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Talaat, Ahmed

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Towards a spatial decision support system for route alignment planning in Egypt

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Towards A Spatial Decision Support System For Route Alignment Planning In Egypt

Paper presented at the 42nd Congress of the
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Ahmed Talaat
Institute of Spatial Planning (IRPUD)
University of Dortmund
D-44221 Dortmund
Tel: +49 (0) 231 755 4411
Fax: +49 (0) 231 755 4788
Email: at@irpud.rp.uni-dortmund.de

Abstract

Route alignment planning for a new highway or railway on the regional level constitutes a complicated planning process which involves the consideration and analysis of various data sets. It also includes the development of alternative corridors for the planned transport link and the evaluation of socio-economic and environmental impacts of different alternatives. In Egypt, these tasks are implemented by using traditional manual systems. The choice of a feasible corridor for a new highway is based mainly on the topography of the land. Historical, economic and geological data are not accurately considered. Environmental and social impacts are often neglected. To overcome such deficiencies, the use of Geographic Information Systems (GIS) is mandatory to manage the variety of data sets from different sources. The present Ph. D. study is intended to explore and demonstrate the potentials of the use of GIS in the route alignment planning process. The study will also identify the information needs of this process and discuss the means to integrate and structur these information in a unified data model. The institutional measures needed for data exchange policies will also be recommended. As a means of achieving these objectives a spatial decision support system (SDSS) for the route alignment planning process will be designed and developed using GIS techniques and capabilities. This paper explains the need for such a system in Egypt, describes the research plan and the methodology to be followed during this study and presents the results obtained so far from the achieved stages namely the literature review and the analysis of the existing systems.

1. Background

Route alignment planning for a new highway or railway on the regional level constitutes a complicated planning process which involves the consideration and analysis of various data sets. In developing countries in particular, where this process is still implemented by using traditional manual systems, a number of problems and challenges are encountered. In most cases the required data are either not available or can not be obtained due to the complicated procedures of the owning bodies. If the data sets are made available, their formats will constitute another problem because they usually come from different sources in different formats. Such formats are mostly old paper maps in different coordinate systems, tables or reports. In few cases, various digital data in different formats are also available. The integration of such data sets is always a difficult, but important task towards the choice of the optimal route. The development of alternative corridors for a potential road and the evaluation of socio-economic and environmental impacts of such alternatives represent further technical challenges. Planners usually end up with helpless information that do not allow them to argue against political decisions. Moreover, the public and affected parties are seldom involved or even informed. This lack of awareness leads to some sort of sceptic reaction and resistance of the public. As a consequence, planners usually loose the chance of being informed of the opinions, ideas and suggestions of the public.

Addressing this process in Egypt, and particularly in the General Authority for Roads, Bridges and Land Transportation (GARBLT), is no exception. Such problems are pronounced with regard to many existing roads and new transport links under development. So far, the choice of a feasible corridor for a new highway is based solely on the topography of the land and the avoidance of physical and natural obstacles. The lack of cooperation between the different local authorities and ministries involved complicates the process of data acquisition, integration and analysis. Therefore, historical, economic and geological data are not accurately considered. Environmental and social impacts are also often neglected.

To overcome these deficiencies, the use of Geographic Information Systems (GIS) is mandatory to manage the variety of data sets from different sources, to offer multi-criteria analysis tools required for the planning process and to provide the presentation tools required for a better communication with the public. But before the introduction

and application of GIS would be of any benefit to the process, some institutional changes are required to allow the data collection and exchange among the different authorities and ministries.

2. Objectives, means and methodology of this research project

2.1. Objectives

The main objective of the present Ph. D. study is to demonstrate to the decision makers and transport planners in Egypt the capabilities and functions of GIS in the field of route alignment planning and the benefits they will gain if they adopt a certain strategy for data acquisition and maintenance.

The study will attempt to explore and demonstrate the potentials of the use of GIS in the route alignment planning process and how GIS can be introduced to enhance the current system. It will also identify the information needs of the route alignment planning process and how it can be integrated and structured in a unified data-model. Finally, the study will formulate some recommendations concerning technical and institutional measures and data exchange policies.

2.2. Means

As a means of achieving these objectives, a spatial decision support system (SDSS) for the route alignment planning process will be designed and developed using GIS techniques and capabilities. Such a system should allow multi-criteria analysis and evaluation so that transport planner can come up with some alternative road corridors and evaluate the environmental, social, traffic and economic impacts of each corridor.

This system should benefit from the geographic database engine available in most of the common GIS packages which is capable of accommodating various types of data needed for the planning process. The editing and updating capabilities of GIS can improve the ability of transport planner building and maintaining their databases. The analytical functions of GIS can play a major role in accelerating and raising the efficiency of the planning and evaluation of different road corridors. Finally, the presentation capabilities of GIS can clearly convey the findings and effects of the

different alternatives to both the public, who should participate in the planning process, and to the decision makers, who may not have deep insight of the planning process.

2.3. Scope

The route planning process involves several engineering factors, such as cut and fill calculations and building costs of roads. However, in this study, the focus of the intended system is to support the route alignment process from a spatial planning perspective. The intended users of the system are transport planners and analysts who are involved in the route alignment planning process. Subsequently, the study will adopt strategic and regional planning approaches and considerations, such as environmental, social, traffic, topographic and economic factors. Engineering consideration may only be incorporated within the system if the time and data availability will allow.

2.4. Methodology

A six-phase methodology is to be followed in this study. The phases of this methodology can be listed as follows:

- Phase-1 Literature Review
- Phase-2 Systems Analysis
- Phase-3: Identification of Information needs
- Phase-4: Database design
- Phase-5: System design and prototype
- Phase-6: Application and evaluation of the prototype

Presently, the study stands at the end of the second phase. Findings and results obtained so far by phase one and two are described here in details. For the remaining phases, a brief description of tasks involved and expected outcomes is presented.

3. The use of GIS in route alignment – a literature review

A first major task of this study was to assess the state-of-the-art of GIS tools and applications. The aim was to come up with an overview on available technologies. In particular, this phase comprised a comprehensive literature review aiming at the identification and evaluation of previous similar attempts conducted in developed countries.

Several attempts have been made in different projects to utilize GIS in the route alignment planning process. The role of GIS differs widely in such projects. A large number of studies utilized GIS in the determination of the environmental impacts of transport corridors (Bejleri *et al.* 2001; Gilbrook 1999; Mikkonen and Tuominen 1998; Aifandopoulou *et al.* 1995; Zura and Lipar 1995). Other applications made use of GIS analytical functions in determining several corridor alternatives based on certain predefined criteria (Yang 1999; Gilbrook 1998; Sadek and Bedran 1998). Addressing engineering aspects of the route alignment planning process was also the focus of some studies (Sadek and Bedran 1998). Finally, in some projects GIS was utilized as mapping and presentation tools in public information meetings (Gilbrook 1999; 1998).

The comprehensiveness of such attempts in addressing as many affected factors as possible was another analysis target of this study phase. The focus of many projects was until recently on natural factors in general and the topography of the land in particular. Because of its direct effect on the economical aspect of the project, land topography was taken into account by almost all case studies reviewed. The focus on economic factors was as common as on the topography. The second most common use of GIS in relevance to transport infrastructure projects is in the environmental impact assessment (Bejleri *et al.* 2001; Scholle 2001; Zura and Lipar 1995), the combination of environmental and cultural impacts (Gilbrook 1999), the combination of natural, engineering and environmental factors (Sadek and Bedran 1998) and the combination of environmental and traffic factors (Aifandopoulou *et al.* 1995).

Very little case studies in the literature looked at all, or at least most, of the factors thought to be directly affected, and hence can be seen as comprehensive. One of the few comprehensive solutions is the combination of GIS tools developed by HDR Engineering to locate a feasible road corridor through the southern Appalachian

Mountains of north Georgia for the Georgia Department of Transportation (Gilbrook 1998). Potential environmental impacts and engineering considerations for potential corridors such as historic sites, wetlands, stream crossings, historical accident data, and vertical profiles were quantified in this study.

In addition, in this first phase of the Ph. D. study, the data model used by previous attempts and the structure of implemented solutions was looked at. A clear distinction can be made between two underlying data structures adopted by the different practices in literature. While most exercises make use of the raster data structure approach (Yang 1999; Gilbrook 1998), others adopt the vector approach to the data structure (Scholle 2001; Sadek *et al.* 1998). Bejleri *et al.* (2001) describe how a combination between both vector and raster data was used in the implementation of a similar project.

Technically, the evaluation of multiple criteria analysis can be conducted using solely GIS internal functions (Bejleri *et al.* 2001; Gilbrook 1999) or by some sort of integration between GIS and other external specialized models (Sadek and Bedran 1998; Aifandopoulou *et al.* 1995). The advantage of using the commercially available GIS tools is the simplicity of working within one software environment without the need for data conversion and transfer. Another advantage is that, most of the governmental bodies, as it is the case in GARBLT and most Egyptian authorities, have or plan to have commercial GIS software but they may not be able to afford the purchase of several specialized software for modelling different factors involved. However, the disadvantage in using GIS only is that, it still lacks modelling functions (Wegener 2000) and that GIS built in tools will only be used based on availability regardless how suitable they are for solving the problem at hand. Sadek and Bedran (1998) integrated specialized slope stability and roadway design packages within the ArcView GIS user friendly environment to produce analysis functionalities that facilitate several tasks involved in the route alignments process. Aifandopoulou *et al.* (1995) integrated ArcInfo GIS with EMME/2 (traffic modelling software) and PAL (environmental pollution model) to support the planning of transport infrastructure taking environmental effects into account.

The outcome of this literature review phase was the definition of a starting point for the present study to build on. Several alternatives were considered and assessed to choose

the most suitable among them for Egyptian circumstances. Lessons learned and negative experiences were also analyzed. Finally, required modifications to existing similar projects, that will make it suitable for application in Egypt, were drawn and suggested.

4. Route alignment planning in Egypt – the present situation

The second phase focuses on the analysis of both the current system of route alignment planning process in Egypt as well as the system proposed by this study to improve and enhance the existing system.

The current systems of route alignment that are followed in Egypt, along with the problems encountered, were intensively analyzed and documented. This was done through a series of interviews and meetings with the related managers and staff of GARBLT. A set of questionnaires and forms were filled up during these meetings. Figure 1 presents a diagram that describes the current system for planning a corridor for a new highway in Egypt. The system is a very simple traditional sequential one which can be described as follows:

- The map acquisition and preparation step involves the acquirement of paper maps that cover the study area from the Egyptian survey authority (ESA) or any other source where such maps are available. The obtained maps are usually of small scale which is useful in giving an overview of the study area but can not assist in the detailed definition of corridors and the calculation of their quantitative effects. They are mostly old maps which were updated for the last time at least 10 years ago. These maps are then updated based on personal knowledge and any available information and combined to compose an overall map of the area.

- Using this composed map, transport planners start to define a set of alternative corridors based on the land topography trying to avoid physical and natural obstacles such as water bodies, buildings and mountains. Minimizing the engineering works along the route, such as bridges and tunnels, is another criterion in the choice of a corridor.

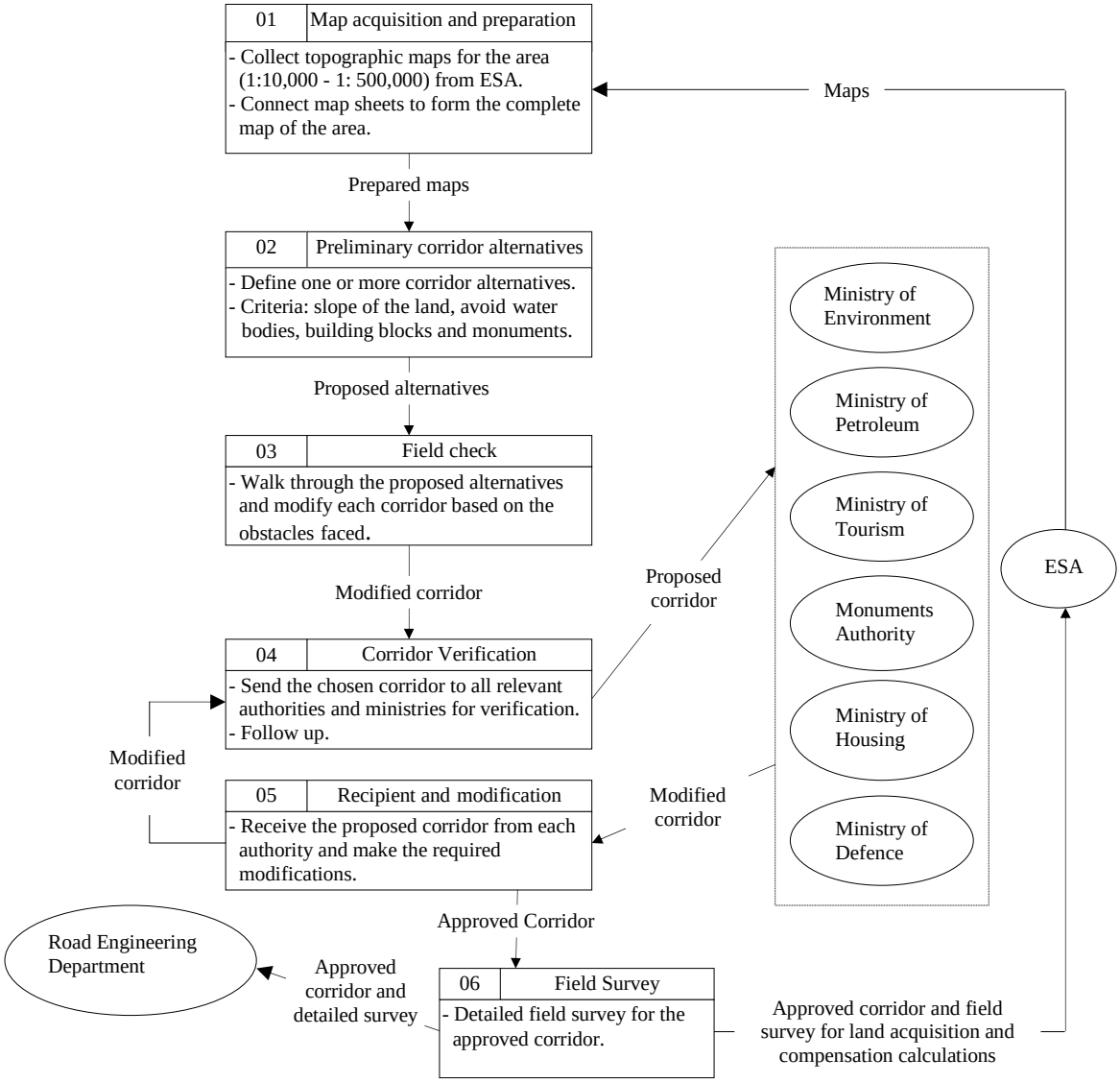

Figure 1. Diagram representing the current system of route alignment planning

- Because the used maps are very old and not regularly updated, the proposed alternatives are dramatically modified during the walkthrough field trips that follow. Many buildings, environmentally protected areas and even recently discovered monumental areas are considered only during these trips. In most cases, the modified routes are quite different from the original ones. The most reliable and cost effective corridor is often concluded at the end of these field visits.

- In the corridor verification process the suggested corridor is sent to the different relevant authorities and ministries to be checked and approved according to their own

data. Each of these governmental bodies verifies if the suggested corridor does not conflict with its properties, and if it does, the necessary modifications on the corridor path are carried out to avoid such a conflict. The corridor is sent back to the transport planners in GARBLT and from there to the next authority and so on. Should any of those authorities make a major change to the corridor path, it has to be sent again to all other previous authorities until the final path is reached. This process is very time consuming and can be eliminated if the data from the relevant authorities were collected properly at the beginning of the process.

- Finally, the corridor which emerges from this process is approved and sent to a detailed surveying process before it is sent to the Engineering department for detailed design. It is also forwarded to the Egyptian survey authority, the organization responsible of land acquisition and compensations.

The main deficiencies of this system are constituted by the lack of information as well as by the lack of cooperation among the different authorities. Another deficiency is the ignorance of social and environmental impacts of transport infrastructure projects which is a direct result of the lack of information rather than the lack of awareness.

5. A proposal for a GIS-based route alignment planning system

Based on the findings obtained from the analysis of the current system, a set of improvements are suggested by this study to enhance the planning system and to improve the ability of transport planners to carry out this process. Such improvements are presented in Figure 2 which demonstrates the proposed system and can be explained as follows:

- Relevant data from all involved organizations should be made available early in advance to an apposite data acquisition and preparation team. As an official source of census data, the central agency for mobilization and statistics (CAMPAS) should be involved in the data collection process by providing the necessary statistics and socio-economic information.

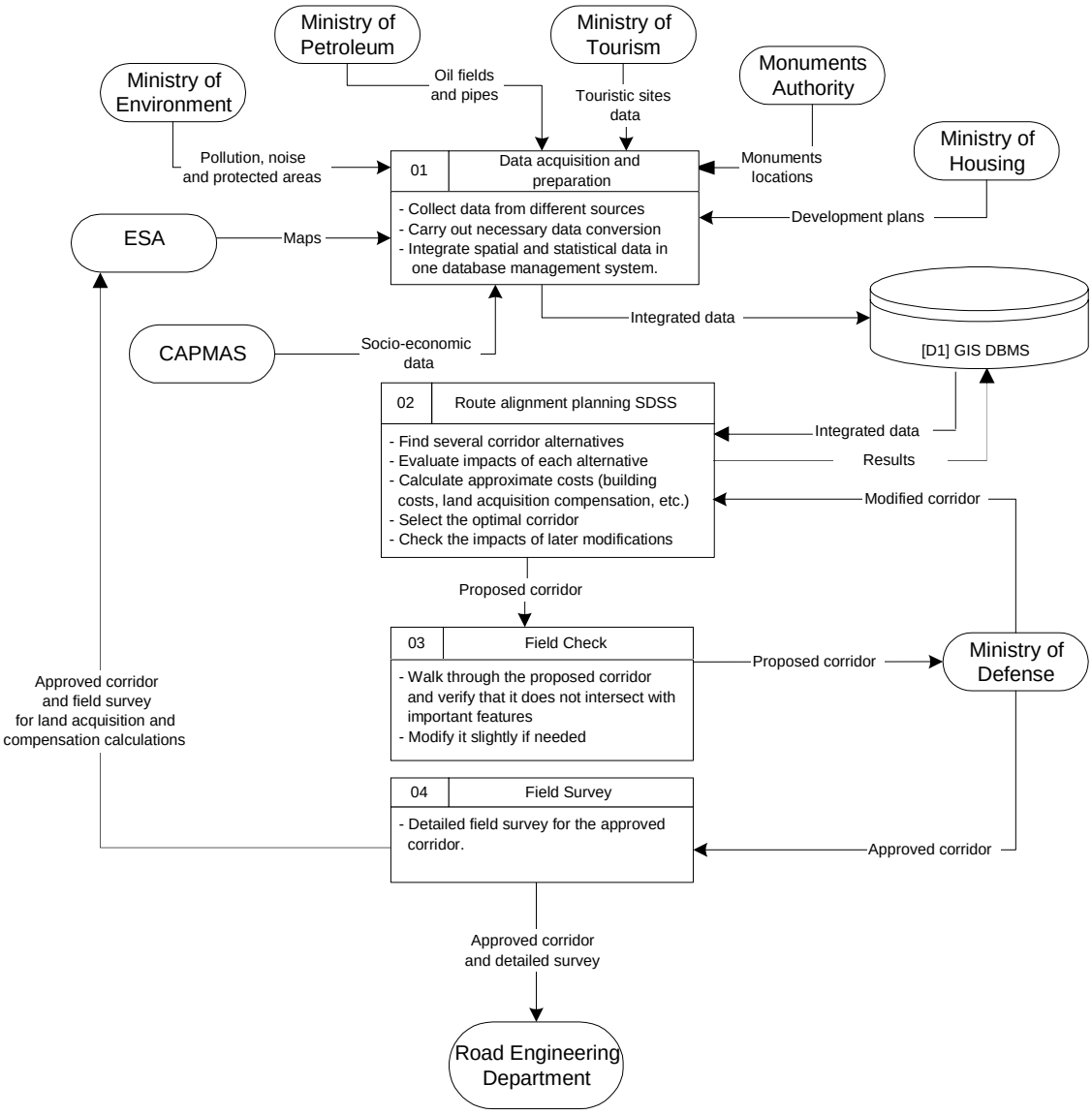

Figure 2. Diagram representing the proposed system of route alignment planning

- In addition to data collection, the data acquisition and preparation team will be responsible of conversion, automation and integration of both spatial as well as statistical data involved. The information needs from each organization will be identified in more detail in the following phase of this study. To overcome the data exchange problems between the different organizations and GARBLT, a data accessibility scheme will be suggested and investigated. Such a scheme will allow the staff of the data acquisition and preparation team to access available digital data at the different sites of the owning organizations rather than acquiring a complete copy of such data. This step, if realized, should facilitate data accessibility and share of

information while maintaining the ownership and control of the different authorities on their valuable assets of data.

- The resulted integrated data should be stored in a reliable database management system (DBMS) where it can be accessed by the different involved parties of GARBLT. As a return for allowing the use of their data, the related authorities should also have the right to access this integrated data.

  A spatial decision support system (SDSS) will be developed to facilitate the route alignment planning process. This system will be fed with the location criteria of a new highway corridor and will use the integrated data collected for the study area as inputs. Such a system should be able to carry out a locational multi-criteria analysis to come up with several corridor alternatives suggested for the new required highway. The evaluation of the impacts of each alternative corridor will also be analyzed by the system and displayed in different ways for better understanding by the decision makers and the public. The different costs involved, i.e. building costs, land acquisition, compensations, etc., may also be estimated by the system as an important factor in the decision making process. The system should also allow the decision makers to carry out ad-hoc modifications to the suggested corridors and to get the impacts of such modifications until the optimal corridor that fulfils most of the criteria and minimizes the effect on the surroundings can be chosen.

  The proposed SDSS will be composed of four main modules (Figure 3). The Editing and updating module will be used by the data acquisition and preparation team to prepare the input data to the system. A geographical database will be designed and constructed for the system that is capable of storing, handling and retrieving both spatial and tabular data. The locational analysis and impacts assessment module represents the core of this SDSS where corridor alternatives and their impacts will be identified. It communicates with a set of models, each of which calculate the impact of the corridor under study on one aspect of the factors involved. The representation and reporting module will be respobonsible for results visualization and reporting. All four components should be accessed and managed through a friendly interactive user interface.

- The selected corridor can then be sent to the traditional field check for verification and modification. The amount of modification to the corridor path during this step

depends on the comprehensiveness, completeness and consistence of the data used and how up-to-date they are. Due to the sensitive nature of the information of its properties, it is suggested here that the modified corridor should also be sent to the ministry of defence for final verification and modifications. If the corridor will be modified, it should be sent again to the SDSS for assessment of the impacts of such modifications. This step should be repeated as many times as required until the final path is reached.

- Finally, the approved corridor will be sent to both, the engineering department for detailed design, and the Egyptian survey authority for land acquisition and compensation calculations.

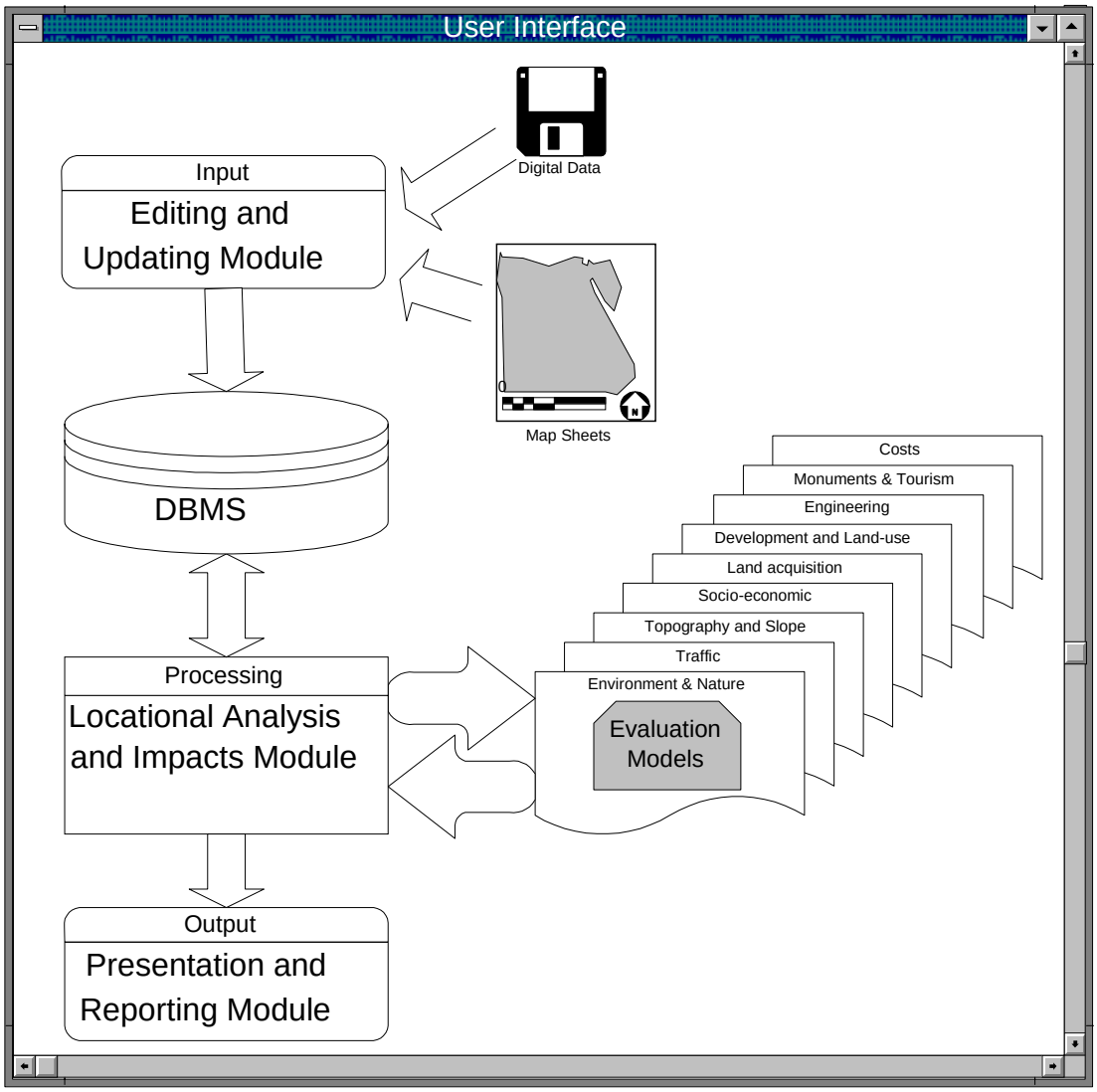

Figure 3. The structure and components of the intended SDSS

6. Further research tasks and expected results

6.1. Identification of information needs

One aim of this study is to identify the data sets and information needed by transport planners for proper route alignment planning. The identification of information needs for this process involves again the evaluation of data used in the current Egyptian system along with the review of the data needs and requirements in the general international practice. That will allow the intended system to improve the current Egyptian system, not only by automating existing tasks, but also by introducing and considering other important factors that may be ignored in the current system such as environmental impacts.

As a starting point, a set of data themes are identified under which the detailed data sets required will be studied and described. These data themes are socio-economic data, transport and traffic data, environmental and natural data, engineering data, historical and cultural data, and legislations and standards.

6.2. Database design

This stage is intended to design a geographic data-model for the integration of all data sets required for the route alignment planning process. A part of the database which is enough to support the data needed for the prototype application should be designed. This part of the database should be enough to demonstrate the capabilities of both the data-model and the prototype in the accommodation, manipulation and retrieval of all data types involved in an integrated and homogenous manner.

This phase involves the implementation of three main tasks. Firstly, a conceptual and logical database design will take place to come up with the data model and relations among the different types of data involved. Then the intended prototype will be defined and the minimum data required to implement such a prototype will be identified. And finally, a physical database design will be conducted for the selection of data required for that prototype.

6.3. System design and prototype

An overall design of the proposed system will be produced at the beginning of this phase. Such a design will identify and describe system capabilities, components, functions, inputs, outputs as well as institutional structures. A detailed design of the prototype will be conducted at a higher level of detail in preparation of the development step. Finally, the SDSS for route alignment is to be developed as a prototype application for a case study region in Egypt with the minimum amount of data which is enough to demonstrate its capabilities. The study area on which the prototype will be applied is to be identified later with the concerned staff in GARBLT based on data availability.

6.4. Application and evaluation of the prototype

In this phase the developed prototype will be applied to a case study area in Egypt to demonstrate its capabilities and to evaluate its efficiency. To do so, the part of the database which is required for the application of the prototype should be constructed. The necessary data sets will be collected, and the developed database will be populated with the collected data. Finally, the results of the application will be evaluated and compared to the results produced by the traditional system if possible.

6.5. Results

The expected results of this study are as follows:

- The identification of the state-of-the-art of the use of GIS in the route alignment planning process;
- The identification of the potentials of GIS in the route alignment planning process;
- The identification of information needs of the route alignment planning process in general;
- The design and development of the database which supports route alignment planning process in general with the minimum information needed to demonstrate the intended system;
- The description of institutional changes required for the application of an automated system to support the route alignment planning process; and
- A SDSS prototype that produces the most appropriate road corridor from a spatial planning perspective.

7. Conclusions

This paper has presented the purpose and plan of a present Ph. D. study which aims at exploring the potentials of GIS in the route alignment planning process for new highways in Egypt. Complications result from the lack of up-to-date data and data exchange policies among the different relevant organizations in Egypt, as well as from the lack of the appropriate tools needed for handling and analyzing such data. The study attempts to define the problems and challenges encountered in the current system, to address some of them and to suggest possible enhancements. Such enhancements were described here in detail by proposing a system that involves technical as well as institutional changes towards the choice of better route alignment.

A spatial decision support system (SDSS) based on GIS techniques and capabilities is envisaged as the main product of this study. This SDSS should allow multi-criteria analysis and evaluation so that transport planners can come up with some alternative road corridors and evaluate the environmental, social, traffic and economic impacts of each corridor. The incorporation of such factors in the route alignment process is one of the most important additions to the current Egyptian planning system.

The paper also described some attempts carried out before in some developed countries in the same field as a starting point for the present study. This review of existing similar studies evidenced the need for developing an interactive system that can be reapplied several times rather than being tailor-made for single projects as it is the case in most of the case studies in the literature.

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