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Model for Analyzing Urban Dynamics Using 4D-GIS Analyses
(The Evolution of Land Uses in the International Coastal Road Region)

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Abstract

Urban field is in need for the integration of the time factor or the fourth dimension (4D) and the Geographic Information Systems (GIS) that is led by our need to make sound and quick planning decisions through new planning techniques. These techniques will help integrated with new technologies in solving planning problems, such as the analysis of land use in terms of change in growth. We want to understand the spatial relationship between the structure and behavior of complex dynamic systems. Where system behavior changes over time from the results of interactions between system components. This paper presents new methods to develop a number of traditional planning analyses using the new technologies. The new methods can provide more realistic understanding of the structural and dynamic relationships of the urban system components. They enable us to diagnose imbalances in the urban system by suggesting possible correction elements. Then we will address an applied case that demonstrates how to activate the (4D) methods using some of the new technologies.

Keywords: urban dynamics (UD), geographical information system (GIS), Fourth dimension (4D), SCADA systems, remote sensing (RS), global positioning systems (GPS)

1 INTRODUCTION

1.1 Main Research Objective

Building an application model to develop an analysis of future needs assessment of land uses using 4D-GIS analyses for the land uses region around the international coastal road.

1.2 Research Methodology

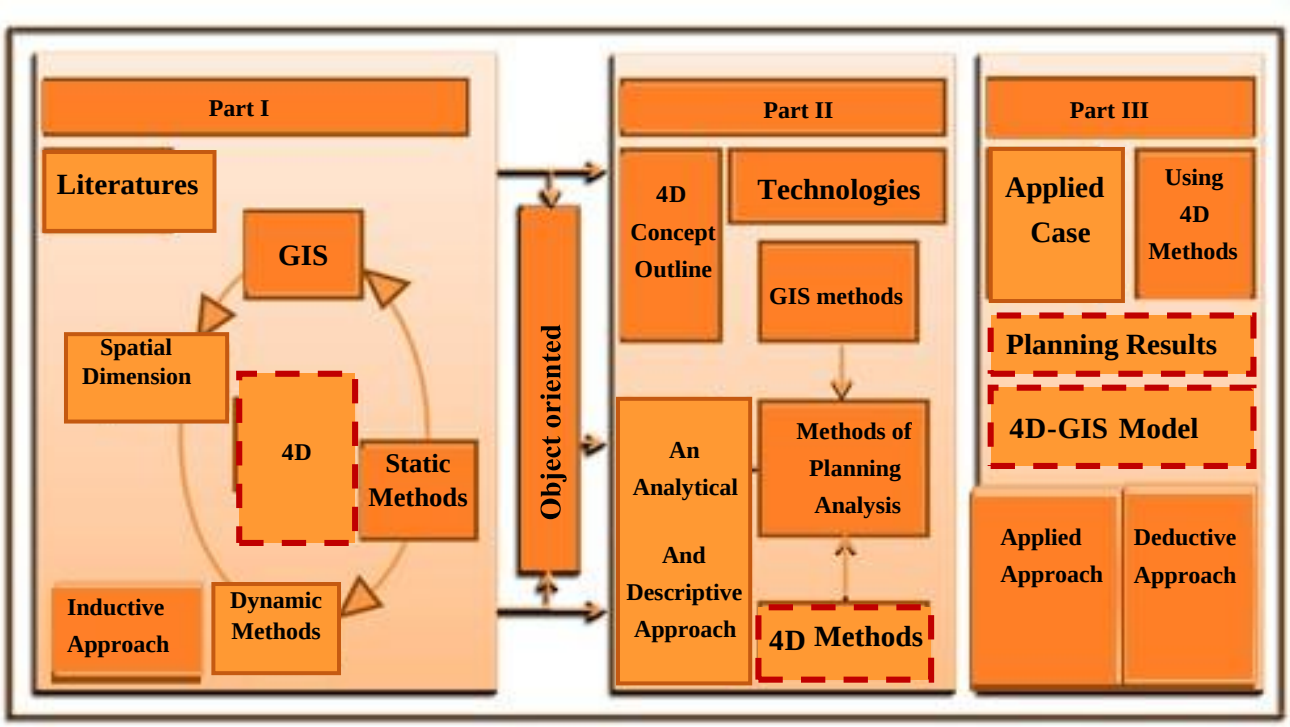

Fig.1. The research Structure

2 STUDY OF THE ANALYTICAL SCIENTIFIC METHODS USED IN THE URBAN FIELD SUCH AS

2.1. Static Methods [1]

The Mathematical Models is considered as static models. They are analytical methods that use mathematical equations and principles to represent the dynamic relationships of systems and area quick way to solve structural problems but only indicative and not accurate as there are many factors affect the schematic decisions are what cause the real problem in the real world.

2.2. Dynamic Methods [2]

Dynamic models are more expressive of complex systems such as urban systems where differential equations with at least one-time derivative are used or algebraic equations with a time limit are used for any function in time. They are accepted by entering values for the variables during the model run time. In the representation of urban systems, many changes occur in any of the values of the constituent parts of the urban system or affect it represented variables within the model. Then, the results are more realistic and give us a clearer vision of the forces affecting the urban system by taking into consideration all the before the work of the model, i.e. during data processing, or during operation, it changes dynamically.

2.3. Cause of Using 4D Concept

Planners need a method that helps them in representing aggregated schematic data in a way that links space with time and gives them a perception of the changes patterns over time. This is why we use the 4D methods, as there are technologies that give chronological information in chronological order for spatial positions, either fixed as in static or dynamic staging stations, as in SCADA stations using GPS. At each reading, fixed track and time such as the different spectra of the satellites and then represent the time factor and its integration with the 4D-Geodatabase to know the Animated Geo-Statistical Surfaces and patterns as shown in Fig.2.

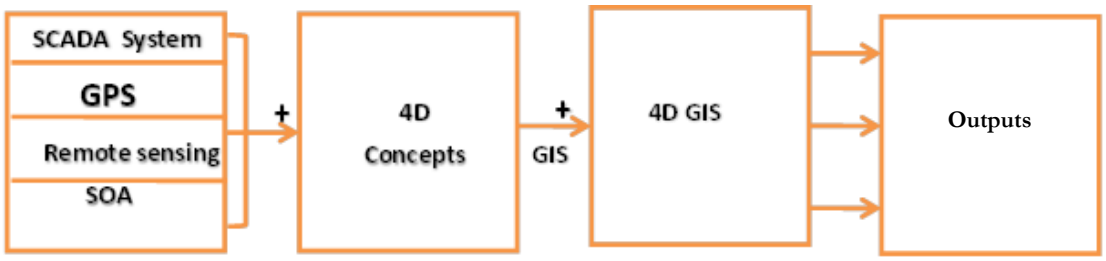

Fig.2. Stages of integration between the 4D concept and technologies and application in GIS to reach the required results

3 RESEARCH STEPS TO RESULTS

We will provide the methods of some planning surveys and analyses that can be developed with temporal analyses with the help of GIS and the use of 4D Analysis and review of the accompanying technologies that are integrated with GIS. This integration will enable us to apply and represent the 4D concept as a method of performing many surveys and planning analyses in an inclusive representation for the dynamic relationships of the urban system components.

Some surveys are carried out to assist planners in different planning projects. These surveys are the basis for planning performance analysis, which will affect planning decisions in the planning process and in the management of cities and services by using GIS integrated with 4D concepts seeking for well performing to these surveys and analyses. Then we will understand the dynamics of urbanization and the reasons for the pattern of change in urban stability. In the light of the emergence of the temporal factor and the 4D analyses, we will consider the addition of (4D) to achieve good performance in the conduct of these surveys and analyses to know the forces and know the reasons behind the change mentioned above.

We will present some of the proposed methods for applying and representing the 4D concept in integration with GIS systems and information, explaining the appropriate method for each type of survey or planning analysis as shown in table.1 and table.2.

Table 1. Some of planning surveys methods that are developed with the concept of 4D and the proposed methods of application and representation

	Land uses surveys	**Networks surveys**
Type of Survey	Land use survey	Transportation survey
Applying Methods	Parametric Equations	Direct use of technologies output
Representing Methods	Animated Geo-statistical Surfaces	Varied levels in color and area

Table 2. Some of planning analyses methods that are developed with the concept of 4proposed methods of application and the D and representation

	Analyses of the Future Situation			**Analyses of the Current Situation**		
Type of Analysis	Analysis of future needs assessment of			Analysis of historical evolution of services and utilities distribution	Analysis of historical evolution of population distribution	Analysis of trend towards uses
	services and utilities	Population	land use			
Applying Methods	Dynamic Simulation			Parametric Equations		
Representing Methods	Varied levels in color and area	Set of varied points in size and number	Animate d Geo-statistical Surfaces	Varied levels in color and area	Set of varied points in size and number	Animated Geo-statistical Surfaces

4 APPLIED RESEARCH CASE

To study the evolution of land use analysis in terms of growth trends and to estimate the future needs of different uses using the four-dimensional analyses methods. In addition, to present the proposed scenario for the work of the spatial model 4D-GIS model and apply it to a planning area, **which is the international coastal road, study, and development of surrounding uses.**

4.1 Planning Background For The Area Of Interest:

The idea of the study is based on studying the growth trend of the land use and the forces affecting the change of the urban system as a whole. as well as the proposals for the future needs of the uses in the study area from Alexandria westward to Port Said eastward and down the international coastal road by 5 km (2620 km2) In light of the time period from 2000 to 2010 until the target year 2030.

The idea of development depends on maximizing the use of the international road. In order to succeed, the development process must be carried out within the framework of a comprehensive plan based on integration between three factors as shown in Fig.3.

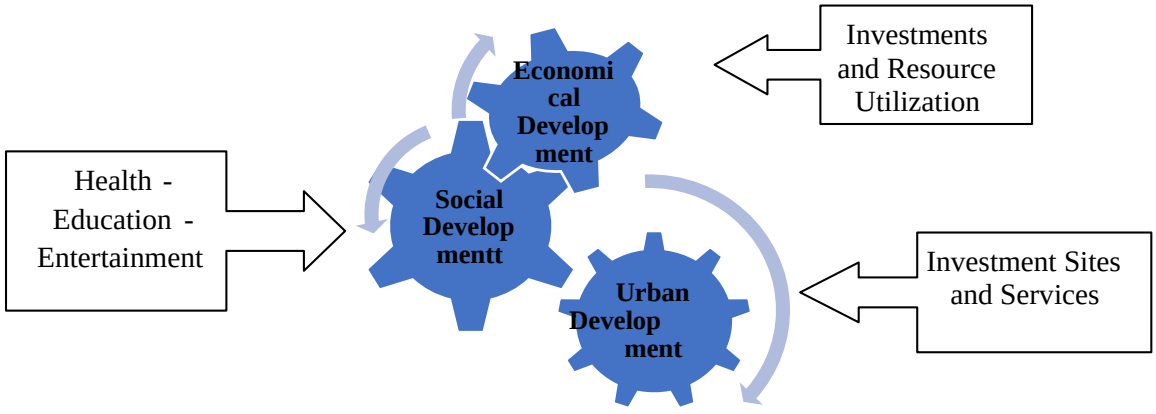

Fig.3. Importance of urban development and its impact on economic and social development

4.2 Stages Of Constructing The 4DModel Through GIS To Study The Evolution Of Change In The Trend Of Land Use Growth In The International Coastal Road Area

The study of the growth trend in land use is the first step to estimate the future needs of land use. In order to study the growth trend and the work of the 4D-GIS model, a number of steps must be taken to construct spatial model parts using GIS.

4.2.1 Planning steps for the 4D model to study the change in the direction of land use in the international coastal road area [3]

We begin by describing parts of the study area, and how analytical work, is conducted:

- The path of the international coastal road from Alexandria to Port Said and its tributaries and dividing the study area into four sectors as shown in Fig.4.

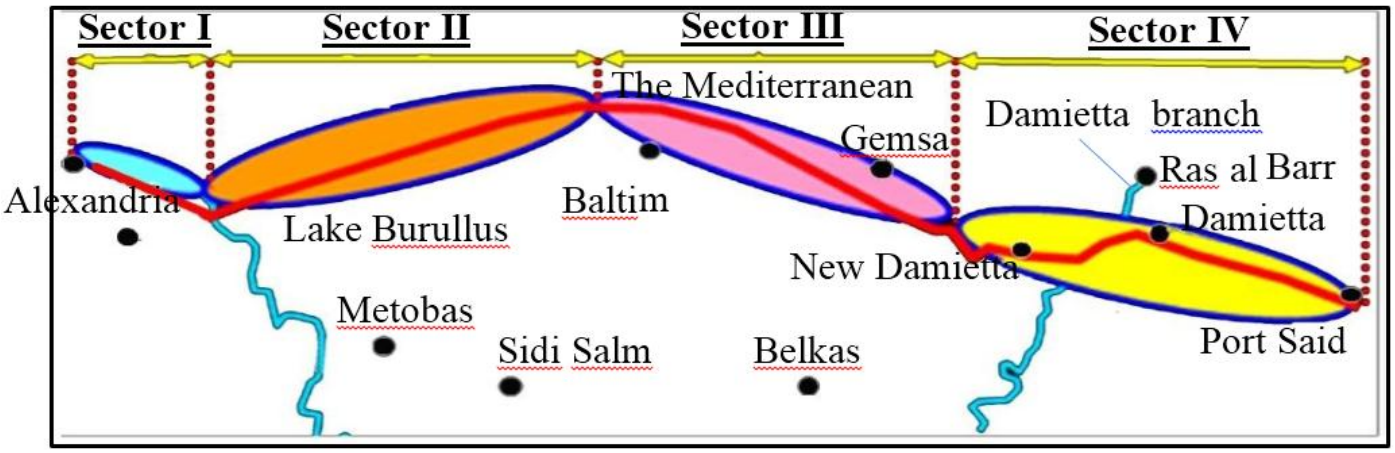

Fig.4. Sketch shows the four sectors of the area of interest

- The land use survey is conducted prior to the existence of the road (year 2000) as shown in Fig.5.

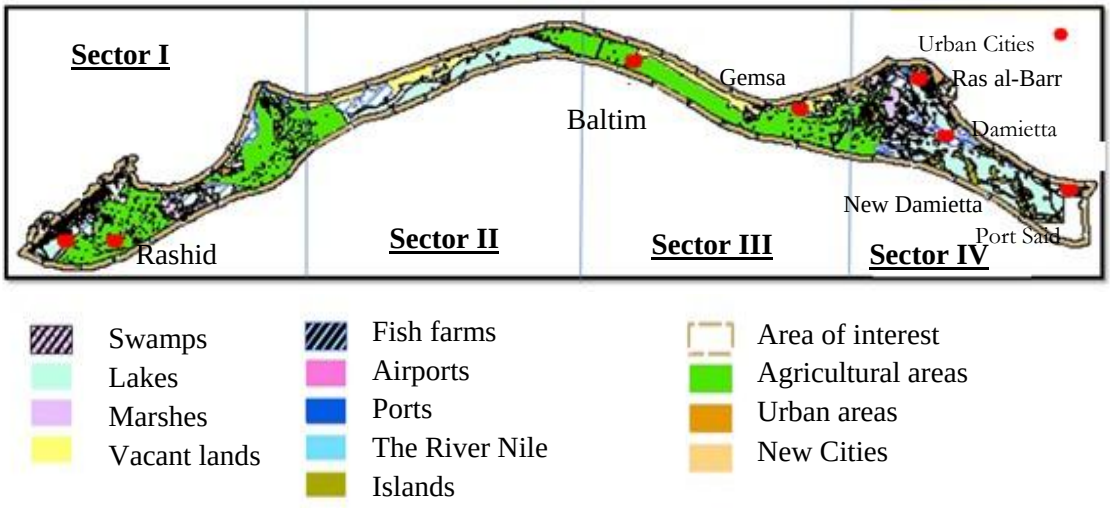

Fig.5. Land Use in 2000

It is shown from the previous figure that after a survey of land uses in 2000, there was no international coastal road, which was not established.

- The process of land use survey of the situation in 2010 and then the update of the survey and satellite images as shown in Fig.6.

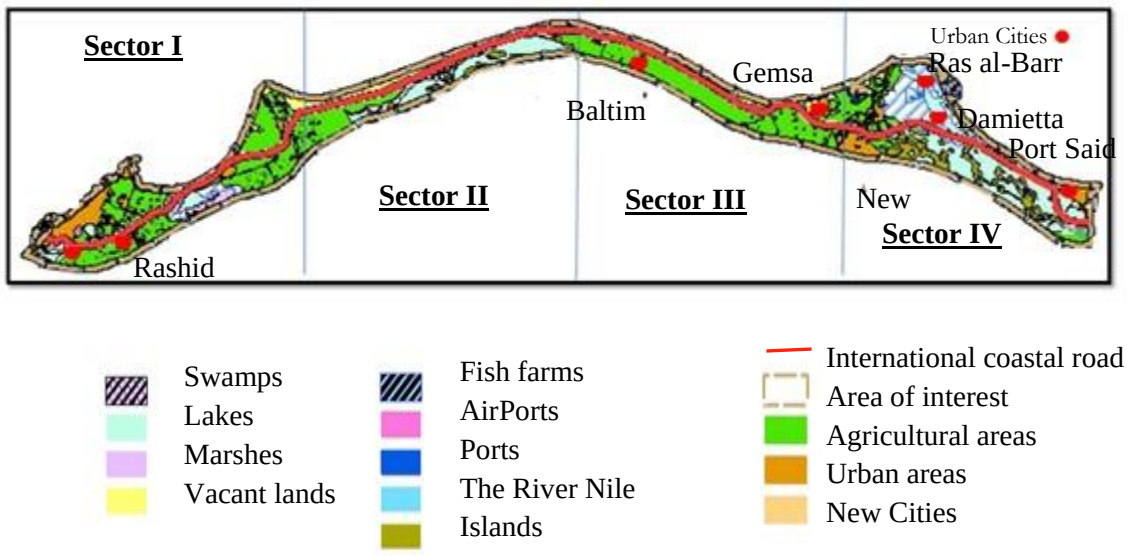

Fig.6. Land Use for 2010

It is shown from the previous figure that after a survey of land uses in 2010 after the existence of the international coastal road.

4.2.2 Analytical procedures of the 4D model to study the change in land use trends in the coastal international road area [4]

- Modeling (to represent land-use change): The 4D model with geographic information systems of the change in land use for each of the four sections of the study area in each of the two periods, under which the analytical study is carried out. Through the collection of spatial and other data in order to identify the problem of planning and its causes to reach the desired results.

- Building 4D model "Temporal GIS (TGIS)" to study the change in land use patterns using 4D applying methods suitable for land use analyses such as the study of the trend of land use growth and change from 2000 to 2010.

- We will use the first method of application is the use of technology results such as remote sensing technology and the GPS positioning system with the updating of data from the various authorities concerned with each land use. In addition to the use of tracking systems SCADA which attached with GPS that can monitor data of distribution and measurement ratios of utilities and services in each sector of area

of interest. For future predictions and alternatives, we will use the simulation method.

- Building a model using the Object Oriented concept integrated with GIS (OO-GIS) to undertake an analytical tracking on land use change.

- Conduct analytical and statistical studies to determine the causes and forces leading to changes in land use patterns and causing problems in the sectors of area of interest.

- Introducing 3D data in the model to achieve the virtual vision of the spatial analysis of land use through 3DGIS.In order to enable the planner to think deeply, and provide the desired analytical study that provides a good understanding to changes land uses in the region around the international coastal road and its impact on urban mobility for the whole region.

- Perform the representation process using 4D concept methods; first, we will use the method of animated geo-statistical surfaces representing the growth trend of each land use over the two periods (intervals) in 2000 and 2010. We use the method of varied levels in Color and area to represent the urban encroachment on agricultural lands. Finally, we will use the method of varied points in size and number to represent .the population densities of each sector of the region

- Building the Spatio-temporal data model to track the land use changes occurring in each sector of the area of interest to reach wherever the growth in each use is directed to through applying and representing the concept of 4D.

4.2.3 Operational procedures of the D model to study the 4 change in the direction of land use The spatial model consists of three parts [4-5]

1. Part of the storage of land use changes through a data modeling process in the two periods for the area of interest (2000 – 2010), the Open Object Oriented Approach of GIS model.

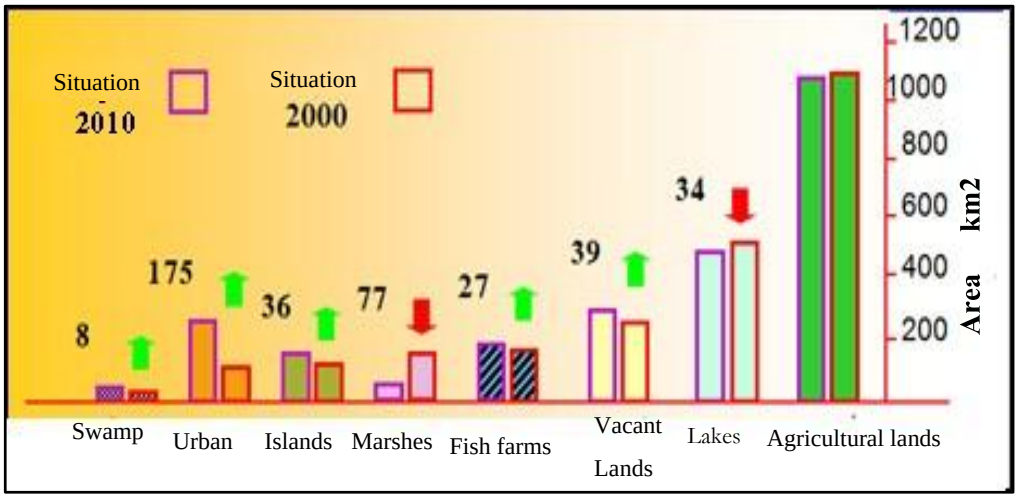

Fig.7. Sample of Statistics applied On Land Use During The Period (2000-2010)

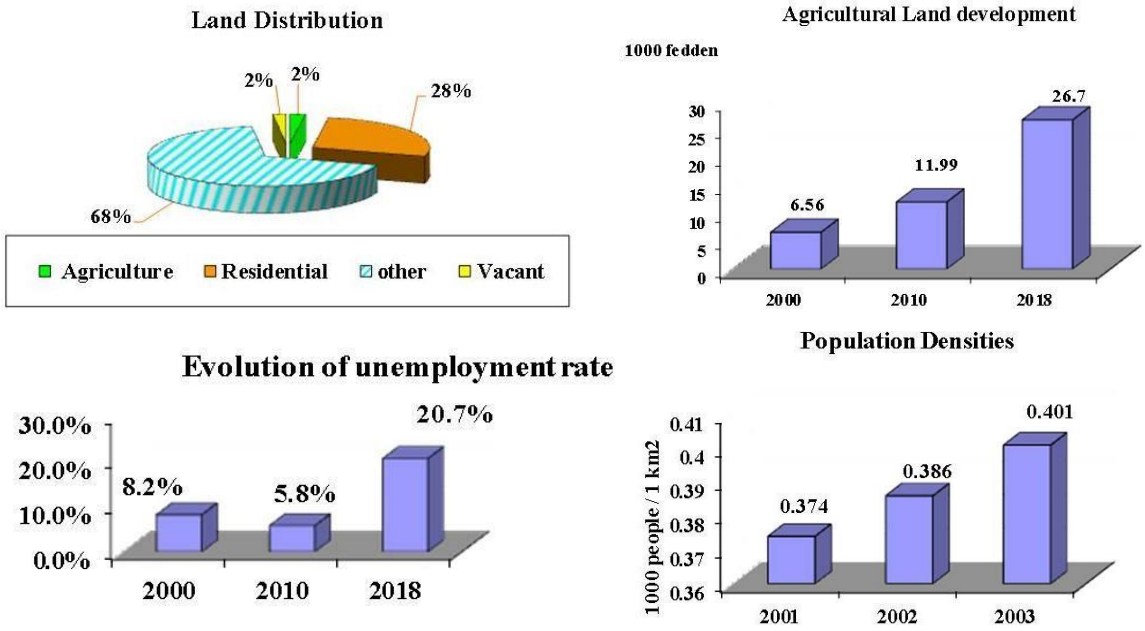

Fig.8. Sample of the Statistics for Each of the Four Sectors.

- The model is concerned with storing the results of spatial analysis and 4D queries that are performed on these data; these spatial analysis and results of the statistics that reflect the changes in land use during the two periods to determine the reasons for these changes as shown in Fig.7.

- How to represent the statistical indicators for each of sector of area of interest during the period (2000-2010) by taking averages of indicators in each governorate of each sector governorates to produce a result of indicators in each section of the four sections as shown in Fig.8.

Sector III: Kafr El sheikh - Damietta

- These indicators are real forces affecting the trend of urbanization; where the population census significantly affects the change urbanization patterns in the city and consequently affected the locations of services as they are affected by the distribution of population and affected them.

2. Part of the representation of changes in land use and the vision of results and effects through the virtual screens presented by simulation method as a method of application of 4D concept. This part is considered as the visualization stage. There is an interactive potential in this part where the scheme through which to form Vision and good understanding of these changes and their impact on the trend of growth for different uses in each sector, such as navigating in the model

through visualization tools. According to spatial data of the time periods (2000 to 2010). Planner will be directed to make the right decisions and to know the driving forces of the urban in each sector, their locations and the extent of their impact on different uses with the help of geo-statistical analyses tools.

- The main objective of using visualization in GIS applications is to demonstrate the spatial data as it helps to provide a better understanding of the plan, reflecting the impact of each proposed scenario and its interaction with the other parts of the urban system. As well as the reasons for the change in the quality of land use. These rates are considered as standard indicators of land use change, so you can know the effect of the driving forces of urbanization in the patterns of changes of different uses in all sectors of the area of interest. Then, we propose possible alternatives for land uses under the ruling political conditions for the area surrounding the international coastal road as well as in the presence of the available potentials in the region so that our assessment of planning alternatives is more realistic and more compatible with the effects of those forces.

- The 4D concept as an analytical method helps to study the problems and potentials of each sector, such as the problem of urban areas encroachment on the agricultural lands as shown in Fig.9. The phenomenon of beaches abrasion exists at a high rate as shown in Fig.10 and the problem of high population densities in some Governorates of the area of interest as shown in Fig.11.

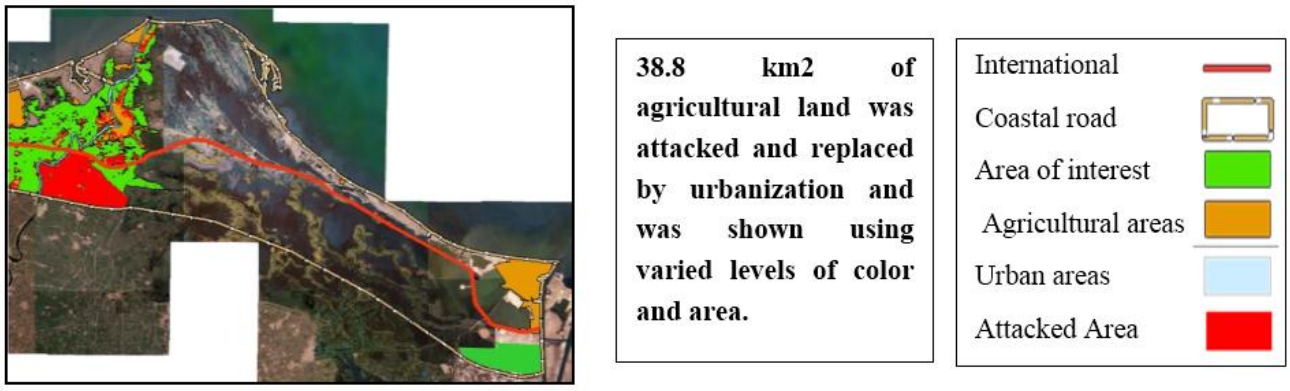

Fig.9. The problem of urban encroachment in sector IV: Damietta - Port Said

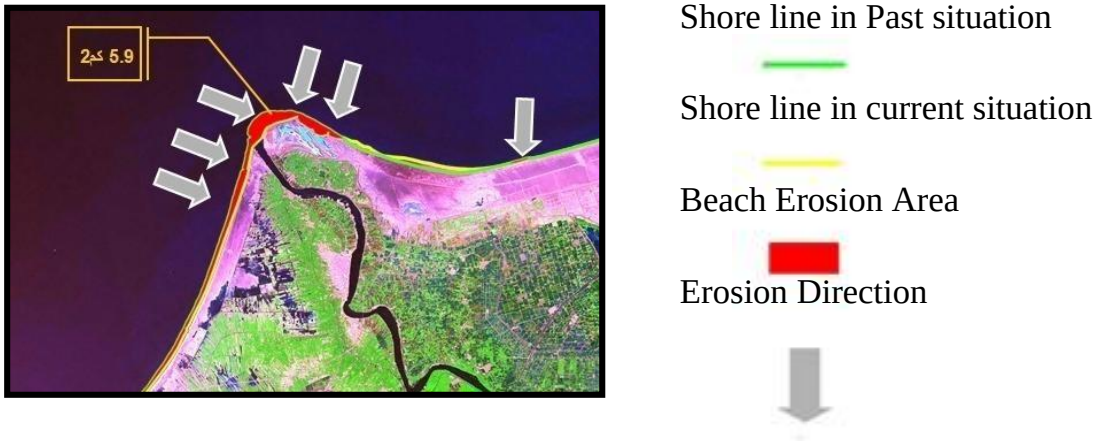

Fig.10. The problem of beaches erosion in sector I: Alexandria – Beheira

Figure 9 shows that analysis and study of the first sector during the period of 20002010, by applying of 4Dconcept through the method of direct use of technologies outputs such as (RS) technology and (GPS) indicates the existence of the problem of urban encroachment on agricultural land where Agricultural area contraction and urbanization increased.

Figure 10 illustrates the problem of Beach erosion at the mouth of Rasheed and indicates that analysis and study of the first sector during the period of time (20002010),by applying 4D concept through the method of direct use of technologies outputs. Such as (RS) technology (GPS) indicates the existence of the problem of Beach erosion. The shore line was changed from 2000 to 2010, where the area of the Beaches Erosion was calculated at **5.9 km 2**. Using the parametric equations method and the simulation method, the erosion rate was predicted and the area of erosion was calculated through20 years to the end of the year 2030.These results was represented using animated geo- statistical surfaces.

Fig.11. Problem of high population densities in sector I: Alexandria - Beheira

Figure 11 shows that the analysis and study of the first sector during the period of time (2000-2010) by applying the 4D concept through the method of direct use of technologies outputs such as SCADA system technology with GPS integrated with GIS indicate the problem of high population densities and inefficient distribution in comparison with governorates' areas. Other technologies that can be used in the case of population analyses are web services, where the direct update of data via GIS connected with Internet networks; the number of the population is not directly proportional to the area. We calculate the average population density of the constituent governorates of each sector. It was about 1.6 thousand people/ km2. We predict the population densities and land use areas in each governorate of the sector in 10 years to 2020, and predict after another 10 years until Target Year 2030 by using parametric equations method and simulation method. Then we use method of the varied points in size and number to represent the historical development of population densities. Also we use method of animated geostatistical surfaces to represent the change in land use areas

Through the values of land use areas for 2000 and 2010, we can create alternatives to improve the current situation of land uses, as well as predict some future uses in the target year such as urban extension by applying the 4D concept using Parametric Equation Method.

- The equation of measuring the overall efficiency of the region and consists of elements that reflect the global goals of land uses as well as local goals, as: It measures the proportionality of the land uses values and their order adjacent to each other and helps us in the process of developing alternatives Calculated from the next Eq. (1) [6].

$$\lambda global \times luv\ global + \lambda local\ \times (\sum\forall_l lot[_l] \times luv) / (\sum\forall_l lot[_l] \times area) \quad (1)$$

- Value of land uses in the region= Natural utilization ratio for area × Global value (extent of realization of the function + actual use ratio in the study for the area × total values for each plot of land use/areas per plot of land)

- $lot[\iota].\ lut$: land use type of every lot.
- $lot[\iota].\ luv$:Value of land use of every lot
- $\lambda\ global: cooficient\ of\ matching$ In global.
- $\lambda\ local: cooficient\ of\ matching$ In local.

- Through this equation, the planners are able to operate the simulation process by integrating 4D concept with GIS to choose the closest-to-reality scenario to determine the growth trend of each land use and the types of forces influencing its change.

3. The part of the temporal spatial queries of the changes in land use for each sector.4DQueries is considered as the spatial interactive part of the 4D-GISmodel. The functions of this model are the construction and storage of the 4D temporal data that resulted from the 4D Queries, this part of the module is concerned with how does 4D Queries work? They are queries for varying information and data through time. Then we must work on 4D Geodatabase, a database with variable and time-driven spatial data derived from a technology of new technologies that collect data in chronological order such as the SCADA system. This is equipped with GPS positioning technology, as well as data from satellite images through remote sensing technology. All of these data are processed by programming languages that can integrate these different outputs [7]

- Then the work of future predictions or possible planning alternatives in addition to the possibility of representing the results of these 4D Queries by one the representing methods of 4D concepts integrated with GIS as shown in Fig.12.

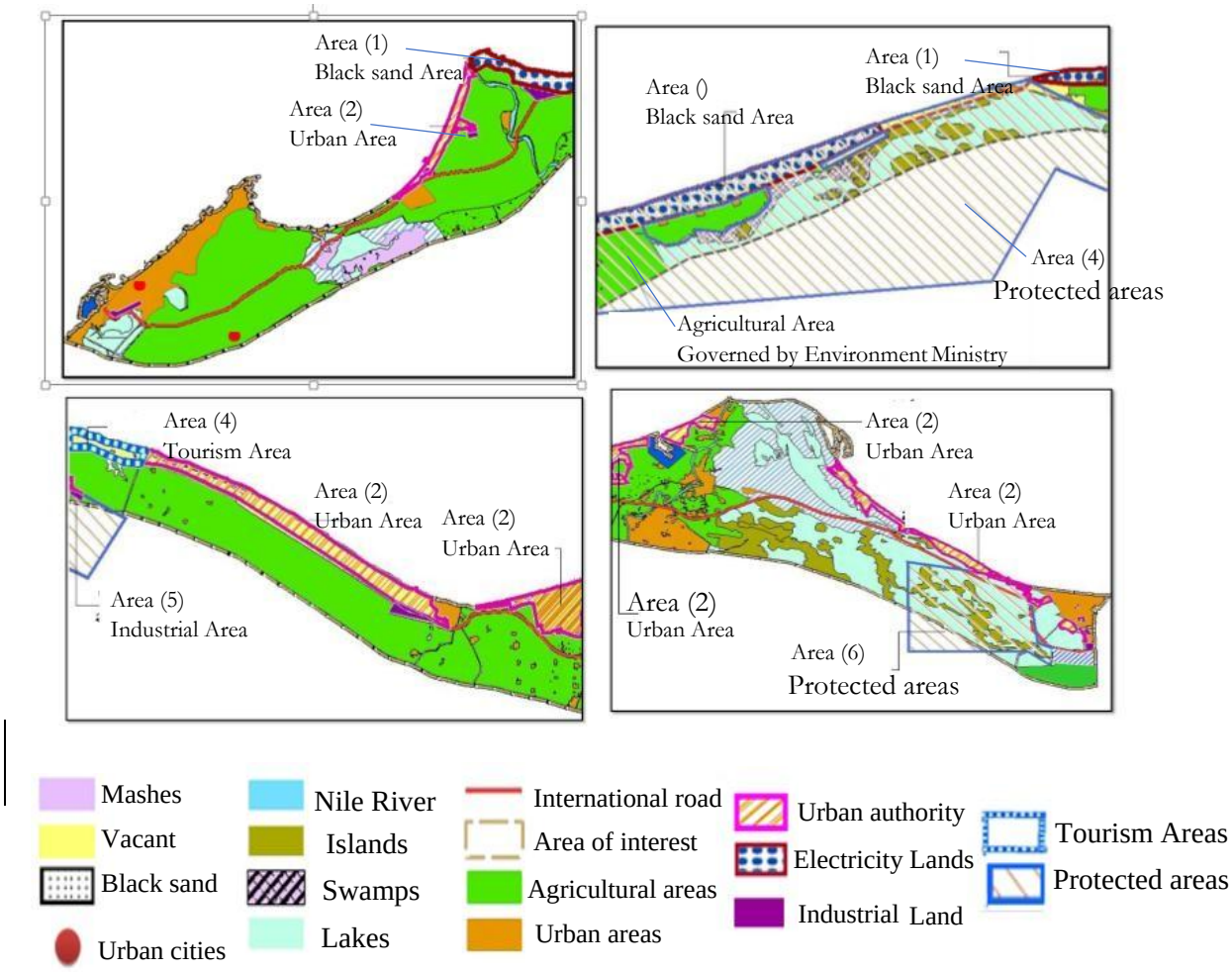

Fig.12. The proposed alternatives and predictions in the four sectors

Figure 12 shows the proposed alternatives and predictions for the future needs of land uses in accordance with current policies and conditions, with some assumptions being made through the simulation model we conclude:

- Exploitation of the area (1) to be part of the activities of the Ministry of Electricity (Nuclear Energy Authority) to extract the minerals available in the black sand ore.
- Exploitation of the area (2) for the activities of the Urban Communities Authority to absorb the increase in population and reduce the encroachment on agricultural land and the extension of the industrial zone in the desert of Albousaily in the future.
- Exploitation of the area (3) to be part of the activities of the Ministry of Electricity (the Nuclear Energy Authority) to extract the minerals available in black sand ore,

Then the state of this land returns after the extraction of these minerals to the Ministry of Environmental Affairs to preserve the natural and environmental life in the Boroulus Protected Area.

- Exploitation of the area (4) is proposed to be part of the activities of the Ministry of Tourism (Ecotourism) due to its proximity to the Boroulus protected area with its good location on the Mediterranean Sea and on the international coastal road directly.
- Exploitation of the area (5) to be part of industrial zone in Baltim of the activities of the Ministry of Environmental Affairs as it is located inside the borders of the Boroulus protected area.
- Exploitation of the area (6) to be part of the activities of Environmental Affairs to preserve the natural and environmental life in the Boroulus Protected Area.

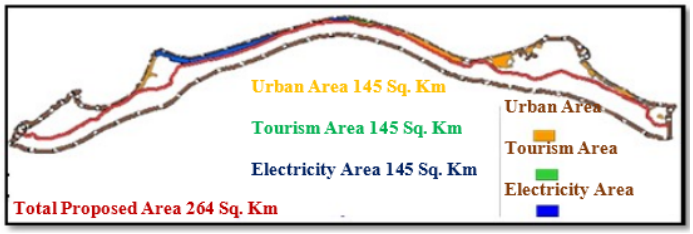

Fig.13. Proposed areas for land use in the whole region

Figure 13 shows the final proposed land uses for the whole region. After the end of the mandate of the Ministry of Electricity on the lands with the black sand is being studied its reuse.

4.2.4 How to operate the technical analysis using the 4D GIS model

The three parts of the 4D-GIS model are worked together; the part of land use data preparations (Modeling part), the part of land use change; building the 4D warehouse (4D Geo-Database) And the part of 4D Queries Interface are customized with programming and script languages such as Java script and PHP. Therefore, the model can handle all kinds of temporal, non-spatial and spatial data. It can be seen through virtual screens. Then, we analyze the three parts of the proposed model from the programmer point of view. The next three charts are considered as the first step of executing the model as shown in Fig.14, Fig.15 and Fig.16.

4.2.5 GIS data modeling for the four sectors of the area of interest area

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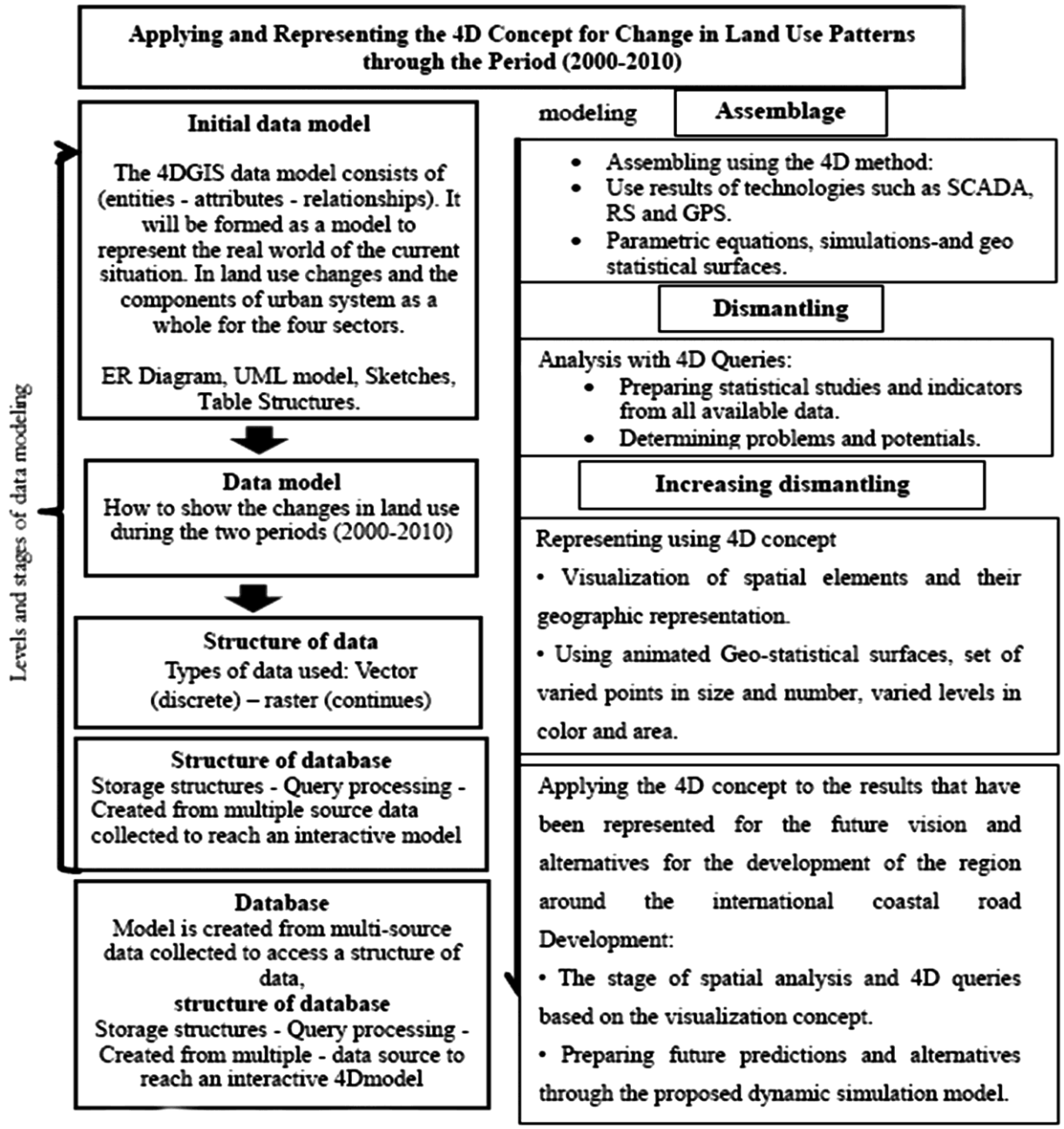

Fig.14. Stages of collecting and modeling spatial data and non-spatial data for the four sectors

4.2.6 The database architecture based on the data model "land use change warehouse in the period of time (2000-2010)

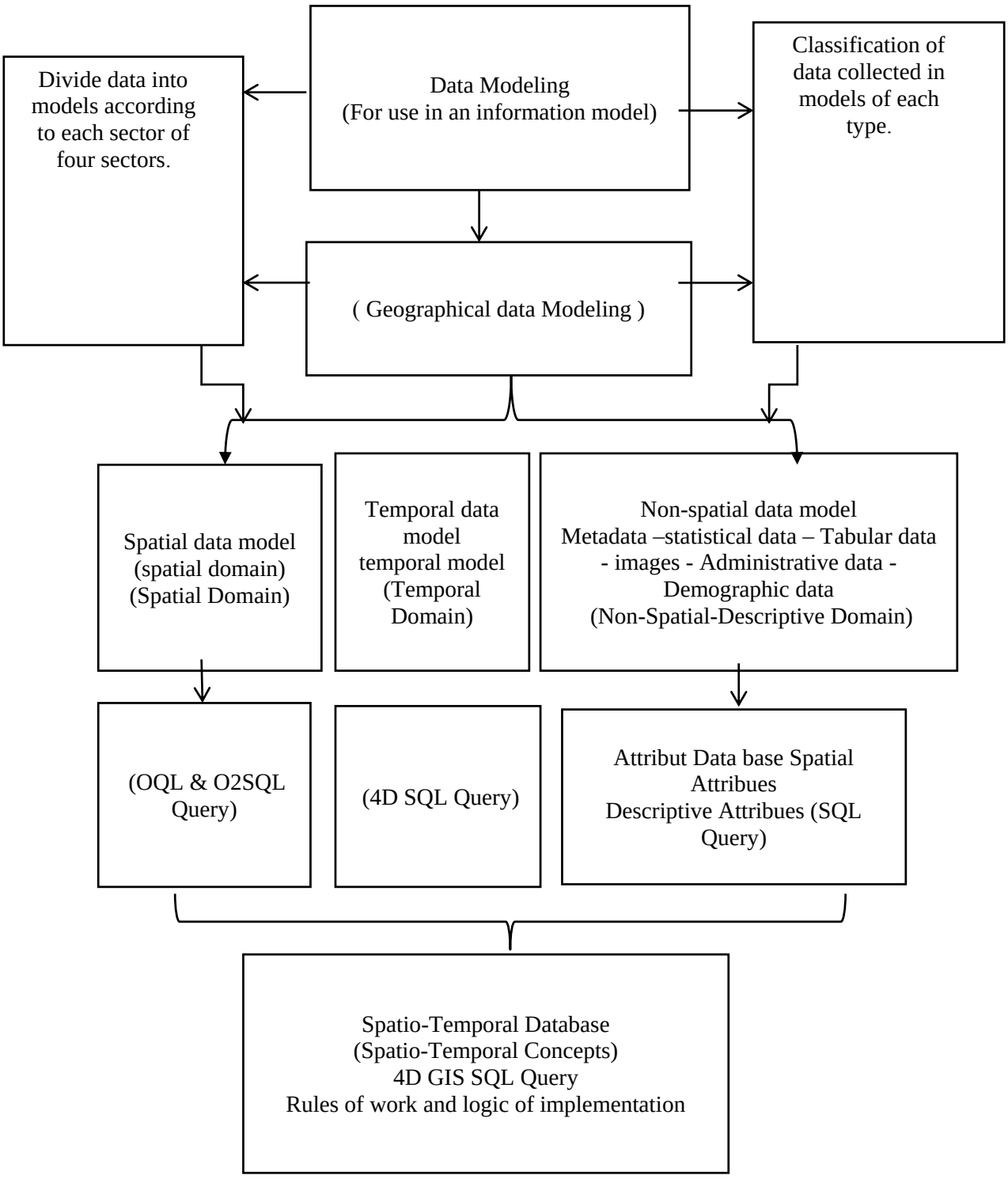

Fig.15. Stages of collecting and modeling spatial data and non-spatial data for the four sectors

4.2.7 Methods of building VRML files to generate the 4D GIS model

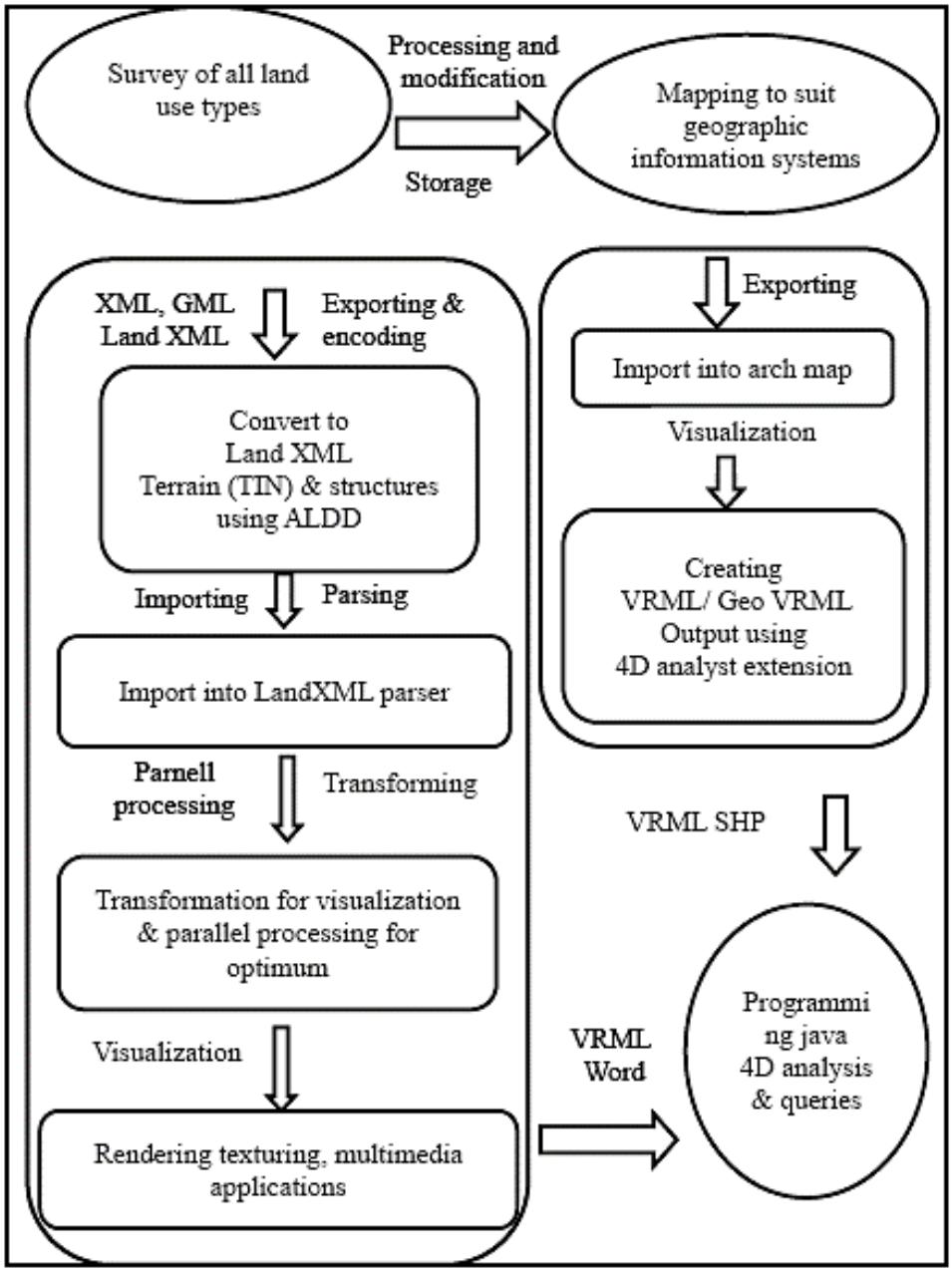

Fig.16. How to implement and represent inside 4DGIS model

5 RESULTS AND RECOMMENDATIONS

Using4D GIS technology is the best way for planners; as it provides the schematic information gathered from the technologies mentioned in the paper to give them scenarios for change patterns of geo-statistical surfaces over time. The importance of using the 4D GIS technology is to represent information in a more dynamic way. We recommend using the suggested methods mentioned in the paper to apply and represent the concept of 4D when studying a planning area to improve the performance of surveys and analyses of planning to be better and faster.

6 CONCLUSION

The main success of the 4D GIS model is the integration of many different technologies outputs that deal with spatial and temporal data in one model. This integration could enable planners to reach a good understanding of the patterns of change in different land uses that include the causes and problems behind this change. Also enable planners to know the forces which influence the growth trend of each individual land use and cause of urban mobility. This will be through the analytical studies of each of the planning factors that must be taken; such as the spatial distribution of services and utilities,

the distribution of population and areas of concentration of age groups, and all these. In accordance with the, political conditions and policies governing the planning process. As these factors, affect the whole planning process of land uses.

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