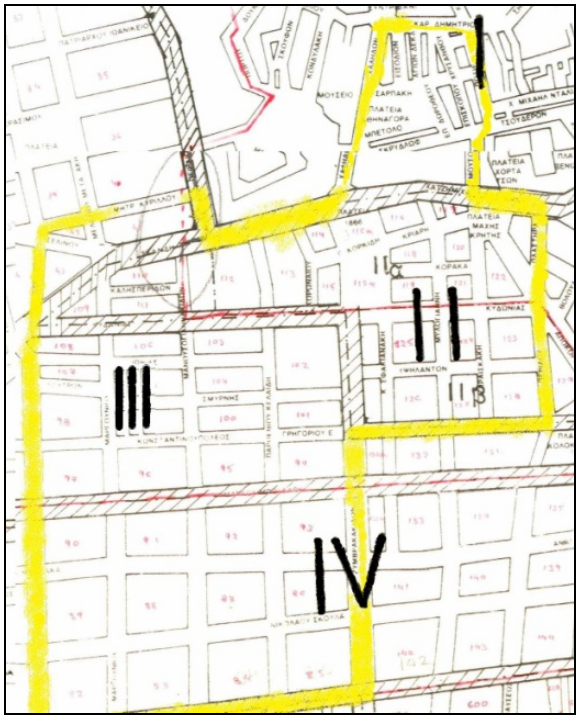

Figure 4: Research area

The task of conducting research on the entire municipality of Chania was not feasible given the budget and time limits of this particular research project. It was additionally recommendable to conduct a pilot scheme, to make observations, to reach certain conclusions and based on them, to reorganise the investigation and improve it where it is necessary, and if feasible, to re-conduct the investigation on a larger part of the city, or throughout the city as well.

3.2 About Data Collection

At first the necessary data were defined as well as the form they ought to have in order to be inserted into the base. Then a list was created, based on previous experience and on related bibliography, which includes all the indices that would define the environmental quality of urban roads (as defined into the categories and subcategories in our research, in previous [13, 15].

The data were fully defined as far as the following features are concerned:

- Precision
- Year of collection
- Type (spatial, non- spatial, point, line, polygon etc)
- The categories and sub categories they belong in this research
- Their Possible source
- Possibility of substitution in case they are non-existent
- Necessity
- Priority in the investigation
- Their scale

With the existing situation in Greece, in which there is not a central, competent body to provide statistical data (apart from the National Statistics Bureau of Greece, which fails to meet the contemporary needs) and according to the overall attitude, every body collect, organize and update the data they need by themselves and then miss to make these data available to other bodies for similar studies, organizing and precisely defining data is considered essential.

The form of the data included in a geographic database may vary, depending on the subsequent role of the system [10]. In the first phase of this research the system enables to create, update and preserve the data in a database and in a later phase it can play the role of spatial, time and comparative analysis, which is the main aim of a database. The data input are spatial and in the form of points (e.g. shooting locations), lines (e.g. road network), or even surfaces and polygons (building blocks). Non spatial data also coexist which bear no relevance to a particular location but are usually characteristic of spatial data (road surface condition, paving material, existence of posters, etc) of a section of the road network. The transversal axial distance between two intersections was defined as analysis unit.

By defining the source of origin of data and their priority in the research, we avoid purposeless search, while data collection becomes organized and efficient.

In times, the existing data are more precise and sufficient than required, but due to a lack of a source of origin, the research has to turn to substitute data or to deleting groups of data, as they are justified as non existent.

It is therefore considered essential to track down the sources with on site visit, be updated about the issue and analyze the required data [13, 15]. On some occasions public offices may not possess the required data, but may be aware of their origin. A first approach to the public offices (data sources), could actually record statistical material and render it available. This would facilitate the collection of data and the research in general. It would also finalize the list of the data which are yet collected, their sources, the necessary procedures for their collection and the time in which they are available.

The collection of data, which as mentioned above is hindered in Greece due to difficulties in providing information, is one of the most time consuming and costly parts of the research. Public offices are informed of the aim of the research, of the data collected and decide which ones exist, which ones could be found and which ones can be provided.

A member of the research team is required at the public office during the collection of data to provide explanation concerning the form of input data, possible encoding of them, any shortcomings and the controlling of their credibility. During this procedure it is not uncommon to find out that the data are incomprehensible, incomplete, or are not the ones required. Such problems are dealt with more easily and efficiently during the collection phase rather than later [10].

3.3. Data Collection

The collection of data and the measurement of the values of indices of the selected area, was conducted through public bodies, while it was based on already existing research and mainly on site recording. The Urban Planning Directorate of Chania provided a map of the town with all the urban units and elements. Data on the noise and parking patterns were obtained from the traffic planning department of the municipality. Data on the commercial value coefficient were derived from the Tax & Revenue Office of Chania [15].

Figure 5: Data Collected from Public Bodies

Some of the indices were measured through the use of a designing program (such as the length and the area of building blocks). Measurements of some other indices though were practically impossible either because the access to some of the files of certain public offices was impaired (i.e. unknown date of building construction) or because there is a lack of relevant research, which leads us to insufficient data (i.e analytical traffic loads).

Figure 6: Data Collected from Existing Research

Most of the indices were recorded by site recording. At the same time analytical photographical shootings were taken for every junction, facing all directions.

Figure 7: On Site Recording Sheets

From a group of 124 indices that were designed, 8 of them were obtained from public offices, 3 of them were calculated through a designing program, 25 of them did not get a value as no sufficient data was found, while the rest of them were recorded during on site measurements. Files have been kept on the means and dates of data collection.

In addition to the data collected in the ways described above, a survey was conducted on 192 inhabitants from all city areas. The answers were given either in writing or via interviews.

QUESTIONNAIRE
Residential area
- How convenient are the roads and pavements that you use in terms of

A) parking?
1. very
2. quite
3. a little
4. not at all

B) walking?
1. very
2. quite
3. a little
4. not at all

- Does the traffic run smoothly?

1. yes
2. no

Table 3: A part of the On Site Questionnaire

The aim of the survey was to record the public's opinion on issues concerning the convenience, aesthetics and attractiveness of the roads, the traffic, the public transportation, pedestrian safety, drivers' safety, etc [5]. One of the basic questions that were included in the questionnaire was whether there was a parameter that had not been included and it should be taken into consideration. According to the outcomes, no new parameters resulted [15].

4 Designing and Creating a Database

A database plays a major role in a GIS while it directly affects its cost. A database is the foundation of the use of a GIS enabling its user to do programming, develop an application, analyze and derive secondary data, which will in turn help in decision making [33, 34].

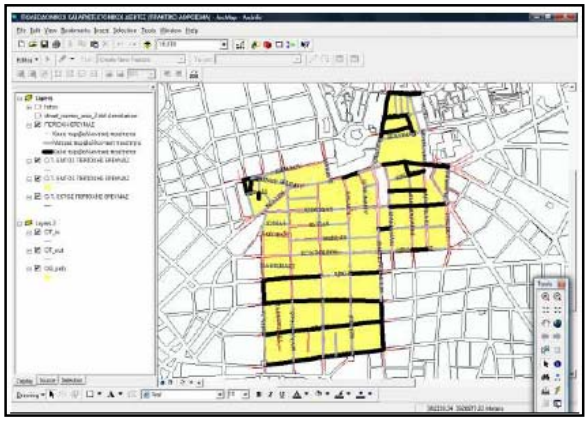

Figure 8: A Screenshot from the GIS

4.1. Data Processing – Database Construction

Data processing is an equally important part of the research, as it is the intermediate level through which the primary collected data "feed" the consequent stages of analysis to achieving successful conclusions. This stage requires being attentive and thorough with the precision, the quality and the credibility of the collected data.

In the present research, the processing is divided into several consecutive phases which aim at producing a result after processing:

- Evaluation of the primary material and select what is appropriate.
- Its modification in order to be input in the database and the Geodatabase
- Data input
- Check the correctness of the data input procedure.
- Correct any mistakes and rectify possible omissions or deficiencies.
- Description and consolidation of the database through a DATA DICTIONARY.
- Check the functionality of the base and of its data in their new form, in subjects of analysis. (TESTS).

These phases are, as mentioned above, consecutive and the last one can lead back to even the original one.

It is evident that data can be found in many different forms, which have to be checked. Then, moving to the processing stage, there is a division of data according to their form. The data required in this research are found on maps, in charts, in graphs, histograms, in a passage or in a bibliography. They could also be on paper, in digital form, (DIGITAL DATA), on an interview recording tape as well as in every possible available form.

The material which is gathered should be "cleared up", the double data should be excluded, data copies should be made for safety reasons and then explained to the members of the research team who undertake the processing. The material is thus presented in a clear form and is suitable to be modified into a particular input format.

The next phase of the processing is the transformation of the material into a different format.

Following on, the input of data takes place as long as the database is programmed to accept these data (programming of the database).

On programming the database one has to pay close attention to present a data input screen (e.g. field names etc) which would explain thoroughly where each datum is input, in what order, as well as avert any possible input mistakes, thus minimizing the need to type (e.g. data encoding). Data input screens are predesigned and basically define almost automatically the structure of data into the files. The next step would be to program the database according to the screens, so as to accept the primary material.

The input of data begins and should be carried out with care, method and consistency in order to avoid mistakes. It is unavoidable though for members of the research team who have no previous experience in inputting data to have questions, which are usually answered at that moment.

With the data input screens, the user of the database (data input inserter) does not have to have any knowledge of programming one. The database is used rather as a registration tool.

During the procedure of the data input or alternatively at the end of it, a check is carried out on the correctness of the procedure. This is a necessary step to take, as there is always the possibility of omission or distortion of data during its transferring. In this way we are able to locate any mistakes and correct or fill in for any omissions.

When the database is completed, it has to be checked for its functionality. Before actually using the base for analysis and as a deductive procedure, we have to ensure that it is functional and reliable as it constitutes a solid foundation for further research and Information Systems development. The functionality and reliability of the database can be tested with the application of a pilot project. Testing on this phase is essential so as to avoid hold-ups when we later analyze data and establish conclusive facts. As soon as the functionality of the base is established, it can be used for research and analysis of any phenomenon of interest.

4.1.1. Structuring the Spatial section of the Database

The use of a Geographic Information System contains by definition at least one spatial information layer which depicts the research area while it is directly connected to the descriptive (non spatial) data of the database.

In this research, three spatial information layers are used:

- A Topographic map of the research area (which results from field measurements in combination with an existing background map of a large scale.
- A map of the city of Chania (a section within the administrative boundaries of the Chania Municipality) of a scale 1:2.000
- Axes and major intersections of the road network of the research area

The topographic diagram which is being used resulted from a combination of on site measurements and of a mapping background of

large scale, which only covers the research area and depicts the building and street lines. As a reference system, the national GGRS87 was used.

After examining the map of the city of Chania - of a 1:2000 scale – it was found that there have been alterations in relation to the present reality. These alterations were noted on the research area. This map has orientation purposes (orientation map), while the included - or non included - details do not affect the research. The method of the georeferencing of the map was followed, using a GPS (developed below).

Using as a base the topographic diagram - which depicts street lines, among other - we were able to digitize the axis of the road network of the research area. The digitization was based on the method of dividing the road network into sections - units which include the axis between two main junctions. These sections of axes of the road network constitute the basic spatial unit of this research. The digitization was carried out thoroughly and in full compliance with the procedure rules to achieve the maximum precision.

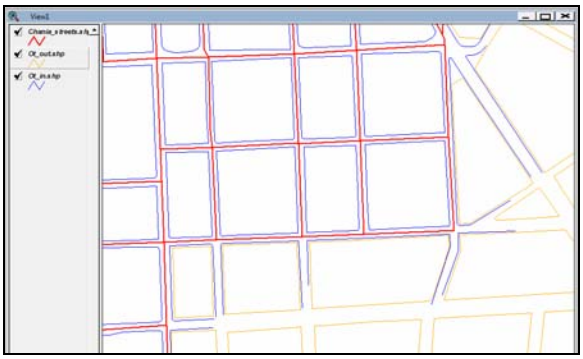

Figure 9: Spatial Units of the Research

4.1.2. Georeferencing the Map using a GPS

For the georeferencing of the map of the city of Chania certain check points are used (control points), whose location is known both in relation to the reference system of the map, and in the reference system we are using (GGRS87).

After the selection of certain reference points (20 on the whole), their coordinates were measured in the reference system of the map of the city of Chania. For the same points it was necessary to know their coordinates on the GGRS87 reference system.

The 20 selected points were measured on site using a handheld GPS, with the advantage of an a-posteriori correction of the measurements (post processing), which resulted to an accuracy range of less than one meter in the coordinates measurements. The coordinates that were measured were in the GGRS87 reference system.

The coordinates of these points were used as data in the application of the map georeferencing so that it can be spatially assimilated into the topographic diagram.

4.1.3. Structuring the Non-Spatial Section of the Database

The values of indices vary. Others are quantitative (i.e. building permit limit, height of buildings, area of building blocks, coverage percentage etc), while others are qualitative as for example telephone booth existence (yes or no), pavement surface condition (satisfactory – medium - poor) [10, 13, 15, 16, 17].

The indices that will be used and for which data have been collected for the current research, are classified into twenty (20) tables, which correspond with the 8 main categories of quality environmental indices that have already been mentioned.

The tables of the database are designed and programmed based on the collected data and the requirements of this research. A basic common characteristic of these tables is the existence of a field which records the codes of the axes sections of the road network in their digital form. The codes in this field constitute the primary key (KEY) which interconnects the tables while it also connects the tables and the thematic layers (spatial information) of the database [10].

When the tables are designed and programmed, they are then updated with the collected data.

These data may be encoded before actually being inserted into the tables if need be, (according to the rules of data collection and the creation of a database.)

After the tables are updated, they are then spatially checked (by connecting them with the spatial information layers of the database), so as to locate any input mistakes and correct them.

Finally, the tables are ready to be used by the research team.

Attributes of Chania_streets.shp

Shape	Id	Odos	Apo	Mexri
PolyLine	0	CHALIDON	XATZ. GIANNARI	SKRYDLOF
PolyLine	1	CHALIDON	SKRYDLOF	SARPAKI
PolyLine	2	CHALIDON	SARPAKI	KAR. DIMITRIOY
PolyLine	5	EPISK. DOROTHEOY	TSOYDERON	SARPAKI
PolyLine	6	BETOLO	CHALIDON	EPISK. DOROTHEOY
PolyLine	7	EISODION	KAR. DIMITRIOY	SARPAKI
PolyLine	8	AGION DEKA	KAR. DIMITRIOY	SARPAKI
PolyLine	9	EPISK. DOROTHEOY	SARPAKI	KAR. DIMITRIOY
PolyLine	10	EPISK. XRISANTHOY	TSOYDERON	SARPAKI
PolyLine	11	EPISK. XRISANTHOY	SARPAKI	KAR. DIMITRIOY
PolyLine	12	MOYSOYRON	TSOYDERON	XATZ. GIANNARI
PolyLine	13	KIDONIAS	KISSAMOY	MARGOYNIOY
PolyLine	14	KIDONIAS	MARGOYNIOY	MANOYSOGIANNAKIDON
PolyLine	15	KIDONIAS	MANOYSOGIANNAKIDON	KELAIDI
PolyLine	16	KIDONIAS	KELAIDI	ZIMBRAKAKIDON
PolyLine	18	SKALIDI	MARGOYNIOY	MANOYSOGIANNAKIDON
PolyLine	19	SKALIDI	MANOYSOGIANNAKIDON	KELAIDI
PolyLine	21	MARGOYNIOY	SKALIDI	KIDONIAS
PolyLine	26	ZIMBRAKAKIDON	KIDONIAS	IPSILADON
PolyLine	24	KELAIDI	SKALIDI	KIDONIAS
PolyLine	23	MANOYSOGIANNAKIDON	SKALIDI	KIDONIAS
PolyLine	22	KALISPERIDON	MARGOYNIOY	MANOYSOGIANNAKIDON
PolyLine	53	KIDONIAS	ZIMBRAKAKIDON	SFAKIANAKI
PolyLine	33	SFAKIANAKI	IPSILADON	KIDONIAS
PolyLine	49	IPSILADON	ZIMBRAKAKIDON	SFAKIANAKI
PolyLine	43	KARAISKAKI	IPSILADON	KIDONIAS
PolyLine	27	ZIMBRAKAKIDON	IPSILADON	GRIGORIOY E.
PolyLine	28	GRIGORIOY E.	ZIMBRAKAKIDON	SFAKIANAKI

Figure 10: Non Spatial Data in a Database Table

4.2. Database Dictionary

A basic tool that should always accompany any database (Spatial or Non Spatial) is the Data Dictionary, or Database Dictionary. This dictionary fully and thoroughly describes the nature of all the data that have been input into the database, their form, the onomatology that is used during the programming of the base, or the possible values of a variable in the database. It is therefore a tool for any one outside the research team that wishes to use the database. In this dictionary one can find information such as [15]:

- The category of indices under which every datum can be found (8 main categories of indices).
- The table (TABLE) of the database that has to be used in order to withdraw certain data.
- Necessary data in order to update the database and for any possible intervention into it.
- Confirmation of the validity, the reliability, the nature, the form and the connection between data that are input into the database.

The Database Dictionary constitutes a tool in the hands of the database user and makes it feasible to explain the data structure in the indices that are included, as far as their content is concerned, the way the indices are stored in the base (e.g. integral number of N digits, decimal number of N overall digits and of ν decimal digits, data of N digits consisting of characters and numbers, etc). It is also inclusive of the database table (Table) and of the main index categories they belong to (which of the 8 main categories).

GEODATABASE					
CATEGORY	URBAN PLANNING AND ARCHITECTURAL INDICES				
PATH DEFINITION OF DATA LEVEL IN THE GEODATABASE: /PINAKES/POLEODOMIKOI DEIKTES.dbf					
SUB-CATEGORY:			URBAN PLANNING INDICES		
SPATIAL DEFINITION TYPE OF SPATIAL DEFINITION			LINE		
TYPE OF DATA NAME OF DATA FILE			SPATIAL / SPATIAL UNIT (PART OF URBAN ROAD)		
DATA FILE TYPE					
FIELD DESCRIPTION					
NAME	FIELD TYPE	FIELD NAME ON SCREEN	VALUES	FIELD DESCRIPTION CODE DESCRIPTION	REMARKS
id	sh3	sh3	No	Serial No	Spatial Unit Unique Code
SYNT_DOM_A	f3.1	f3.1	Number		Building Permit Limit(L)
SYNT_DOM_D	f3.1	f3.1	Number		Building Permit Limit(R)
POSO_KAL_A	sh3	sh3	0-100	Percentage %	Plot Coverage Percentage(L)
POSO_KAL_D	sh3	sh3	0-100	Percentage %	Plot Coverage Percentage(R)
SYS_DOM_A	sh1	sh1	Code 1 2 3	Former Terraced Deviations Former Detached	Building System(L)
SYS_DOM_D	sh1	sh1	Code 1 2 3	Former Terraced Deviations Former Detached	Building System(R)
PROKIPIA_A	sh1	sh1	Code 1 2	Yes No	Entrance Gardens(L)
PROKIPIA_D	sh1	sh1	Code 1 2	Yes No	Entrance Gardens(R)

Figure 11: A part of the Database Dictionary

4.3. Photographic Documentation

Photographic shots were taken throughout the research area, and specifically on every intersection. Photographs were taken facing every direction, which means that there are two photographic pieces of evidence for every basic spatial unit (the section of the road axis between two junctions), one at the beginning of and one at the end of the section. The codes of the digital photos that were taken were charted on a map, where one can trace a certain photograph.

The photographic file is also available in digital form, while through the GIS (ArcGIS) which is used in the research, one can retract the photographs by working on the correspondent area of interest on the map. The photographs illustrate one section of the street each time while the level of the existing environmental quality of every street is apparent.

Figure 12: Typical example of photo shootings.

Figure 13: Typical example of photo shootings.

Through these photographs one can make observations on the area, cross-check data of the base, possibly collect further data of interest, thus having a combined overall visual perception of the data. In this way, the photographic file provides evidence, reference, explanation and most likely a mechanism of cross-checking the database.

5 Various Uses of the Database

5.1 Development of the Database

The system as developed in this specific research (GIS), can be helpful to the urban and local administration offices (for example Municipalities and / or Prefectures of urban areas), by supporting them in decision making, in action planning and in taking measures.

The system has the capacity - by taking full advantage of its features – to process spatial and non spatial information, to illustrate the indices that record the environmental quality of the streets on a map layer, thus enabling the administration offices to observe and supervise within the boundaries of their administration at any given time. [10].

This stage comprises the processing of data which are in the form of primal material in the database and the creation of subsequent data in the form of indices in tables, on simple geographical maps and in thematic maps. This material then constitutes the foundation which supports decision making on matters concerning the development of the prefecture. The same material illustrates the picture of the environmental quality indices of the streets of a city as well as indicates which index category is in need of improvement. Causes and interdependent facts which create an overall negative and unattractive image of the urban environment can then be located [26].

Right at this point, the Geographic Information System plays its major role. The tools it provides for analysis, its direct linking to the base of non spatial data (Interactive) and the enormous load of information it can administrate at the same time, render it necessary to researchers in order to reach conclusions.

Its sections, which can combine spatial with non spatial data, its capacity to turn layers of information (Layers) into a system of interrelated parts creating new subsequent data with different methods of interference and interconnection in conjunction with methods of retracting information used by the database, make the system an integral part of such research. Its role also covers the diachronic monitoring of a phenomenon (Monitoring) and the update of the base with new data (Updating).

More specifically, the system enables one to:

- Directly map the spatial distribution of the indices of the base.
- Have a comparative inspection of the categories of the indices in the form of diagrams (histograms, pies, graphs etc), distributed in the area within the administrative boundaries that are being examined.
- To search for certain sections of the area which adhere to certain criteria, spatial or not.

The database that was developed includes indices that fall into eight (8) main categories of environmental quality indexes for the streets of a specific part of the town of Chania which was selected as research area. The collection of data on all the indices for the whole of the city was not feasible owing to the financial and time restrictions of this research project. It is nevertheless considered a necessity to extend the data collection area into a larger part of the city and update the system of its database, so as to render it a powerful tool for the environmental policy on the urban network.

The product of the analysis can be apparent and understandable provided that different mediums / forms of results presentation are used, and should be supervisory, easily understandable and provide with the capacity to compare and contrast between the results. Maps are such mediums of results presentation and in specific, there are:

- Maps depicting the phenomena described by the indices
- Maps of indices comparison in the form of diagrams (histograms, pies)
- Maps of multiple criteria searching (spatial or non spatial)

One of the targets of this research is, as previously mentioned, to provide with a scientific framework which enables one to record the existing level of the environmental quality of the streets in an area of the Municipality of Chania, to locate which parts seem to differentiate in relation to the rest and define the volume of intervention that has to take place in order to remove this differentiation in the level of environmental quality.

5.1.1. Mapping Simple Indices

The simplest way presenting results through a map is to depict indices as they are recorded and stored in the database (Figures 14, 15, 16, 17, 18).

This form of mapping presentation enables researchers to observe the indices they are interested in and form a view on their spatial distribution. Observing this distribution leads to identifying the homogenous zones that are created and the spatial differentiations that appear.

Examples of indices that can be depicted in this simple form are the index of enclosure level, of the presence of advertising signs, of cleanliness level, the index of building permit limit, and so on. Some of these indices appear further on.

One can be either convergent with the area, or obtain data besides the environmental quality indices in order to draw useful conclusions about the picture of the indices in the research area.

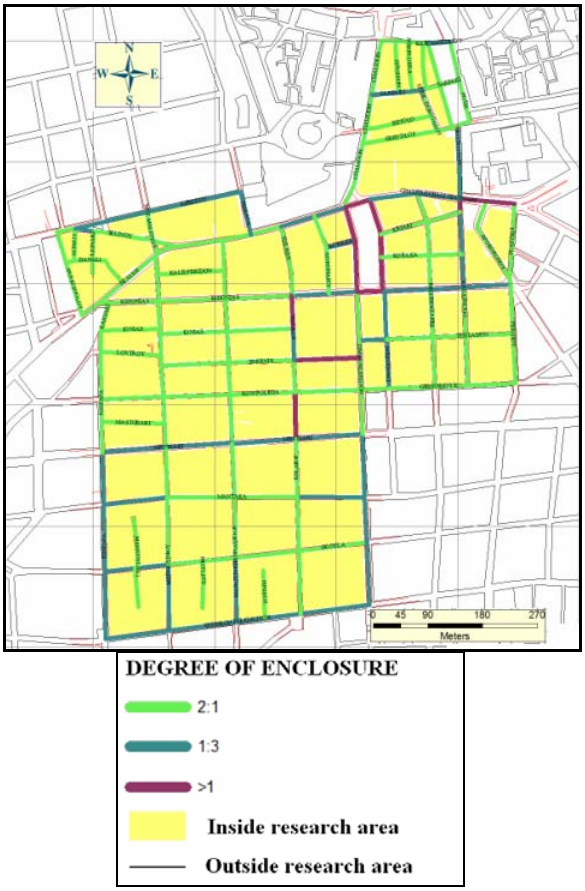

Figure 14: Map – Degree of Enclosure

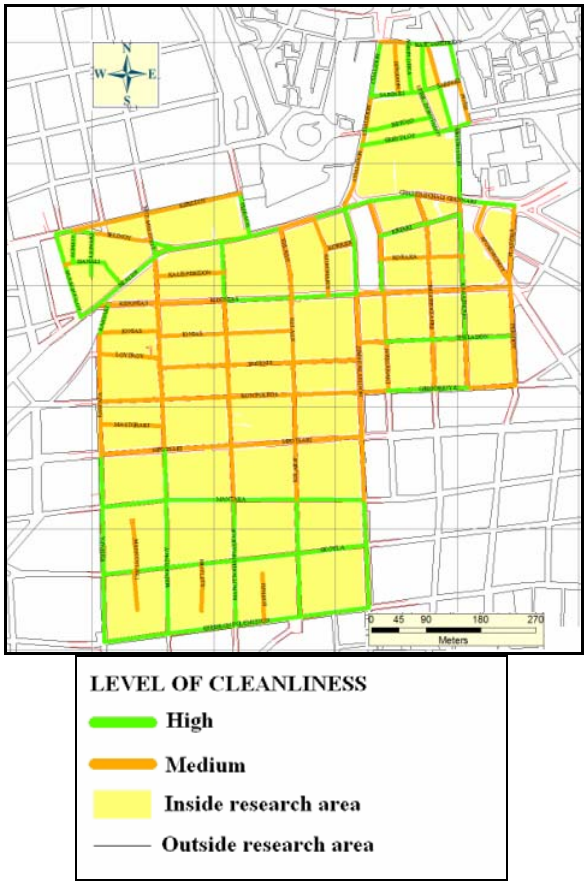

Figure 16: Map – Level of Cleanliness

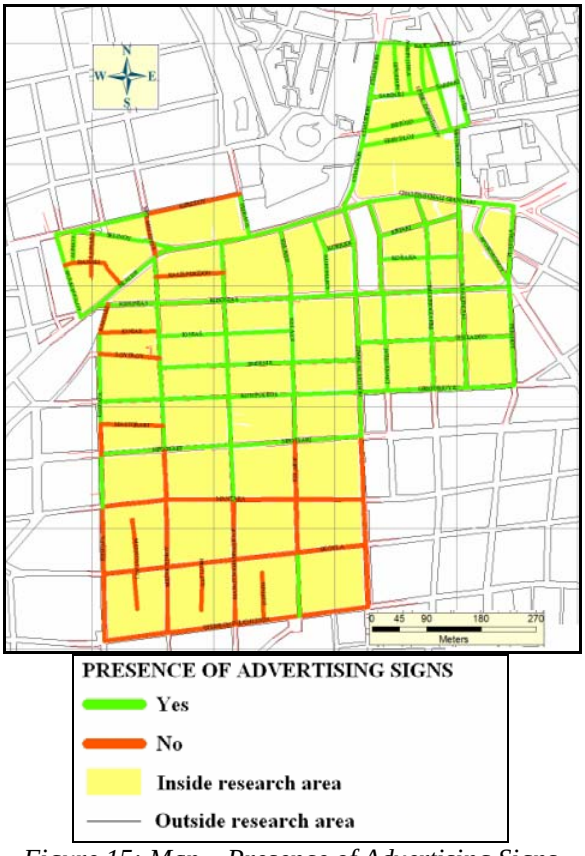

Figure 15: Map – Presence of Advertising Signs

An example of that would be the fact that we observe a frequent differentiation of the south part in relation to the rest of the research area, as far as the environmental quality indices that are recorded and depicted are concerned. A basic difference of this part is that it is a residential area with non existent commercial activity, which usually degrades the surrounding area.

5.1.2 Diagrams (Pies, Histograms)

Maps are another form of depiction as they enable us to contrast comparable indices. The comparison is feasible and through it one can identify the existing similarities and differences, through the charting of index groups in the form of histograms or pie- charts (Figures 19, 20).

It is worth noting that the indices that are to be included into a group to be mapped must be comparable among them. For example, one can choose to chart the index group concerning the commercial activity, some of them being the index of retail and wholesale transfers, of department stores, etc.

In the event of indices being charted in the form of histograms then the comparison is full (indices directly comparable between them), while in the form of pie-charts the comparison is relative and on a per cent basis.

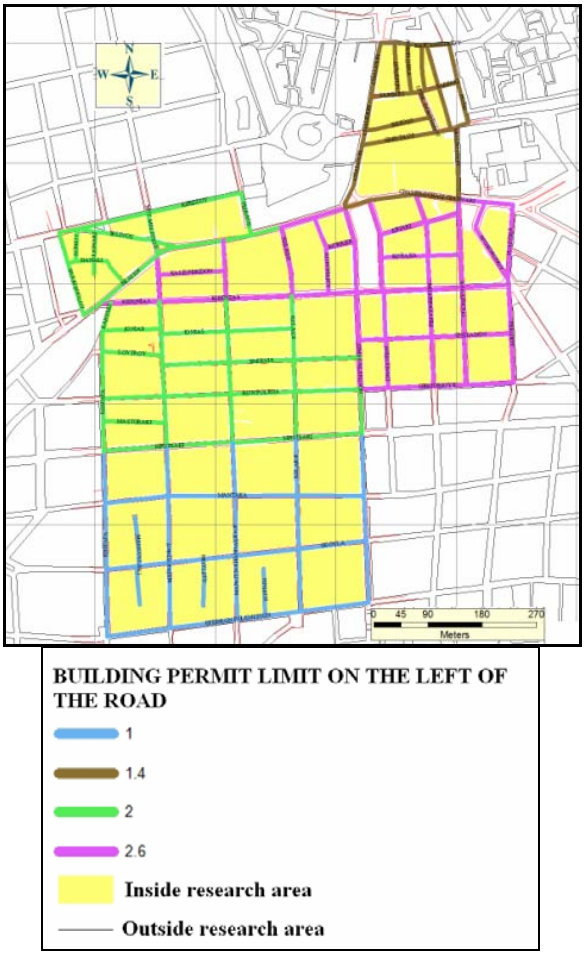

Figure 17: Map – Building Permit Limit on the Left of the Road

Certain examples of charting index groups in the form of diagrams to compare them follow further on.

5.1.3. Search based on Criteria (Spatial and Non-Spatial)

The third way of depicting analysis products on a result map, is the creation of maps of multiple criteria search (spatial or not) (Figures 21, 22, 23).

This type of charting reflects the logic of GIS since a search is conducted either on the spatial database or on the descriptive (non spatial) one [10].

The search for parts of the research area which meet certain criteria (simple or complex) , helps the researchers to locate any occurrences –or lack of them- or even foresee any eventualities. The criteria could be so complex that it would be practically impossible to process without the use of a GIS.

Concerning this research, examples of such searches could be:

- Which streets display high commercial activity but restricted pavement width

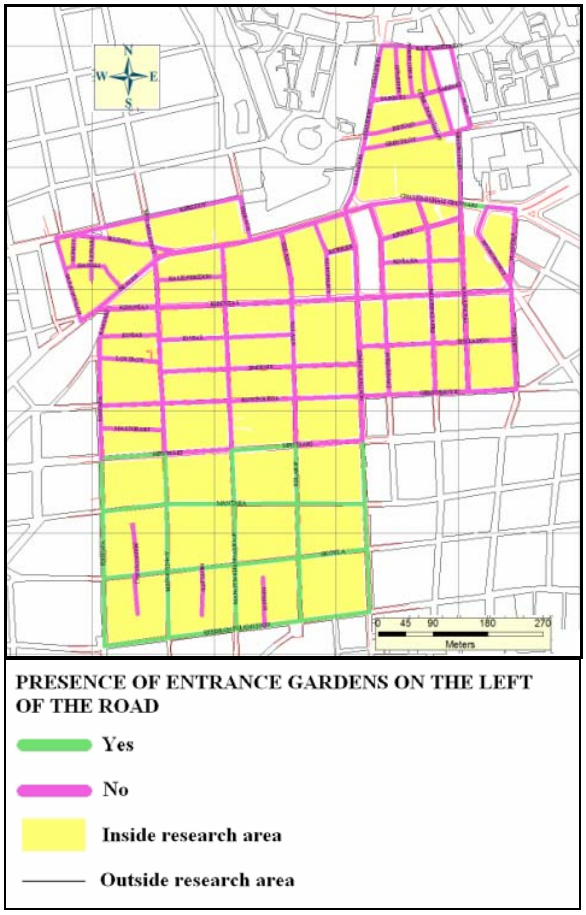

Figure 18: Map – Presence of Entrance Gardens on the Left of the Road

- In which streets the road and pavement surface quality is very low.
- The streets on which despite their restricted width, parking is permitted on both sides of it

Examples of mapping such questions based on certain criteria follow further on (Figures 21, 22, 23).

5.2. Contribution of the Database to Decision Making

This research, after having programmed all the stages of this approach, completed all the processing and analysis and prepared all the produced material, is then on its last phase, which is the presentation of analysis results in the form of maps (spatial depiction), as mentioned before.

However, the maps (geographic and thematic ones) and the comparison indices that are created in a forward and dynamic manner by the GIS are not an aim in itself in this research system.

The database has to constitute a policy tool in decision making, as predefined in this research. In order for such a tool to be complete, it has to be accompanied by a framework of criteria which will lead and direct the researcher objectively in decision making [13, 15].

These criteria will function both as a model and as a restriction for the user of the database and will lead him / her to reach the right conclusions in his decision making for the political improvement and ceaseless development of the urban network. The environmental quality of the streets is an important parameter for the standard of living of the residents, especially in big cities.

It should be noted that in order to achieve correct planning and fill in any omissions and improve areas of low environmental street quality, one should follow the model given:

- What is there in every area
- What should there be in every area
- What is missing from every area

The difference between "what there is" and "what there should be" reveals any shortages (or surplus).

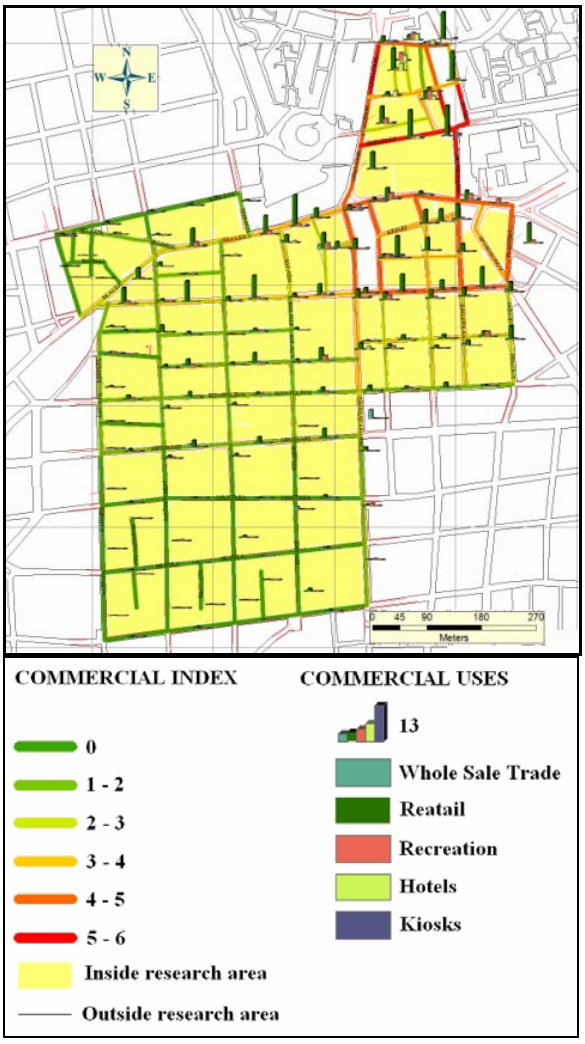

Figure 19: Map – Commercial Uses and Index

This research can assist in all three phases of this model by providing the information for the descriptive stage, the tools for analysis, the several forms of analysis that can be applied on the "what should there be" stage as well as some form of locating omissions / shortcomings and priorities in the "what is missing" stage.[15].

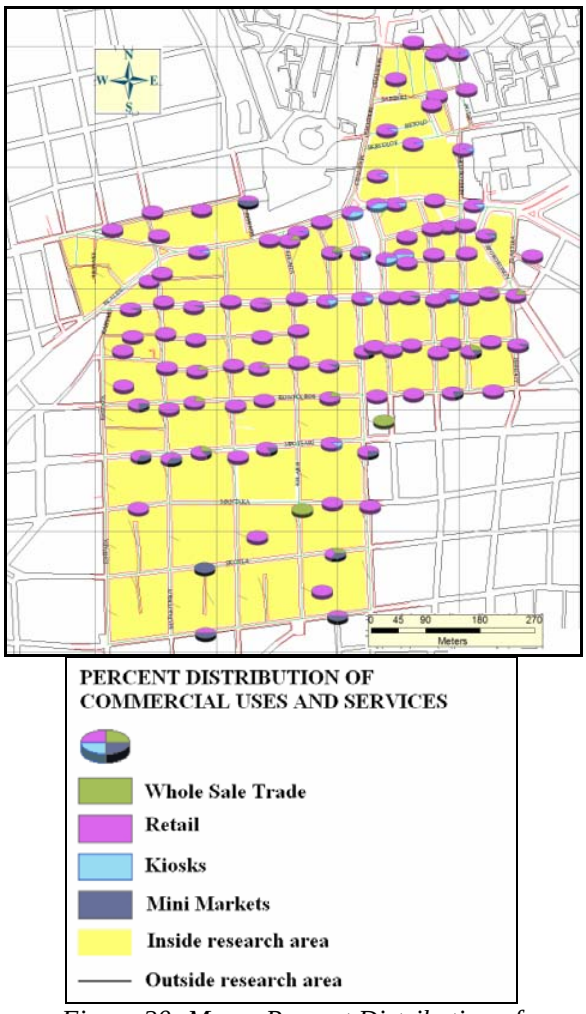

Figure 20: Map – Percent Distribution of Commercial Uses and Services

6 Problems - Recommendations

6.1 Problems Located

The great usefulness of the Geodatabase and of the analysis that can be conducted through the use of the GIS is directly acknowledged in the process of describing the research area and the problems that are observed.

By spatially analyzing the research area, several problems have been observed and are presented further on in this unit. The capabilities of this digital geographical system are such that the user has knowledge of the spatial distribution of the parameters that are examined as well as their possible combination.

6.1.1 Streets Profile

On occasions, due to the high building permit limit, there are many high buildings.

In other areas, due to the high building permit combined with a lack of entrance gardens, the fraction of building height / road width (h/w) takes high values which are not acceptable for the public health or for the convenience of the street user of this area. The same applies to the area of the old town, where buildings may not be too high, but the streets are narrow and there is absence of entrance gardens. On the contrary, in areas where the fraction h/w gets low values, the parameters guarantee a high standard of living for the street user due to the lower buildings and the presence of entrance gardens in building blocks.

It is also observed that on certain streets the continuous building in conjunction with the height of the buildings, create the effect of "street gorge" in the lengthy street sections, while in the shorter ones they create an enclosed, undesirable environment.

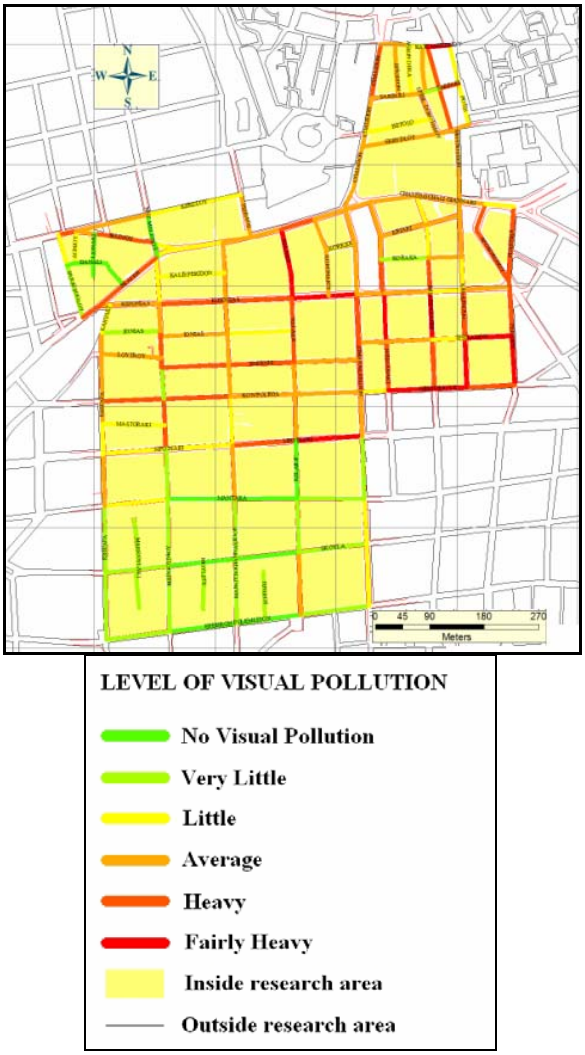

Figure 21: Map – Level of Visual Pollution

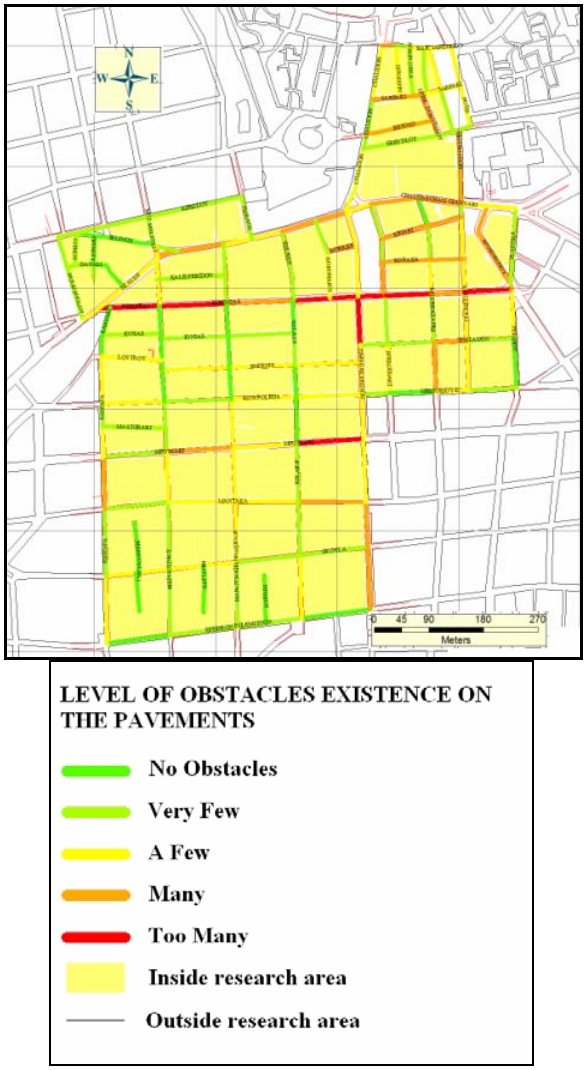

Figure 22: Map – Level of Obstacles Existence on the Pavements

6.1.2 The Increase of Car Use

The rise of the standard of living and the need for more and longer transportation marked an upturn in the car market and in car use. During the last decade the number of cars has increased in the prefecture, which led to the creation of both environmental and social problems [18, 21]. It is therefore considered essential to take measures against the continuous use of cars and promote policies of viable mobility.

6.1.3 Road Network and Traffic Conditions

Apart from the increase in car numbers, there are other parameters that contribute to the degrading of the traffic conditions, such as the layout of the uses of land, the condition of the road network and the lack of parking spaces.

The concentration of all the commercial, administrative and other kinds of services in the central area in combination with the high building permit limit, attract a great deal of transportations, thus creating traffic congestion conditions,

especially during rush hours. These conditions are very unpleasant for the street users. The decentralization of certain administrative services, the creation of other local centers, the removal of the bus station from the square of the old market are some of the steps that could improve the environmental quality of the streets (diminishing of the noise level, of the fumes, accidents, stalling, etc). In residential areas though, one does not observe unpleasant traffic conditions, as the building permit is low, while the need for moving about within these areas is restricted [26].

Figure 23: Map – Existence of Recreation Places and Free Parking Facilities

The intersecting of central arteries and of secondary streets around the central area increases the traffic load, as the continuous and unhindered traffic flow is impossible. The problem is then expanded around neighborhood streets, as many drivers wishing to avoid traffic jams and traffic lights opt for the side streets. It is therefore considered crucial to divide the road network into easily discernible rings which would protect neighborhoods form the passing through of the traffic and would discourage the unnecessary passing through the city center. Turning some of the streets into one way streets will contribute in a positive way to their environmental quality as it will facilitate traffic and diminish the chances of an accident. A negative effect of it though is that the traffic capacity of the streets hasn't really improved, as the space that was made available is usually occupied by illegally double parked cars. An alternative would have been to render the extra available space to pedestrians, or permit parking at an angle, which would mean more available parking spaces.

Illegal parking is due to the fact that the demand outstrips supply in the central area. As a result, intense environmental and social problems are created in central areas and thus this renders the necessity for new parking spaces off the road imperative.

6.1.4. Pedestrians' Convenience

The pavements are usually narrow and their condition is usually poor, as there is evident bad workmanship, excessive wear and tear and obstacles.

In certain areas the width of the pavement does not exceed 1.5 meters. In other areas the situation seems better, as most pavements have the minimum required pavement width, which allows for two people walking abreast, while a substantial percentage of them are wider, which allows for three or more people walking abreast. Especially for the streets with high commercial activity, the reconstruction of pavements and the provision for more available space to pedestrians can only be rendered possible through one-way streets and the exploitation of the remaining undeveloped space.

Pedestrian crossings are mainly found in streets with heavy traffic which are usually the ones with high commercial activity. The geometric features seem adequate, which cannot be said of their maintenance. There should also be provision for the construction of ramps which will meet all the specifications for wheelchair friendly streets, as in a large percentage there is a lack of them.

6.1.5 Urban Transportation Network

It is observed that the frequency and reliability of the existing bus lines is not satisfactory. The provision for new bus lines is recommended, as well as the use of mini buses which will accommodate sparsely populated areas or those whose streets do not allow the passing through of large buses.

6.1.6 Street Equipment

It has been observed that the street equipment is adequate in the central – commercial areas. In the areas which are off the center though, the street

equipment is non- existent, as there are no dustbins, telephone booths, etc. The whole urban complex lacks some pieces of basic equipment, such as benches and taps, resulting in an image with no identity and of poor aesthetics.

6.2 Recommendations for the Improvement of the Environmental Quality of the Streets in the city of Chania

Any research would be incomplete if, apart from the observations being made, it didn't offer any recommendations- urgencies which would improve the problems that arise.

6.2.1 Traffic Interventions

- Discourage the use of vehicles in the city center by providing less available parking spaces.
- Extension of the controlled parking zone into areas off the city center with simultaneous increase in parking tickets and stricter traffic police supervision on the controlled parking zones of short duration.
- Prevention of transversal traffic through the extended city center and construction of a peripheral road.
- Reinforcement of the public transportation system by increasing the number of available vehicles, the frequency of itineraries, and the creation of new ones.
- Provision for greater use of the public transportations and access to environmentally friendly vehicles.
- Reduction of the traffic load by decentralizing main functions (e.g. public services) and the creation of flexible shifts.

6.2.2 Urban Planning Interventions

- Stricter control from the urban planning offices concerning issues such as the outdoor constructions without a permit. Unavoidable demolition of these illegal constructions which affect the micro-climate of the city and alter the airing conditions. The banning of pilotis and the building of apartments where parking spaces ought to be, only increase the number of cars that are parked on the pavement.
- Intervention in the constructed environment with an aim to restore and develop.
- Integrate outdoor spaces to create private spaces of green.
- Use of environmental friendly paving materials for the streets and pavements.

6.2.3 Interventions in Transportation

- Increase the pavement width in order to attract pedestrians and construction of appropriate ramps in order to facilitate immobility vehicles and achieve harmonious co-existence with and integration of disabled people into the society.
- Tree plantation on wide pavements. The opening of pits of at least 1 meter width to allow for optimal growth is recommended. The placing of grids on those pits in order to facilitate walking along and to prevent falls.
- The creation of green networks by connecting pavements and pedestrian streets to green element spaces.
- Turn the electrical power network into an underground one.
- Use of similar and of the same color paving materials, which would guarantee an homogenous appearance , smooth and less noisy moving of wheelchairs and other immobility vehicles, and would have anti – slippery properties.
- Enforce construction companies to use specific layering materials and colors
- Creation of a network of bicycle lane in areas where the inclination allows it.

6.2.4 Rest of equipment for public convenience

- Putting up seats wherever necessary, such as in bus stations, squares, communal spaces, recreational spaces, etc
- Installing telephone booths in areas off the city center.

6.2.5. Cleanliness and Sanitation of Public Spaces

- Implementation of a mandatory recycling scheme. Placing of recycling bins for paper, glass, metal and so on all through the city. The particular scheme would define the date of the collection as well as which material will be collected each time. The volume of waste will be charged in order to reduce the waste and encourage recycling.
- Placing of the waste bins inside the perimeter of the plot only the night before the collection of the waste.

7 Comments - Conclusions

The aim of this research was to design and develop a database which would include all the elements relevant to the quality of the urban roads, so that the local administration bodies are facilitated in handling the urban environment and in their decision making. This database was designed and could serve as a pilot research for the local administration offices. The 124 indices aimed to cover the whole spectrum of the environmental factors. The potential for processing and analyzing

is endless; mapping, classification of areas according to their homogeneity, environmental evaluation based on multiple criteria, and the diachronic updating and observing of the urban environment.

One of the problems encountered was that for some of the indices no data was obtained. This is a problem that occurs frequently throughout Greece and is owed to the fact that every municipality have conducted their own projects, which means that the conclusive data is quite diverse. This particular database though, includes fields for those indices that haven't been recorded so far, so that when more data becomes available, the base can be updated.

Another obstacle was that in some cases the available data were in relation to the city as a whole (i.e climatic indices, temperature, rainfall, etc). The variations throughout the city though, are unknown, which is why it is recommended that new research should be conducted, based on recording every individual street.

Yet another problem is the specialization of the people who take part in on site recordings of data. Certain indices -such as colour variety, harmonious mixture of colours- should ideally be carried out by an architect. In such cases, the research team should consist of researchers from all related sciences.

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