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A review on state-of-the-art practices and research of using GIS in transportation corridor planning

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A REVIEW ON STATE-OF-THE-ART PRACTICES AND RESEARCH OF USING GIS IN TRANSPORTATION CORRIDOR PLANNING

By

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A Review on State-of-the-Art Practices and Research of Using GIS in Transportation Corridor Planning

Master of Engineering, 2005
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ABSTRACT

Transportation corridor planning is a process that is in nature collaborative with local governments and includes extensive public participation opportunities. A corridor may be divided into logical, manageable smaller areas for the purpose of corridor planning. The planning process looks at the existing transportation system within the corridor and how the system could be changed or expanded to meet long-term needs and includes discussion of existing and projected travel patterns and social, environmental, and economic issues within the corridor. It includes discussion of infrastructure improvements in combination with wise land-use and system-management actions. GIS is assessed as advanced tool because of the spatial nature of transportation planning and the determination of a range of potential outcomes.

The research is intended to investigate the state-of-the-art technology with a goal of greatly improving corridor planning process together with understanding of GIS capabilities, data awareness and accuracy, decision-making and communications. GIS is utilized as tool in such a way to enhance the ability to accurately predict and easily understand these capabilities. Its main motivation is to better represent GIS in the corridor planning process. It is intended to provide transportation organizations, planning practitioners, and transportation decision-makers with GIS tools and guidance for planning, organizing, and managing to effectively support transportation investment decisions tailored to the specific conditions and performance needs for major transportation improvements. This research proposes to address the capabilities of GIS in corridor planning and enhance the ability to accurately predict and easily understand these capabilities.

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Finally, I am grateful to the Grace of God for the countless blessings I have received.

Dedicated
To
My loving parents

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1. INTRODUCTION

In the field of transportation, professional designations, such as highway planner, airport planner and urban transportation planner are common. Clear planning is considered an important function in modern society, and whatever this function is, it has a specific focus, that is, it concentrates on particular areas, subjects, or systems. For the purpose of my project, planning may be defined as the activity or process that examines the potential of future actions to guide a situation or a system toward a desired direction, for example, toward the attainment of positive goals, the avoidance of problems, or both.

The most important aspect of planning is the fact that it is oriented toward the future. A planning activity occurs during one time period but is concerned with actions to be taken at various times in future. However, although planning may increase the likelihood that a recommended action will actually take place, it does not guarantee that the planned action will inevitably be implemented exactly as conceived and on schedule. Another time element of importance to planning's forward looking perspective is the lag between the time when the action is to be taken and the time when its effects are felt. This time lag depends on many factors, including the scope and magnitude of the contemplated action.

The fundamental purpose of transportation is to provide efficient access to various activities that satisfy human needs. Therefore the general goal of transportation planning is to accommodate this need for mobility. Within specific context, however such questions as whose mobility, for what purpose, by what means, at what cost and to whom, and who should do the planning and how, are not amenable to easy answers. Contemporary responses to these questions are largely rooted in history and have been influenced by a confluence of many factors, including technological innovations, private interests and government policies.

1.1 TRANSPORTATION CORRIDOR PLANNING PROCESS

Transportation corridor is a broad geographic area, defined by logical, existing and forecasted travel patterns served by various modal transportation systems that provide important connections within and between regions of the provinces for people, goods, and services. Travel within the corridor may include vehicular, rail, transit, water, air, or non-motorized.

Corridor planning is a process that is collaborative with local governments and includes extensive public participation opportunities. A corridor may be divided into logical, manageable smaller areas for the purpose of corridor planning. The process looks at the existing transportation system within the corridor and how the system could be changed to meet long-term needs. The overall corridor planning process includes discussion of existing and projected travel patterns and social, environmental, and economic issues within the corridor. It includes discussion of infrastructure improvements in combination with wise land-use and system-management actions.

1.2 PURPOSE OF CORRIDOR PLANNING

The purpose of corridor planning is to comprehensively address future transportation needs, and to recommend a package of improvements and management strategies for the transportation system within a corridor. Various purposes of corridor planning can be summarized as following;

- Promotes the safe and efficient movement of people, goods, and services.
- Initiates an intergovernmental cooperative planning process to promote community and province based transportation decisions.
- Provides opportunities for public, local government, and agency participation early and throughout the process, and allows them to actively participate in potential corridor solutions.
- Meets objectives by comprehensively addressing transportation issues, and evaluating a full range of multimodal solutions for increased mobility.
- Saves money by identifying long-range right-of-way needs by anticipating potential problems resulting from growth before solutions become too expensive.
- Fills the gap between the state-wide modal plans for highways, public transportation rail, aeronautics, and bicycle/pedestrian, and the project selection process.
- Furnishes a link between land-use planning and transportation planning.
- Determines the extent of the social, economic, and environmental issues within the corridor and analyzes potential alternatives at an appropriate and economical level of detail.

- Facilitates resolution of major issues (i.e. public opinion, cost, environmental constraints) before specific project programming and development begin.
- Protects transportation investments by exploring alternate means to accommodate transportation needs, with and without capital-intensive improvements.
- Provides an opportunity to direct future development, and minimizes environmental, social, and economic impacts.

1.3 BENEFITS OF TRANSPORTATION CORRIDOR PLANNING

Generally the benefits of any transportation corridor planning are as follows:

Resolution of Major Planning Issues

Prior to the initiation of project development consensus among local, regional and provincial governments regarding project purpose and needs is essential to successful project development. In fact it is corridor planning that provides a framework for any project development consensus within local, regional and provincial governments regarding project needs and requirements.

Costs for transportation right-of-way increase substantially as land suitable for transportation is developed for other purposes. Uncertainty about right-of-way needs may also impact property owners, businesses and sometimes entire communities. The planning horizon of a corridor plan identifies a long-range right-of-way need which serves to direct future development, thus reducing development and environmental costs.

Social and Economic Impacts

To prevent premature obsolescence of highways and other facilities, corridor planning examines alternate means to accommodate transportation needs with and without capital-investment improvements. Alternatives such as access management, utilization of parallel local streets, reconfigured land use patterns and demand management programs (i.e., telecommuting, rideshare, public transportation, flex-time, etc.) are considered in lieu of or in addition to major capital improvements.

Partnership with Diverse Public and Private Agencies and Organizations

Corridor planning provides a forum for resolution of policy issues and negotiation of strategic partnership between organizations striving to fulfil complimentary missions with limited resources.

1.4 GIS APPLICATIONS IN TRANSPORTATION CORRIDOR PLANNING

Geographic information system has been mostly used for replacing the traditional manual techniques of dealing with maps and also the daily tasks related to geospatial data processing. In many cases, knowledge about GIS is generally confined to a tightly-knit group in local governments. Campbell (1994) showed that for the British local governments, the success of GIS implementation depends on the organisational culture of local governments.

The late 1980s saw the first widespread use of GIS in transportation, mainly in the planning community. Engineers had been using CAD (computer-aided drafting or design) tools for some time, but the early applications of GIS were implemented in scales and accuracy below the standards of most engineering applications. As GIS differs from CAD because of spatial analysis capabilities and topological data structures in GIS, early decisions about scale and accuracy can have long lasting effects.

Modelling is largely a mature science in transportation corridor planning. Corridor planners model trip generation for impact studies, land use projection, population and employment projection, and four-step traffic projection for corridor studies. Database supporting these models includes hourly and daily traffic volumes, geometric data, travel survey data, existing and historical land use information. GIS can be used for these applications individually. The integration of these models and datasets in a framework to effectively support decision making is a greater challenge, particularly as many decision makers are unaccustomed to the terminology and limitations of the approaches. However recent development in GIS should be helpful in the design of such a framework.

Figure 1 shows the information flows in traditional (pre-GIS) transportation corridor planning (Nielson 1995). The expenses and difficulty of data collection, analysis and communication makes information dear. This tends to create a rigid and linear corridor planning process in which data and information are revised at a minimal rate. This encourages disconnection between planning process and other stakeholders including the public. Although metropolitan planning organization and departments of transportation have traditions of public participation in corridor planning process, this tends to be narrowly circumscribed roles at the beginning (to identify preferences) and end (to select among a small set of alternatives) of the planning process. There is limited input to the processes that translate preferences into a small set of alternatives. This is not the result of malicious intent; rather, it is a by-product of distributing scarce time and limited resources among competing needs, including traditional methods for geographic information processing that are expensive, slow and have limited spectrum, fidelity and flexibility.

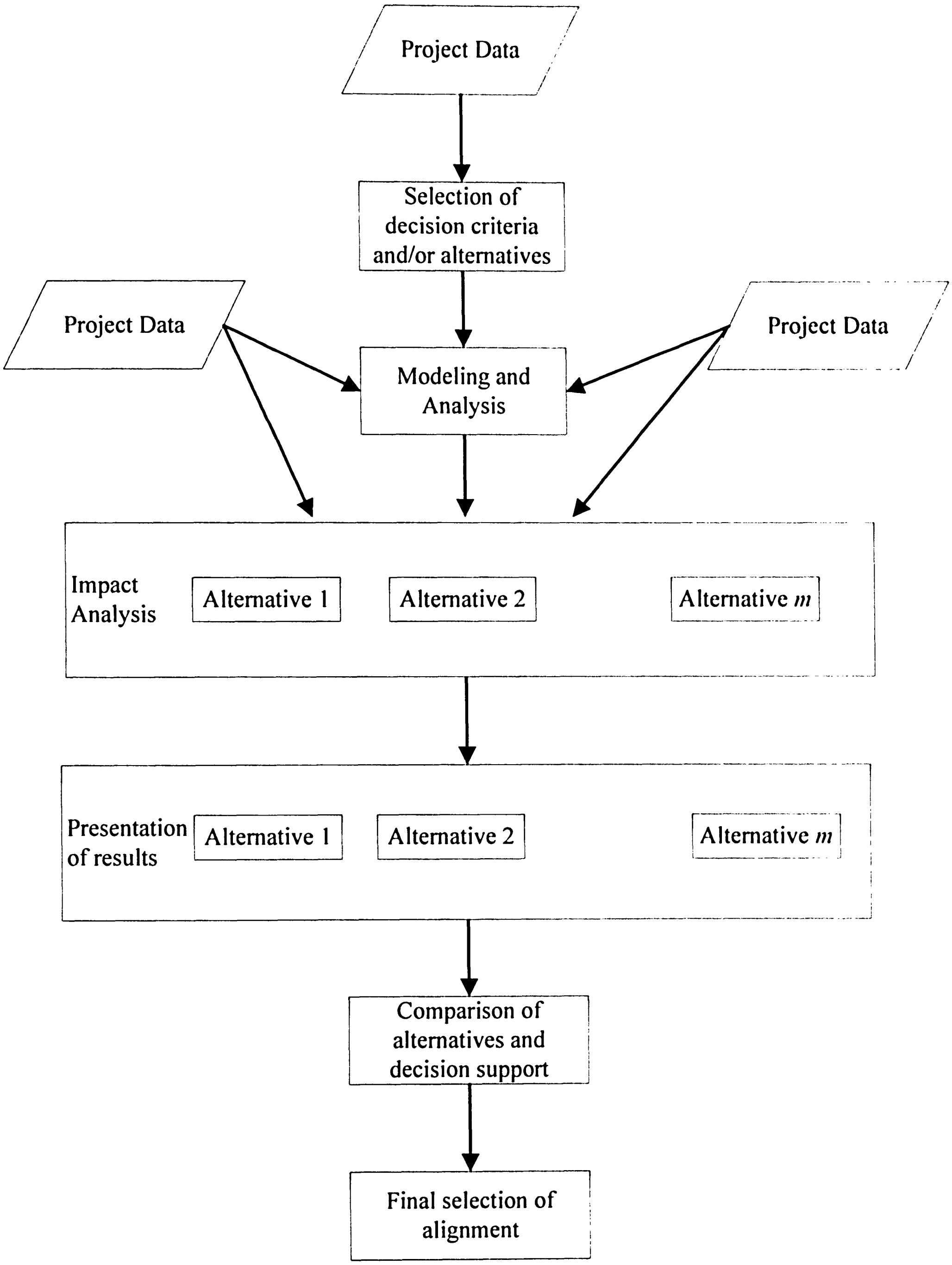


Figure 1 Information flows in the traditional transportation corridor planning process (Source: [Nielson 1995])

Figure 2 shows the information flows in a corridor planning process enhanced through GIS technology (Miller 2001). Since most transportation corridor planning data have a geographic dimension or can be related to geographic features, a GIS can support all activities. The relative ease of data sharing, integration, data management and reporting encourages a more flexible structure where plans can be manipulated and revised at any point in the process. It is easier to involve other stakeholders and the public in technical decisions so they understand and provide input.

GIS is not a "magic bullet" for corridor planning that guarantees only bright transportation futures. GIS can have negative effects on this process. The combination of sophisticated computer technology and powerful visual communication can be very compelling. This could allow a planner to create an illusion of technical soundness for poorly conceived and constructed plans. Indeed, GIS can strengthen the rigid and linear corridor planning process by giving the façade of a more flexible and democratic process. GIS enables nimble and responsive transportation corridor planning; this must be actively pursued by the planning organization.

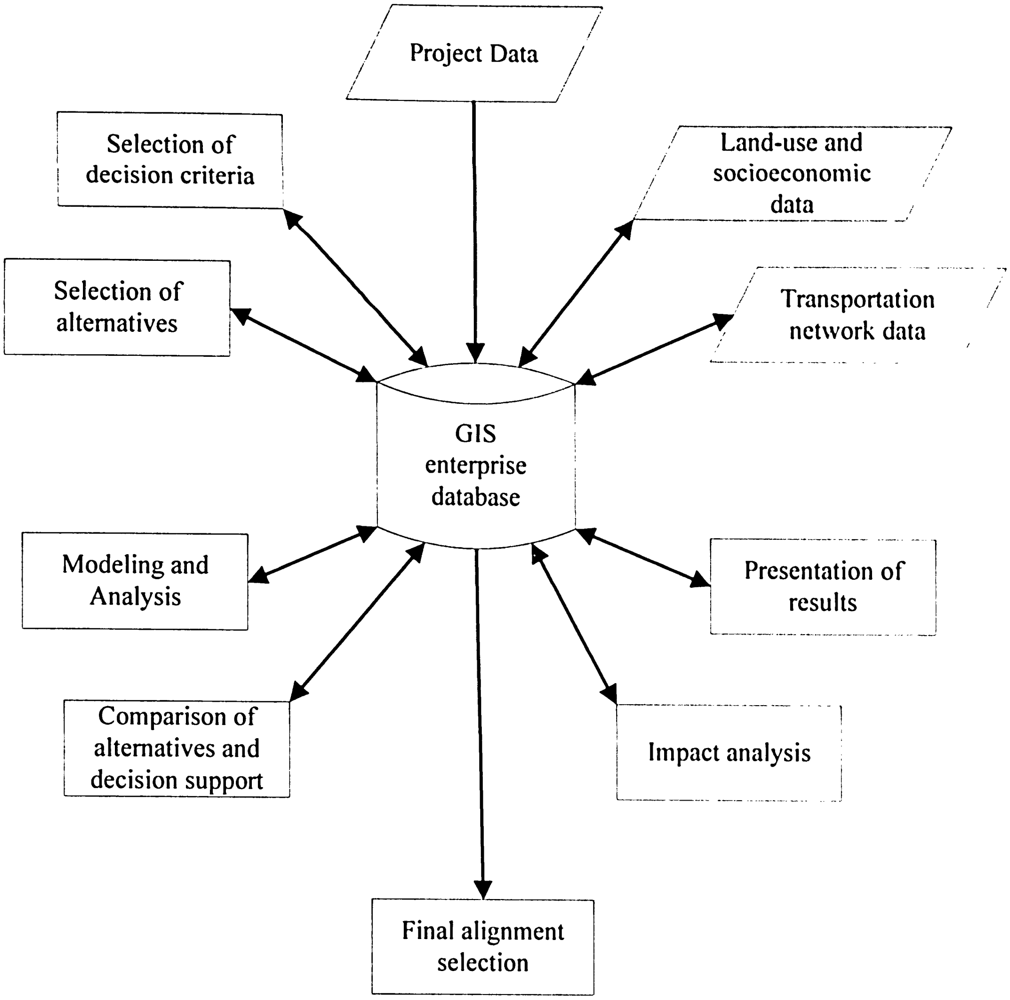


Figure 2 Information flows in the GIS-enhanced transportation corridor planning process (after: [Miller 2001])

1.5 RESEARCH OBJECTIVE AND SCOPE

The main objectives of this study project are;

- To investigate the utilization of latest GIS tools documenting, control, and modelling of conceivable overall transportation corridor planning process.
- To show the potential and the possibilities to further improve transportation corridor planning process by applying GIS.

To implement a GIS as a tool into transportation corridor planning process that has been carried out in the same way for many years can bring different impacts such as technical, social and even economical impacts.

The implementation of GIS can be complex and one of the most difficult barriers for this process to take place can be the acceptance of this tool, not only for the government but also for the community. As it is stated by de Man (2000), "Common in much of the literature on the effectiveness of geographical information technology (or any technology for that matter) is value and acceptance". This shows how the effectiveness of such a tool can depend on the acceptance by the group making use of it.

This study focused on Phase 1 (which is to describe the impacts of land use and environment impacts on corridor strategies) and Phase 2, (which includes corridor alternative analysis, implementation priorities, operation and maintenance program) as discussed in Chapter 3 of this report. The appraisal of Phase 3 (describing specific planning to resolve particular issue) is beyond the scope of this study. In the context of this research the GIS is especially referred to eight steps in corridor planning process.

2. GIS AND TRANSPORTATION PLANNING

Planning could be defined as a systematic approach used to analyse and answer social, physical, and economic problems of certain areas. In other words, it is a problem-solving field that deals with factors influencing the quality of life at scales ranging from small localities to large regions. Therefore, planning agencies usually employ several professionally trained planners specialized in different fields including land use, hydrology, housing, economic development, transportation and geographic information system (GIS). These planners attempt to apply methods of data analysis to explore solutions for community problems and urban issues.

Transportation corridor planning is a continuing, comprehensive and collaborative process to encourage and promote the development of a multimodal transportation system to ensure safe and efficient movement of people and goods while balancing environmental and community needs. The objective of transportation corridor planning is to guide development of a land use / transportation system to achieve beneficial economic, social and environmental outcomes.

2.1 ROLE OF GIS IN SUPPORTING CORRIDOR PLANNING

Harper and Manhein (1990) emphasized that the possibilities for GIS in transportation planning seem endless. Geocomputing concepts have developed out of parcel-based or polygon-based disciplines such as land-use planning and environmental management. Transportation networks have been used primarily as references for other features in these parcels – based systems. They added that transportation planners are applying the concepts of spatial analysis to networks. Geocomputing software, land-use modelling software, and transportation modelling are evolving towards an ideal geocomputing software solution for transportation planning that integrates all the capabilities.

GIS and spatial analysis offer much to the transportation corridor planning process. Most obvious is the support at the back-end as spatial database management system while at the front-end to produce graphic and cartographic visualizations of present and future scenarios. In the middle are tools for processing geographic data into geographic information.

GIS software tools, as well as spatial analysis techniques, support processing of very large quantities of transportation data and analysis of these data to produce reliable geographic information. This can help find effective solutions to transportation problems, identify the factors that influence the transportation planning system, and determine desirable future states of the system and the paths to achieve the desirable states. GIS can also greatly enhance the quantity and quality of information flows among all components of corridor planning process, potentially enhancing decision-making within this process. The purpose of this chapter is to examine and report on how GIS have been used to support decision making in transportation corridor planning.

2.2 GIS AND LAND-USE IN CORRIDOR PLANNING

The planning, design, and construction of highways as well as other transportation modes affect existing land uses and plans and proposals for future development. Safe and efficient travel, whether by walking, taking a car, an airplane or a bike is also influenced by the types and patterns of land uses.

The land use and transportation relationship can be viewed as cyclical rather than as a one-way, causal relationship in either direction. The development cycle begins when population and economic growth create demand for land development. New economic development, especially low-density development at the edge of urbanized areas, results in more vehicle trips and places greater demand on surrounding streets and highways. Land use forecasting undertakes to project the distribution and intensity of trip generating. In practice, land use models are demand driven and are used as inputs to aggregate information on growth produced by an aggregate economic forecasting activity. Land use estimates are basic inputs to the corridor planning process.

The benefit of using GIS in the early planning stages of a corridor planning leads to sound decision-making. When decisions are made earlier, overall project costs are minimized due to less wasted time and avoidance of lawsuits.

The San Diego Association of Governments (SANDAG) during the corridor planning process, planners proposed 47 km of new corridor to be added to the existing transportation network (FHWA 1998a). But many conflicts arise from the natural habitats department stating that the proposed corridor is threatened to endangered species. GIS was chosen as the best method for maintaining and analyzing both the dataset (i.e., of natural habitat as well as proposed corridor dataset) in such a way that both datasets were combined together and further analyzed to solve the problem. Figure 3 shows the existing and proposed corridors location.

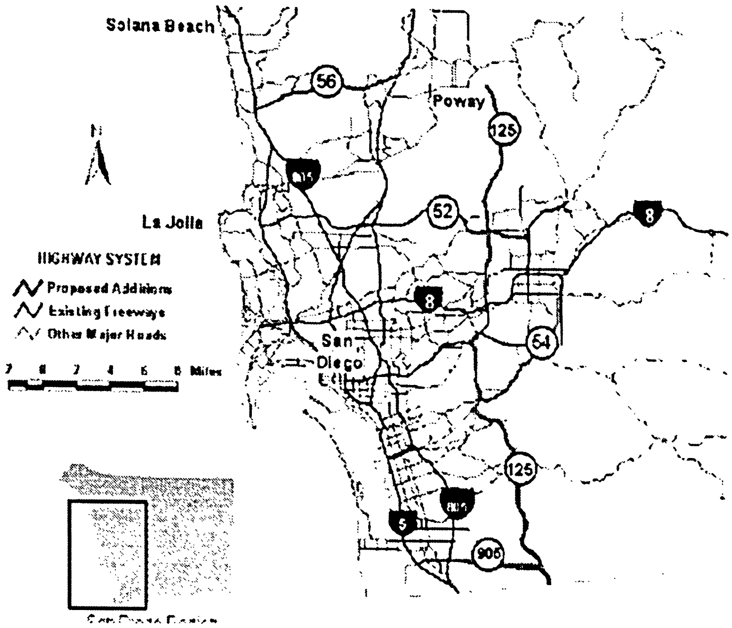


Figure 3 Existing and proposed corridor network
(Source: [FHWA 1998a])

GIS function of overlay was used for the proposed corridor alignments onto the habitat data. Thus allowing planners to prepare map that shows alignment with respect to the natural habitats. The propose alignments encroaching or bisecting natural habitats areas were highlighted the final alignment of the proposed corridor along with habitat area as illustrated in Figure 4.

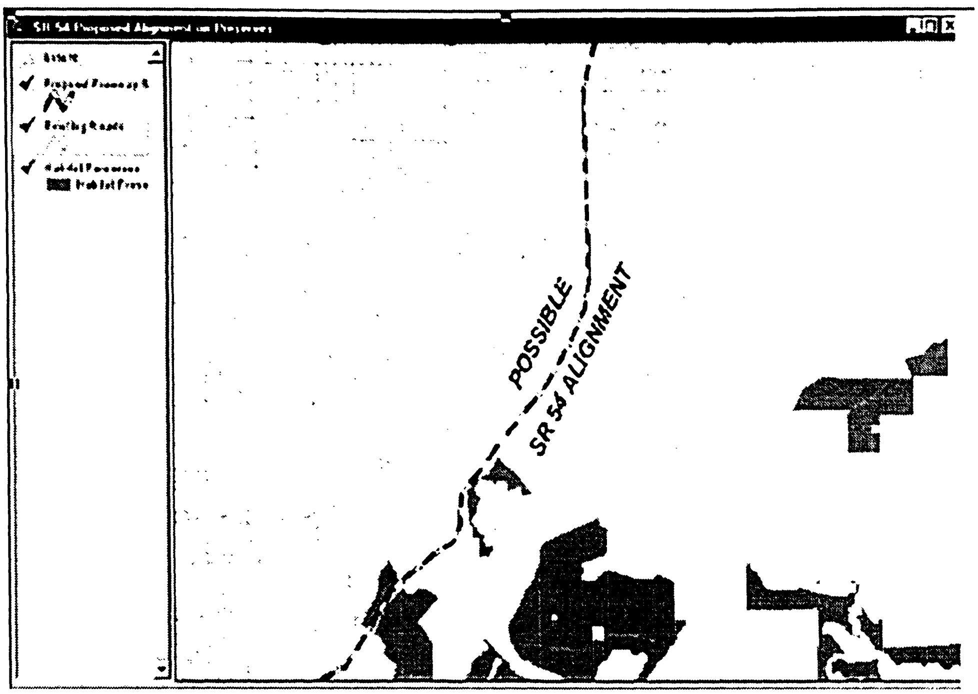


Figure 4 Habitat preserve nearby the proposed corridor
(Source: [FHWA 1998a])

In one of the other case study, Union Township, located near Michigan Lower Peninsula, was experiencing predictable growth (Francek and Frankovich 2001). New service industries brought in employment opportunities; at the same time, poorly planned development; can result in traffic congestion, roadway safety. To maintain traffic safely moving was one of the objectives of this study. Geographic Information System (GIS) provided valuable assistance in making future land use decisions. Several data layers (e.g., population, land use, trip generation and distribution) were combined. In addition, a number of "what if" scenarios were visualized, through maps, tables, and graphs, to simulate the form and process of development, giving citizens and local officials new insight into a particular land use problem (FHWA 2004).

FHWA also conducted some projects in 50 states. Many of those projects have applied innovative analytical approaches to assess and communicate the impacts of transportation and land use decisions. Geographic Information Systems (GIS) have played a key role in supporting these analytical methods. Advances in GIS-based tools and data, however, made it easier for the transportation planners to construct and model such scenarios. The method used, environmentally constrained land identified using state databases of wetlands, slopes, flood plains, and riparian buffers. Potential areas for redevelopment and infill also were identified using GIS: redevelopment by comparing assessed property value with the mean value in the surrounding area within 300 meters; and infill by identifying areas with existing low residential density in areas with higher residential density as identified in local general plans.

2.3 GIS AND TRAFFIC ANALYSIS ZONE (TAZ) IN CORRIDOR PLANNING

A traffic analysis zone is the geographical unit most commonly used in conventional transportation planning models. The size of a zone varies, but for typical metropolitan planning software, a zone of under 3000 people is common. The spatial extent of zones typically varies in models, ranging from very large areas in the suburbs to as small as city blocks or buildings in central business districts. There is no technical reason why zones cannot be as small as single buildings, however additional zones add to the computational burden.

During corridor planning process when partitioning the study region into TAZ, the overwhelming criterion is to capture as many trips as possible. Any trip that does not cross a TAZ boundary is lost to travel demand analysis. TAZ size is an obvious factor: the smaller the TAZ, the more likely that a trip will cross its boundary (Miller 2001).

You et al. (1997) use cluster analysis in a GIS based toolkit that configure TAZ to maximize zonal homogeneity and maintain spatial contiguity. Figure 5 illustrates the conceptual design of their system. Iterative clustering analysis uses agglomerative clustering to derive the initial TAZ and iterative partitioning to refine the initial zoning system. Multiple attributes can be used in the clustering, with the user supplying relative weights for each attribute that reflects their importance. Iterative partitioning involves individual reassignment of entities among clusters based on their relative differences to cluster centroids. The user can visualize and statistically evaluate solution properties between iterations. Adjacency measures enforce contiguity constraints by not allowing reassignments that violate these constraints.

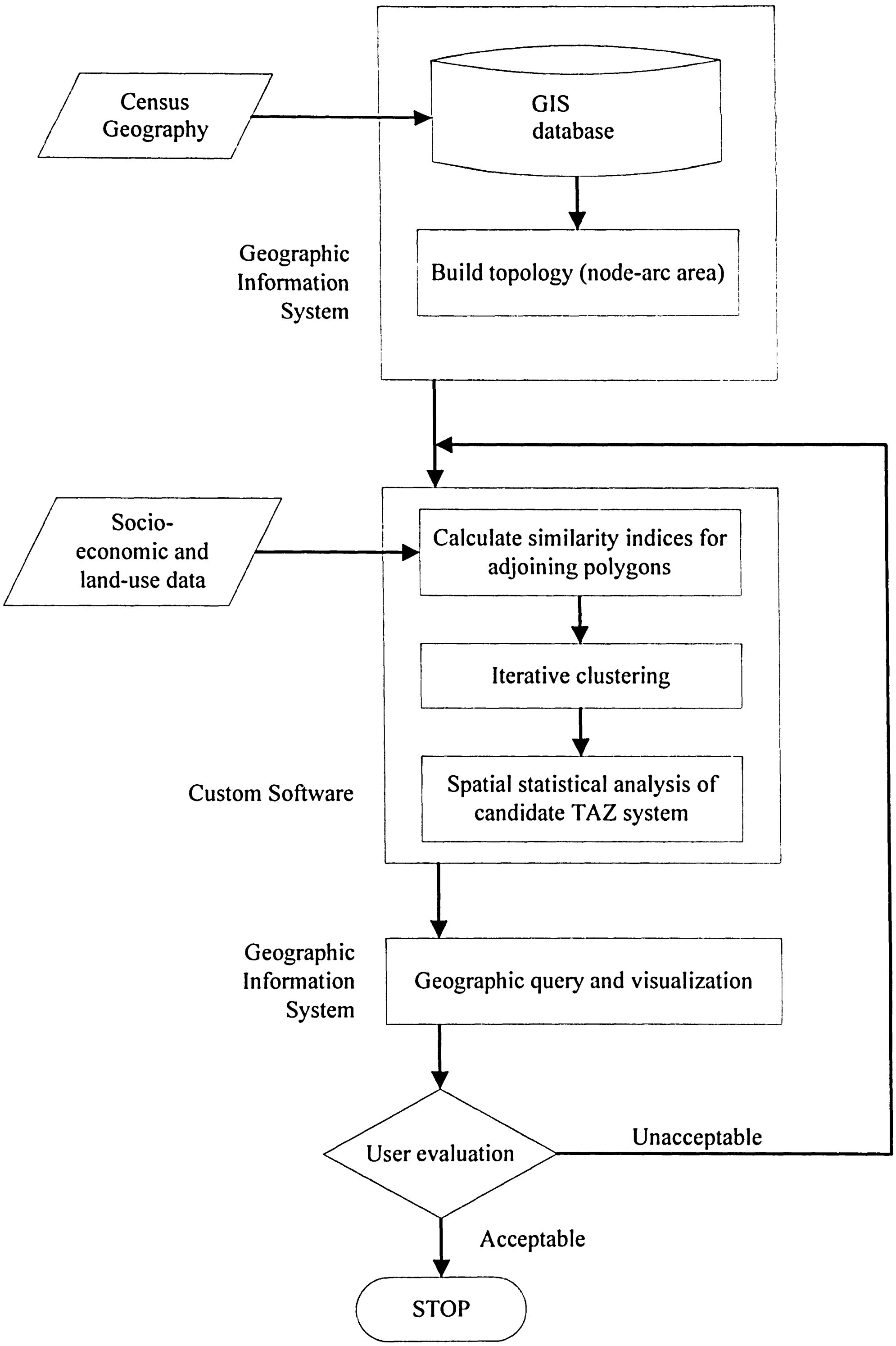


Figure 5 Conceptual model of GIS traffic analysis zone design system
(Source: [You et al. 1997])

Ding (1998) describes an interactive TAZ design module incorporated into a software system that links a GIS with the TRANSPLAN travel demand software. The module measures properties of a candidate TAZ system, including the observed trip generation from each zones, boundary consistency, compactness, contiguity and zonal homogeneity. The user can specify relative weights as well as minimum threshold values for these measures.

In one of the case study reported by FHWA (1998), the Maine Department of Transportation (Maine DOT) developed a travel demand model linked to a Geographic Information System (GIS). The travel demand model, based on the TRIPS modelling software, provides a standard forecast of province wide traffic growth that can be used to evaluate capital improvement projects and as inputs for air quality analysis. GIS software, including ARC/INFO and ArcView, was instrumental for combining the existing model networks into a unified province wide model with common format and coding conventions.

The use of GIS for this project served two main purposes; integration of the source networks and display of assigned model outputs. Various GIS functions performed during the process are:

- Overlay of the model outputs with other data sources. For example, other geographic layers such as town boundaries or socioeconomic data are easily overlaid on the model network with GIS as shown in Figure 6, providing much greater mapping detail than with the model network alone.
- GIS also provides better tools for text labelling.
- While the TRIPS software is able to incorporate other layers, the process is laborious and would be inefficient with regard to storing and maintaining data in multiple formats. This is a function easily handled by GIS.
- Transferring the model to GIS format also enables display of the model outputs with other source data sets.

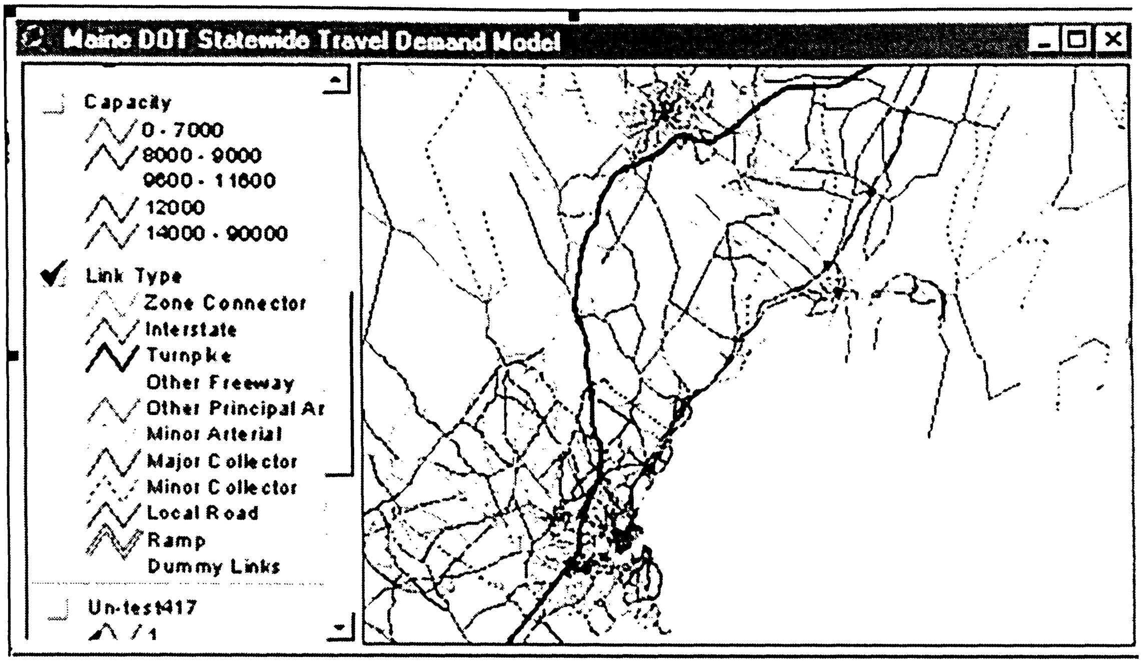


Figure 6 Standardized link classifications across original networks
(Source: [FHWA 1998b])

In one of the case study in Qatar (Doha) GIS was being used while developing TAZ model for the city (Balamohan 2001). During 1994 initial TAZs were derived from census blocks, which were delineated during 1987 census. Due to the rapid change in the development and implementation of various sub-division projects, the census blocks were changed and re-delineated during 1997. TAZ validation task was undertaken to identify the consistency of the TAZs against the new census blocks. The data (land use, cadastral and census) used for the validation process was sourced from different agencies. This task was carried out using multiple map overlay technique in ArcInfo environment. After using GIS it was realized that it helped in:

- Minimising (in fact eliminated) lose of information during the data collection
- Minimising conflicts of source and redundancy of data is minimised
- Minimising frequency of data capturing and updating for the respective database is maximised.
- Minimising misestimating of trip generation, as the land use and population data were readily available via WAN during continuous case by case transportation impact studies due to land use change.

- Presenting the transportation analysis reports in a more meaningful way with the help of supportive information available with other agencies.

2.4 GIS AND CORRIDOR LOCATION

A difficult aspect of the corridor location problem is that it involves multiple, often conflicting, criteria. These can include construction cost, user (flow) cost, environmental impacts (e.g., wetlands, sensitive species, biodiversity) and physical factors such as slope and soil stability. One solution is multicriteria decision-making which refers to the process of solving problems involving multiple, conflicting attributes. Figure 7 shows a generalized version of the multicriteria decision making process (Jankowski 1995). We must first identify a set of criteria for evaluating alternatives.

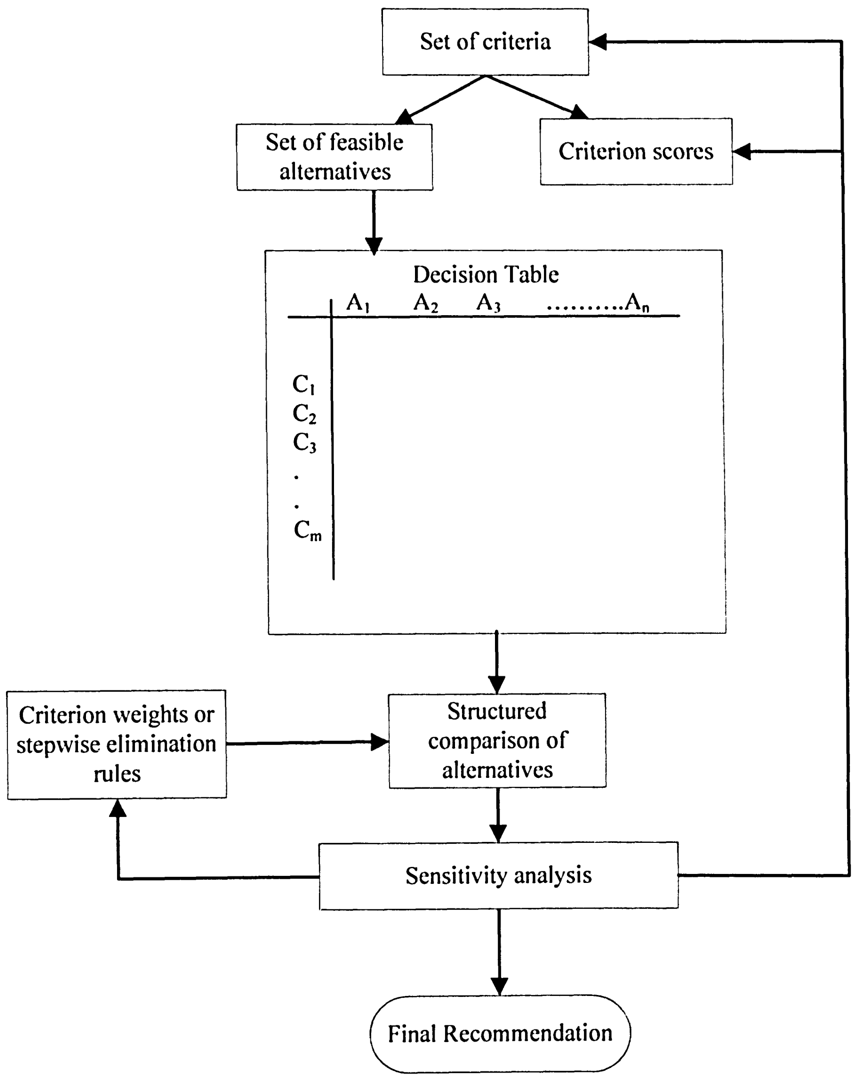


Figure 7 Generalized multicriteria decision-making process (After [Jankowski 1995])

GIS supports multicriteria decision making for spatial decision problems (such as corridor location) through geographic data integration, analysis and visualization tools. GIS, modelling software, or some combinations can generate a set of solution alternatives. The alternatives can be integrated with geographic data through overlay. Criterion coverages are thematic GIS layers showing the spatial distribution of the attributes in the study area expressed using criterion scores. We could construct geographic visualizations of elements, rows and columns (or some combinations) of the decision table. We could also summarize, overlay and visualize the original attribute data (Jankowski 1995; Jankowski and Richard 1994).

GIS software has the ability of displaying data in different layers. Each layer displays sorted information. Thus the complicated corridor planning and design data can be displayed in different layers. In a conceptual design of a GIS product for highway corridor planning and design, each layer represents one aspect of the design, and one or more attribute tables can be related to this layer to store inventory and other text information (Uddin 2002).

The results of a recent airborne remote-sensing technology evaluation study funded by the National Atmospheric and Space Administration (NASA) Stennis Space Center through the Mississippi Space Commerce Initiative (MSCI) and supported by the Mississippi Department of Transportation (DOT) are presented. The airborne LIDAR remote sensing digital mapping technology, in conjunction with GPS receivers and aerial photography, was evaluated by the Center for Advanced Infrastructure Technology (CAIT) at the University of Mississippi (UM). The study focused on an 8-km long corridor alignment project of the Raleigh Bypass near Jackson, Mississippi.

A bare-earth terrain model was developed after filtering the data through vegetation-removal software. Subsequently 0.3 m interval contours were generated through CAD software. The digital maps produced by processing laser data were superimposed on digital aerial photo images for corridor alignment location and other environmental applications, as shown in Figure 8.

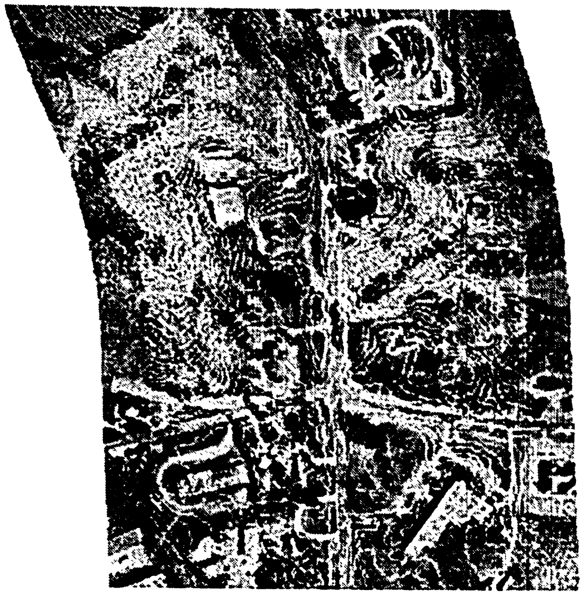


Figure 8 Overlay of LIDAR contour map on aerial photo image for a section of Raleigh bypass project site, Mississippi
(Source: [Uddin 2002])

2.5 GIS AND PUBLIC PARTICIPATION

Public involvement is an integral transportation mission. Without meaningful public participation, there is a risk of making less than optimal decisions. With it, it is possible to make a lasting contribution to an area's quality of life. Public involvement is more than an agency requirement and more than a means of fulfilling a statutory obligation. True public participation is central to good decision-making.

Generally, the main purpose of public participation is to improve decision-making, by ensuring that decisions are soundly based on shared knowledge, experiences and scientific evidence, that decisions are influenced by the views and experience of those affected, that innovative and creative options are considered, and that new arrangements are workable, and acceptable to the public.

In practice and especially from a GIS perspective one has to define the rights to participate, to object or to collaboratively decide. We can observe different kinds of dichotomy of participation techniques: a) approaches focusing on a broad public and b) a stakeholder centered approach. In practice, it is impossible to actively involve all potential stakeholders in all issues. A selection has to be made which is usually based on some of the following factors:

- The relation of the stakeholder to the planning issues concerned;

- The scale and context at which they usually act, who they represent;
- Their involvement, being governor; user/victim/stakeholder; expert and executer of measures;
- Their capacity for engagement; and
- The political, social, environmental context.

According to Arnstein (1971), "*...inviting citizens' opinions, like informing them, can be a legitimate step towards their full participation. But if consulting them is not combined with other modes of participation, this rung is still a sham since it offers no assurance that citizen concerns and ideas will be taken into account. The most frequent methods used for consulting people are attitude surveys, neighborhood meetings, and public meetings. ...Public participation is concerned with the redistribution of power that enables the have not citizens, presently excluded from the political and economic processes, to be deliberately included in the future. It is the strategy by which the have-nots join in determining how information is shared, goals and policies are set, tax resources are allocated, programmes are operated, and benefits like contracts and patronage are parcelled out. In short it is the means by which they can induce significant social reform which enable them to share in the benefits of an affluent society...*"

Current GIS models of participation include voting in elections, some of them focus on ethical issues (Solomon and Hanson 1989) such as democratic ethics, citizen ethics, citizen's rights and duties, mutual respect and help. Some other found their origins in social capital theory considering citizens to be the social capital and stressing the importance of the social learning (Crick 2001). One of the popular theories of participation is voluntary theory of participation represented by the civic voluntarism model (Parry, et al. (1992). The authors of this model identify resources, such as money, time, education, etc., motivations and mobilization as the three most important classes of participation. They argue that individuals with high socio-economic status and enough time available are likely to participate more than the individuals with less time. The ladder analogy developed by Arnstein (1971), as shown in Figure 9, was applied and further developed by several authors. Weidemann and Femers (1993) use it for the classification of the public rights adapting it to their analysis of decisions needed for the purpose of hazardous waste management. According to their analysis, public participation increases with the level of access to the information as well as the rights that citizens have in the decision making process. Some other authors (Smyth 2001; Carver 2001; Steinmann, et al. 2004) apply the analogy of a ladder in GIS-based public participatory approaches.

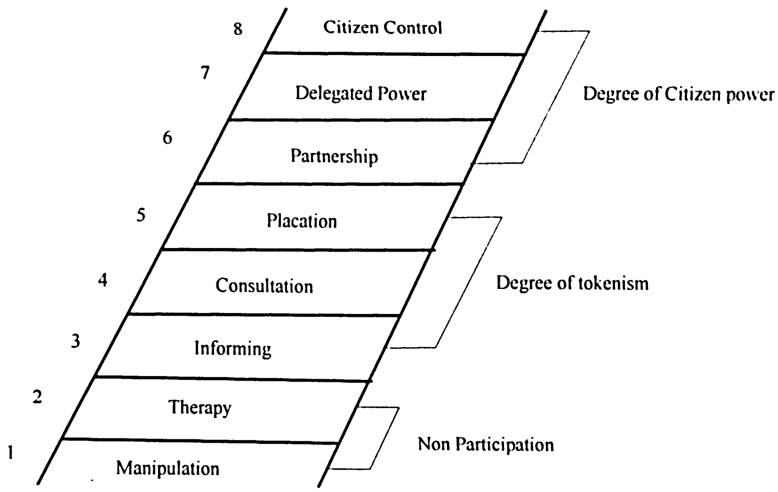


Figure 9 Public participation ladder
(Source: [Arnstein, 1971])

Standard, classical methods of public participation in spatial planning include personal discussions, meetings organized in a public place, presentation of the planned activities with the help of analogue maps, etc. In contrast to the traditional methods of participation, novel forms are beginning to evolve due to the new technological possibilities. Web-based user-friendly applications and broader use of Internet as a communication tool encourage the evolvement of the novel ways of the involvement. These new forms include web surveys, online forums, virtual workshops and conferences, exchange of e-mails, and online map-based discussions. They can be supported by geographic information systems (GIS) and integrated in a public participatory GIS.

As an example, a case study in northern Brevard County, Florida and within the City of Titusville is discussed here (Schulte 1999). The extent of the study area along the two corridors were SR50 from its western approach starting at the Great Outdoors development entrance road to its intersection with US1, (see Figure 10) and SR405 from its intersection with Fox Lake Road to its intersection with US1.

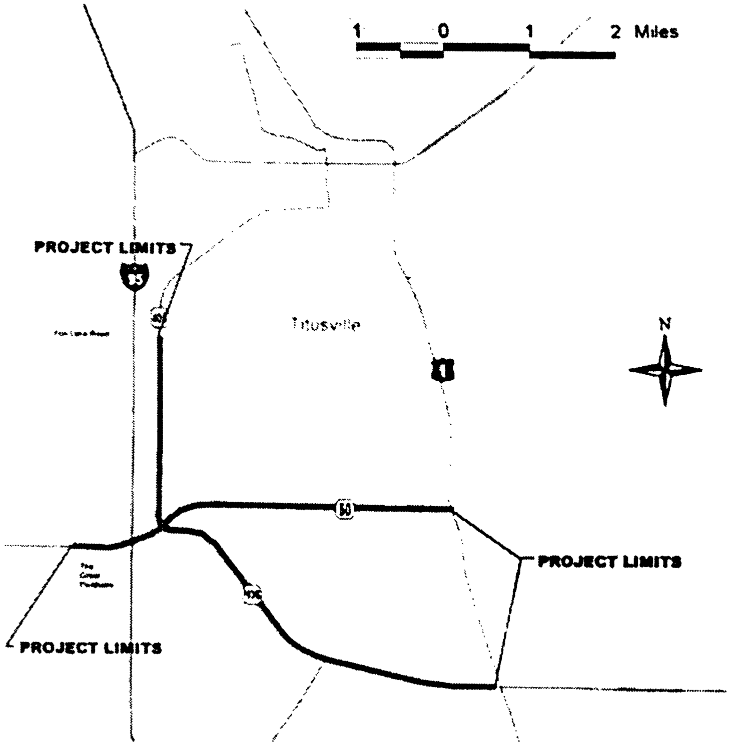


Figure 10 Project location
(Source: [Schulte 1999])

The Florida Department of Transportation (FDOT) conducted a planning study for the SR50/SR405 corridors which would address transportation issues related to current and future development. With the scope of this project so expansive and with extensive public involvement, the use of GIS technology for the production of alternative design scenarios was crucial given the six month time frame of this project. The traditional planning methods commonly used would have occupied too much time and money and could have jeopardized the success of this corridor study.

Much of the success of this study was a result of the quick turn around time that was allowed with the use of a GIS system. Public comments were evaluated and graphics were updated without much labour power. Also, with the property data that was received for the appraisers office, the team was able to place a 300m buffer around the project corridors and extracted all of the properties (with owner's information) that would be affected by this transportation corridor. Once extracted, a comprehensive database was imported into Microsoft Access where mailing labels were easily developed. This technology proved extremely helpful in determining who showed up at each of the public meetings. Cross referencing the 300m buffer dataset with the sign in sheet from each of the public meetings, a graphic representation of public turnout was generated and used to re-evaluate how effective the public outreach techniques were.

The cross-referencing of various datasets is the essence of GIS and without the ability to overlay data sets and query land uses with population data the tasks of data creation and analysis were not seamless. Aerial data from in digital format made the task of overlaying simple. As shown in Figure 11, aerial raster data with property lines were easily manipulated and used to present on both large graphics for public meetings and reduced size for report graphics. In addition to the graphics capabilities, the study team was able to generate areas of potential property take with actual property values to assess property damages.

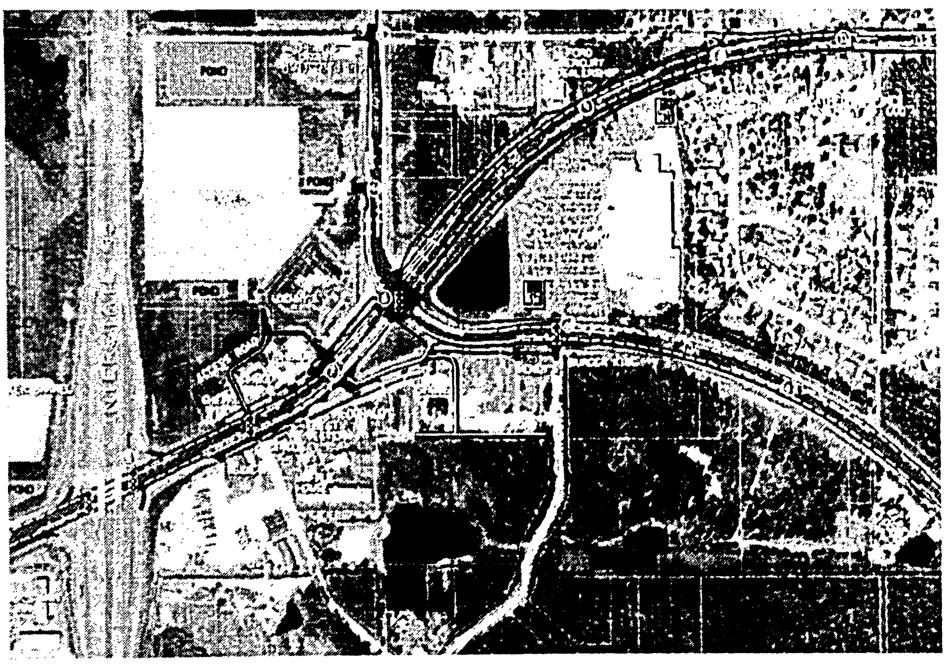


Figure 11 Raster aerial image
(Source: [Schulte 1999])

2.6 SUMMARY

GIS provide the uniform environment in which the data for numerous planning purposes can be integrated. GIS technology provides the core framework for an integrated highway information system. The developed database can be further supplemented with new information as and when it is available. So, the database keeps on evolving, which is otherwise not possible to compile at one time. The topological information available in GIS database opens the new ways for analyzing the transportation related data for different purposes. Various GIS functionality, spatially the spatial analysis functions and querying capability, are very useful tools for the day-to-day management of the road network by the concerned organizations.

The impact of GIS technology in development of transportation information system and highway infrastructure management is profound. If GIS technology is utilized to its fullest extent it will completely revolutionize the decision making process in transportation corridor planning. GIS is being recognized world-widely as the most efficient tool for integration of all types of data necessary for transport sector. The huge amount of information related to transport infrastructure in the country could be put together for its most efficient utilization in planning, design, construction, maintenance and management of the transport system.

GIS provides the tool a corridor planner would need to convey ideas and present implications of planning decision for non-planners visually. GIS provides a means of communication that allows for an interactive understanding between the public and transportation professionals. Corridor planners have used GIS in several aspects that include land-use, traffic analysis zone and corridor location.

GIS can be used to maintain and manage all map layers and their attribute data related to corridor planning as long as the map layers are geo-referenced. GIS allows integration of data from different sources and different scales. It can also aggregate forecasted traffic data and produce cross-reference files between different levels of geography. Traffic analysis zones link travel with population, land use, and socioeconomic data. Traditionally, transportation corridor planners have treated land use and traffic analysis zones together to define either traffic analysis zones or land use. The manual process is, however, time consuming. With the use of a GIS, preliminary TAZ boundaries can follow census statistical boundaries, such as block groups, census tracts, or counties.

3. CORRIDOR PLANNING PROCESS

Generally transportation corridor planning process can be divided into three stages/ phases that progress from the general to the specific. It is important that the planning should not occur in a linear fashion, i.e., the activities described in phase 1 may occur after phase 2 or phase 3 planning.

Phase 1

With requirements to consider a range of transportation modes and impacts on land use and the environment, corridor strategies are established in this stage in order to properly address the goals and policies. A corridor strategy provides a set of transportation performance and impact objectives for each corridor.

Transportation facilities and systems in each corridor are identified and analyzed for present and future performance in areas of modal balance, intermodal and regional connectivity, congestion and safety. In addition, characteristics of the corridor and the role it plays in the region are described in terms of land use, social, environmental and economic development impacts.

Phase 2

Most of the corridor planning effort occurs in this phase, focuses on developing corridor improvement and management elements, and city and county transportation planning. During Phase 2, a corridor improvement and management element of each corridor plan is developed to test interim corridor strategy objectives, analyze alternatives, provide general cost estimates, and establish implementation priorities. Implementation decisions for each corridor objective may entail transportation improvements, operations and maintenance programs, agency liaison agreements, and management system category assignments. These decisions may be regulatory (e.g., level of importance, access management category assignments, etc.) or advisory (e.g., proposed capital projects, maintenance programs, etc.) in nature.

Phase 3

Some portions of corridors may require specific planning. Therefore during Phase 3 the activities to be done are: to resolve particular land use, access management or other issues that require a more in-depth analysis than generally required to prepare a corridor improvement and management plan element. Corridor plans may then be amended to incorporate the products of these refinement plans.

CORRIDOR TRANSPORTATION PLANNING PROCESS

As stated in Chapter 1 of this report that appraisal of Phase 3 is beyond the scope of this study. Referring to "Guide book for Transportation Corridor Studies: A process for Effective Decision Making" used as guidelines by various Ministry of Transportations in Canada as well as in United States the various steps used in Phase 1 and Phase 2 of the planning process are;

- Develop a corridor work plan and public participation plan.
- Research existing conditions of the transportation system.
- Existing and projected land use conditions and environmental issues in the corridor area.
- Analyze the projected future travel demand and performance in the corridor.
- Establish purpose and need, and the relative importance of corridor needs through project goals.
- Generate alternatives to meet the corridor goals.
- Identify feasible alternatives by first evaluating all alternatives.
- Use comparative analysis to further evaluate alternatives and generate a preferred list.

Each step contains the purpose for the activity, the tasks necessary to accomplish the step, and expected products as given below.

3.1 DEVELOP A CORRIDOR WORK PLAN AND PUBLIC PARTICIPATION

The tasks to be accomplished under this step establish the framework for the development of the corridor plan. The corridor work plan establishes the key decision points, letting all participants know how and when they can provide input into the plan's development and where the decision-making authority resides. The tasks to be accomplished under this step for any corridor planning are as follows.

Task 1.1 To Identify Key Decision Points in the Plan

Key decision points include establishing a statement of purpose and need, and listing the goals for the corridor; generating alternatives to meet the goals; identifying feasible alternatives; and prioritizing the preferred alternative(s).

Task1.2 Corridor Boundary and Width

To draw the boundary on a base map along with key features of the transportation system and the areas that need changes to the system. Use the area within the corridor boundary as the focus for subsequent data gathering and analysis.

Corridor boundaries should be selected in such a way that the effective solutions can be found to improve the transportation system up to, through, and beyond problem areas. Consider the effects of physical or environmental constraints extending past the constraint. This will assure that decisions made in one section will not set up the next section for severe consequences.

Corridor width should not be a set width because in an urban area, it may focus on a single roadway. However, the corridor may include parallel facilities which may be located 0.5 or 1 kilometre on either side (generally, parallel facilities have a lower functional class). Otherwise, the study becomes an area-wide study, with a network of roadways rather than a corridor.

Task 1.3 Public Participation

In order for public participation to truly be collaborative, there must be ample opportunities for meaningful involvement throughout the planning process. Creating the public participation work plan makes the development of the list of stakeholders a top priority. This can be accomplished by talking to key decision makers within the corridor planning area (local elected officials, agency representatives, and community leaders). Then a list can be compiled.

Depending upon the number of stakeholders that are identified, it may be more appropriate to create several subcategories of stakeholders, such as elected officials, agency representatives, and associations.

Expected outcomes from this step are;

- Base maps illustrating corridor boundary.
- List of stakeholders.
- List of transportation related issues raised by local elected officials and stakeholders.

3.2 RESEARCH EXISTING CONDITIONS OF THE TRANSPORTATION SYSTEM

This step is an information gathering process. Professional judgment and general knowledge of the corridor area should be used to determine what information sources, and how much data, are necessary to provide a complete picture of the existing transportation system within the corridor. For this purpose the base maps are being used throughout the corridor planning process.

The purpose of this step in the process is to gather enough information to provide a complete picture of the existing transportation system within the corridor. This information should be supplemented with information regarding land uses and environmental conditions in the corridor area. These information forms the factual basis for analysis in the further process, i.e., how the existing transportation system can be expected to perform in future conditions. The various tasks to be accomplished under this step for any corridor planning are as follows.

Task 2.1 Analyze the Existing System

The purpose of this step should be limited to information that builds a complete picture of the transportation system in the corridor.

All the elements of the transportation system within the corridor should be studied to get a complete picture of the existing system. The level of details of the information gathered should correspond to the importance of that element to the transportation system. Types of information needed for the corridor plan include: functional classification maps; construction plans; pavement conditions; records of existing traffic control devices; access control policies; crash data; results of any origin/destination surveys; data on freight usage; seasonal and daily traffic volume peaks; and turning movement counts at major intersections.

Transportation system elements within the corridor should have the record /data as of the system as information about state/local streets and highways within the corridor, locations, right-of-way widths, number of lanes, adopted functional classifications, peak travel times, access management, and system management or demand management policies or tools in effect. At a minimum, the average annual daily traffic (AADT) should be identified for every logical link within the corridor (A link is a segment of the corridor between major crossroads where traffic volumes are likely to change and it may be many kilometres long in a rural corridor or only a few blocks in an urban area). AADT should also be identified for the highways and streets which cross the corridor and form the limits of each link. AADT information, along with information on the size of the facility, should then be used to determine the level of service.

Task 2.2 Role of Transportation in the Corridor Area

The role of transportation within the corridor is not solely a hard data need. Local knowledge and professional observation of the existing system should be used, and supplemented with hard data when available. For example:

- If it appears from observation and from discussions with local officials that farm-to-market transportation is important, data should then be collected from local grain elevators, state weigh stations, and the county extension service regarding local farm production, shipping, and trucking.
- If the corridor is located in a tourism area, data regarding tourist destinations and number of visitors should be gathered. Sources should be selected as different government officials.

All the information gathered in the above two tasks should be added to base maps of the corridor. Expected outcomes from this step are;

- Base maps that illustrate existing and committed transportation facilities serving the corridor.
- A written report that describes features, operational characteristics, and performance of the existing transportation system, and the role of the corridor in the region.

3.3 EXISTING AND PROJECTED LAND USE CONDITIONS AND ENVIRONMENTAL ISSUES IN THE CORRIDOR AREA

The purpose of this step is to gather information about the region served by the corridor, in terms of its current and planned land uses and historical, cultural, environmental, social, and economic features. Later on this information will be used to identify issues that could impact corridor improvements. Various tasks to be completed under the domain of this step are as described below.

Task 3.1 Land Uses and Other Characteristics of the Region

Land use data should include general zoning classifications found in the corridor planning area, existing and planned land use patterns, existing and planned major developments, and vacant land inventory (if available).

Any major pipelines or large utility facilities (natural gas and petroleum pipelines, electric substations, etc.) locations need to be identified. Utility companies serving the corridor area are the primary source for this information. Human characteristics should be analyzed to understand potential impacts that may be caused by corridor improvements. Incomplete or out-of-date information regarding land uses, population, and employment may be supplemented by tracking existing trends in rezones, building permits, utility extensions (numbers and locations), and the observations of planning and zoning commission members, local planning staff, and elected officials.

Task3.2 Identifying Environmental Factors of the Region

Any existing environmental studies or studies that include geotechnical data, hydrological information, soils, and subsurface geology should be reviewed. The critical environmental issues within the corridor include the following:

– Flood ways and flood plain boundaries

– Wetland boundaries

– Archaeological sites

– Mines

– Hazardous waste sites

– Historical buildings, sites, and districts

– Rivers and lakes (identifying any designated wild and scenic rivers)

– State and national forests

– Wildlife reserves

– Public parks

– Prime agricultural land

– Pedestrian and bicycle access

– Neighbourhood/business displacement

Expected outcomes from this step are:

- A report summarizing the results of the land uses and its other characteristics such as: community profile including population, growth trends and employment trends which are essential for use in future forecasts, current land uses, planned land uses and historical and cultural buildings and sites.

- A list of environmental issues within the corridor, and identification of areas that require further analysis.

3.4 ANALYZE THE PROJECTED FUTURE TRAVEL DEMAND IN THE CORRIDOR

The purpose of this step in the corridor planning process includes estimating the future travel demand of the transportation system within the corridor, and identifying the elements and geographic areas where the performance of the existing transportation system is expected to fall short of meeting that demand. Further the sub-processes of this step include:

Task 4.1 Estimating Future Transportation Travel Demand in the Corridor

To estimate travel demand in the corridor future travel demand is usually counted for 20 years, the simplest forecast is a straight-line projection of growth. Straight-line projection assumes the travel growth experienced over the past 20 years will continue at the same average rate over the next 20 years. If there have been regular traffic counts over a number of years in the corridor, those historical counts can be used as the basis of the projection. Straight-line projection is best suited to corridors where little change is anticipated in the spatial pattern of growth of the region.

If a forecasting model is available for the area served by the corridor, it is important to coordinate the forecasting effort to match modelling assumptions as much as possible. However, using the model to produce the forecasts for the corridor may not be useful because models are usually developed to forecast traffic within a city or county boundary, not a corridor. Some special precautions required while using an existing model for future travel demand are:

- The model assumptions are not kept up-to-date.
- The model covers only a portion of the corridor.
- The corridor carries a large proportion of trips from outside the area covered by the model.
- The corridor is located close to the edge of the area included in the model.

Expected outcomes from this step are:

- A table or other graphic display presenting the future forecasted travel demand.
- A map of locations within the corridor showing where transportation system

deficiencies are likely to occur with the 20-year demand.

3.5 ESTABLISH PURPOSE, NEED AND THE RELATIVE IMPORTANCE OF CORRIDOR NEEDS THROUGH PROJECT GOALS

This step uses public participation techniques to establish the direction for the rest of the corridor planning process. Activities include meeting with the public to explain the corridor boundary and using public input to develop a statement of purpose and need, and identify goals for the corridor.

Task 5.1 Review of Corridor Boundary

During this process the review and discussion of the mapped boundary chosen in step 1 should be explained to the public with respect to why the boundary was chosen. The boundary on a base map along with the key features of the transportation system of the corridor should be explained. Where possible, location of the deficiencies on the base map for use at the public participation events should be mentioned.

Task 5.2 Identify goals for the Corridor

Goals that are developed should be measurable as much as possible, although some non-measurable features may be included. They should also answer the questions, e.g., what will we need and expect from our transportation system in this corridor in 20 years? The goals may include maintaining the existing level of service (LOS), reducing farm-to-market travel time, improving safety, improving access to public transit, improving intermodal connectivity, implementation and funding strategies, or other objectives. Public events should be utilized to generate a list of goals as a framework for developing corridor goals. Expected outcomes from this step:

- List of goals for the corridor.
- List of concerns/issues raised by the public and statement of purpose and need

3.6 GENERATE ALTERNATIVES TO MEET THE CORRIDOR GOALS

This step is designed to compile as many alternatives as possible for improving the transportation system within the corridor. The open exchange of ideas for all corridor stakeholders in this step encourages collaboration among the participants to identify all of the potential options for system improvements.

Task 6.1 Generate a preliminary list of alternatives

To develop a preliminary list of improvements and strategies to the transportation system that is expected to meet the goals for the corridor. This preliminary list can be used to stimulate discussion for the production of a more complete list of feasible improvements and strategies at the public participation events.

All alternatives proposed at the public participation events should be listed, even if they appear impractical. These alternatives should then be evaluated. The public should be encouraged to consider improvements not related to conventional solutions.

Task 6.2 Preparing Conceptual Map of Potential Road Alignments

Potential alignments should be shown as single lines on a map. Other proposed transportation improvements should be mapped or listed, as appropriate, at a conceptual level of detail. Expected outcomes from this step are:

- A complete list of alternatives.
- Conceptual maps of potential road alignments.
- List or illustration of other transportation alternatives.

3.7 IDENTIFY FEASIBLE ALTERNATIVES BY FIRST EVALUATING ALL ALTERNATIVES

This step includes comparative analysis of the various alternatives suggested in Step 6. The analysis is used to screen the complete list of alternatives to identify those alternatives which are the most feasible and promising.

Task 7.1 Screening Criteria

Prior to the screening, it is important to contact elected officials, agencies, and other key stakeholders identified in the public participation work plan, to gain their understanding of the screening criteria to be used. From the literature review it is observed that various goals which should be kept in mind for the screening criteria include:

- How well each alternative meets the goals established for the corridor.
- Costs of each alternative. Dollar costs need not be exact at this step. Relative grouping of low, medium, and high cost is adequate.
- Impacts of each alternative on important environmental resources and feasibility regarding environmental issues and regulations.
- Impacts of each alternative on historical and cultural sites and resources.
- Feasibility of each alternative regarding conformity with local comprehensive plan goals and policies.

- Feasibility of each alternative regarding geologic considerations.
- The degree of improved access to important educational, medical, industrial, or recreational facilities.

On the other hand, an extensive public participation process is also being used to screen the complete list of alternatives and identify feasible alternatives that are reviewed in detail. The public is invited to compare alternatives and to try to achieve consensus on feasible alternatives. Expected outcomes from this step include:

- A list of feasible alternatives for transportation-system improvements and strategies.
- A report summarizing the reasons of why other alternatives are no longer being considered and public participation activities and key decisions that may have been made.

3.8 USE COMPARATIVE ANALYSIS TO FURTHER EVALUATE ALTERNATIVES AND GENERATE A PREFERRED LIST

This step refines the list of alternatives into a unified package of recommendations capable of achieving the goals for the corridor.

Task 8.1 Gathering the Information for Comparison of Alternatives

The following information for each of the alternatives is being considered effective:

- General right-of-way and facility requirements and constraints.
- Preliminary cost estimates.
- Conceptual geometric configurations for major bridges, interchanges, and roadway segments.
- List of impacts, feasibility, and actual locations of environmental resources which need additional geotechnical, environmental, or hydrological investigation in subsequent phases of project development
- Draft implementation process for each alternative.
- List of interim improvements and strategies which could begin if funds are not available for the long-term upgrading to the 20-year improvement.

Task 8.2 Conducting a Detailed Analysis of Feasible Alternatives

A more detailed analysis of the alternatives should be completed using both the criteria in previous Step 7 and the following specific criteria:

- Comparison of each alternative to the others in terms of general order of costs.
- Relative impacts on environmental resource.
- Relative ease of implementation.

Expected outcomes from this step are corridor plan documents that include all items required for corridor planning.

The above stated phase/stages in the planning process can be summarized in the flow chart in Figure 12.

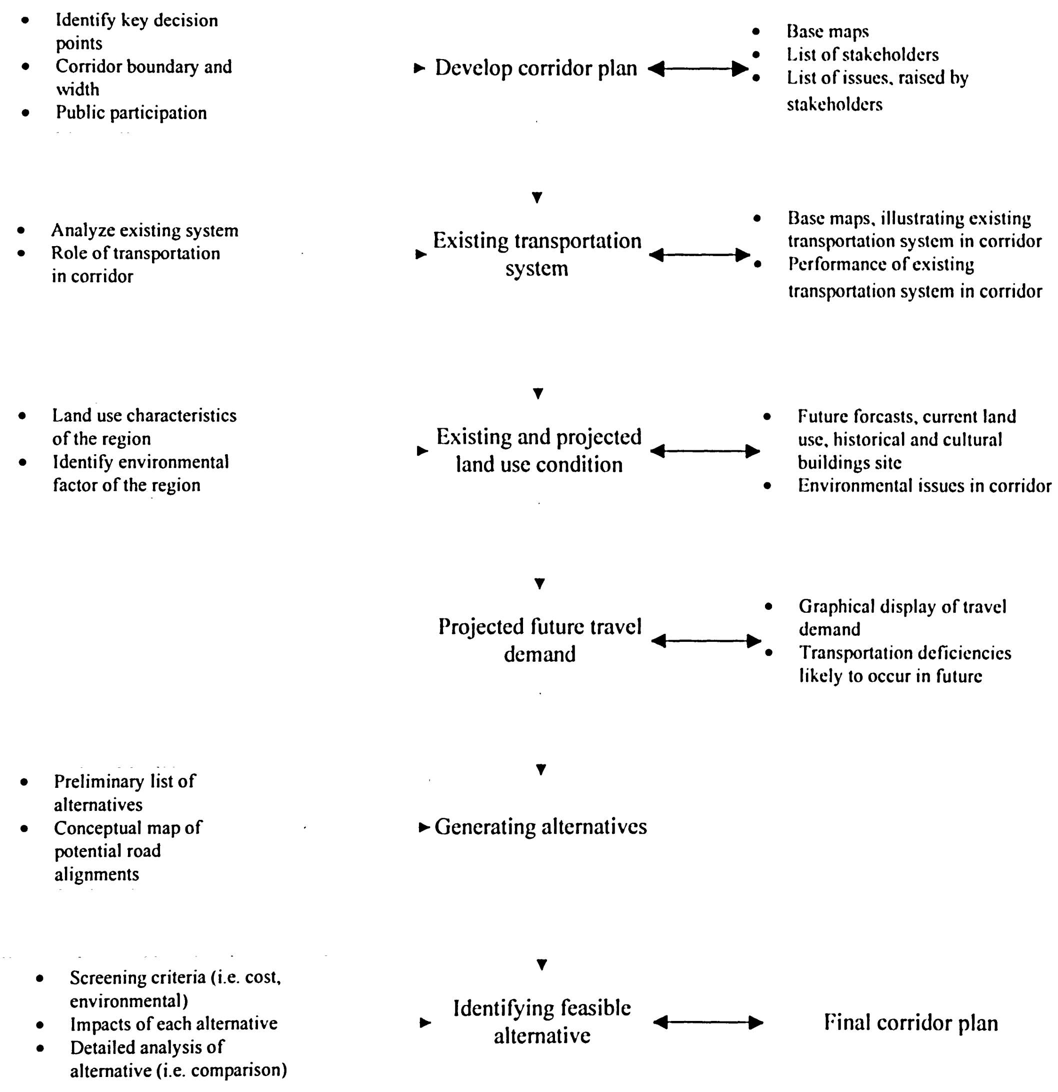


Figure 12 Flow chart showing the planning corridor planning process

4. DISCUSSION AND RECOMMENDATION

For years traditional planning activities have made use of Geographic Information Systems (GIS) technologies. Land use planners have used GIS systems to determine future development boundaries, commercial and industrial zones. GIS technology and its application have been easy targets for many ethical critics during the last few years.

Transportation planners are increasingly using GIS for all types of planning purposes. The ability to integrate transportation data with GIS is among the most useful applications of this technology. Transportation planners are still discovering how useful GIS is for corridor planning studies. With GIS a corridor planner can overlay alignments of proposed highways on multitude of data available, and thus quickly assess the feasibility of alternate alignments.

GIS combines a database of attributes with geographical coordinates, where the attributes refer to points, lines or areas defined by the coordinates. Although the majority of GIS applications are concerned with mapping, the term GIS is increasingly used as shorthand for a great diversity of computer-based applications involving the capture, manipulation, analysis, and display of geographic information and the associated services.

In such a planning process where funds are limited and decisions have to be made in a timely manner, geomatics technologies can bring into this environment a number of supporting tools for better and speedier decision-making process. Furthermore, a GIS-based system can not only support regional analysis of multi-modal transportation solutions and corridor selection but also support decisions, which relate to maintenance and upgrading.

In developing countries, and even true to a certain extent in more developed countries, fully operational GIS systems that already form a part of the decision-making process are often nonexistent. Even though the private sector has a key role in such areas as real estate development, marketing and forestry, it is the public sector that still carries out and consolidates most planning activities.

The main objectives for bringing in a GIS system into a planning process are to provide the means for visualizing the spatial aspects of the problem being tackled and to provide a number of additional analytical tools that transform existing data into valuable information, which in some contexts may be transformed into knowledge.

With reference to Chapter 2 and Chapter 3 of this report, this section focuses on the overall transportation corridor planning process from the GIS point of view. In this section, how GIS can be used for each step of the planning process in Chapter 3, is explained and some related issues are discussed.

4.1 GIS FOR CORRIDOR WORK PLAN AND PUBLIC PARTICIPATION

The tasks to be accomplished under this step establish the framework for the development of the corridor plan. The corridor work plan establishes the key decision points. The corridor boundary gives a physical structure to the plan. Finally, preparation of the public participation plan assures that a proactive, collaborative planning process will be implemented.

Task 1.1 Corridor Boundary and Width

The length or section boundaries of a corridor depend on many things, including the roadway function, departmental and governmental boundaries, and political forces. However corridor boundaries should match the functional use of the corridor, reflecting patterns of movement between activity centres or major route junctions.

These boundaries and widths can be more efficient and cost-effective by using a GIS for defining georeferenced locations, storing attribute data, and displaying data on maps. As most corridor design documents are usually developed through computer-aided drafting and design software. CADD software is very versatile for graphic editing and design visualization but less capable for spatial analysis. Integrating CADD with GIS can allow integrated representation of the facility design and geographic setting, capturing interconnections among design elements and the physical environment. This will also allow generation of a common design document spanning length and boundaries of the corridor.

Most of the leading commercial GIS packages now provide functions for accessing CADD files in their native formats. Good practice is to develop consistent data models and standards for the corridor boundary and width which include coordinate system, map projection, geodetic datum and graphic symbols.

Task 1.2 Public Participation

The public includes anyone who resides, has an interest, or does business in a given area potentially affected by transportation decisions. This includes both individuals and organized groups. It is also important to provide opportunities for the participation of all private and public providers of transportation services, including, but not limited to, the trucking and rail freight industries, rail passenger industry, taxicab operators, and all transit and par-transit service operators.

The information contained in the spatial database is held in the form of digital coordinates, which describe the spatial features. These can be points (buildings), lines (streets and roads), or polygons (administrative regions). Normally, the different sets of data will be held as separate layers, which can be combined in a number of different ways for analysis. The attribute database is of a more conventional type; it contains data describing characteristics or qualities of the spatial features: number of households, type of road, population of the administrative regions. Thus, we could have corridor plan limits (polygons) and building either commercial/ public (points) effected by corridor plan in the spatial database, and characteristics of these features in the attribute database, for instance how many financial buildings are being effected.

The ability of GIS to physically overlay and perform analysis on selected criteria enables project designers to limit the impact to environmental sensitive areas. However, the potential that computing technology including GIS technology brings to the general citizens for public discourse remains largely untapped. In effect, maps are mostly used to only provide effective visual communication aids (e.g., large-format colour displays) for presentations to the public during public meetings.

The overlay function is handled differently for raster data and vector data. Raster data divides each map layer into a regular grid. When two map layers are overlaid to drive new information, the values of corresponding grid cells in the two map layers are evaluated. Vector data, on the other hand, assumes a continuous coordinate system. It requires comparing the coordinates of map features in two map layers to evaluate topological relationship.

The overlay type for the analysis of corridor public participation can be categorized as, polygon-on-polygon, line-on-polygon and point-on-polygon overlays. They are also know as topological overlay operations because they evaluate the connectivity relationship of map features between two GIS layers and generate a new GIS layer with the combined topology of the original two GIS layers. These procedures combine attribute data from both GIS layers into a single attribute table, which is very beneficial for public participation.

The ultimate objective of a GIS based decision support system for planning processes is, or should be, to improve planning and decision making processes by providing useful and scientifically sound information to the actors involved in these processes, including public officials, planners and the general public. This decision relevant information must be accurate in relation to the information requirements. This requires the use of state-of-the-art tools, methods, models and the necessary input data.

But on the other hand obtaining public input on long-range regional transportation plans has traditionally been limited to oral and written narrative communications, e.g. citizens speaking at public meetings and writing comment letters to planning agencies. Public participation has often been limited to narrative expressions of input and has excluded spatial ideas, e.g. citizen-drawn maps. Therefore web-based GIS are now able to offer spatial sketching as an additional means of public expression through on-line editing of spatial features.

4.2 GIS FOR EXISTING CONDITIONS OF THE TRANSPORTATION SYSTEM WITHIN THE CORRIDOR

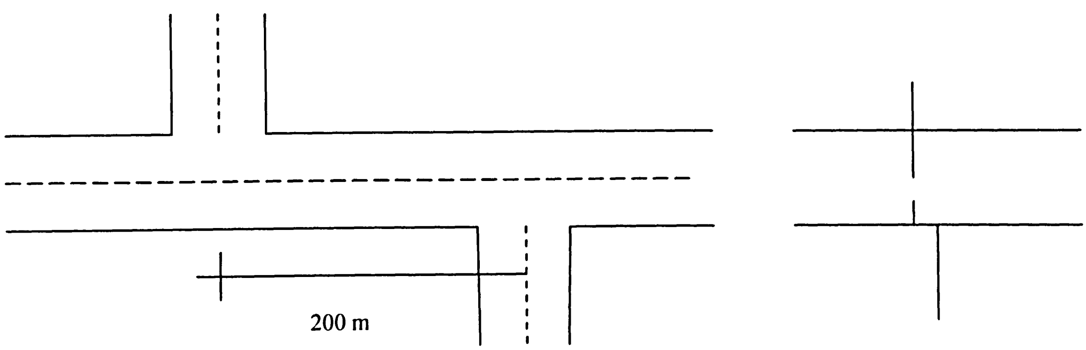
The purpose of this step in the process is to gather enough information to provide a complete picture of the existing transportation system within the corridor. These information forms the factual basis for analysis in the further process, i.e. how the existing transportation system can be expected to perform in future conditions. This information are very data intensive as they require detailed data files as well as characteristics of the network to be created by the transportation corridor planner. The major task under this domain consists of analysing the exiting transportation system in the corridor.

Task 2.1 Analysing the Existing Transportation System

Features related to any transportation corridor include identification markers, pickup/drop-off zones, adjacent structures, signals, signage, and monitoring devices. Associated corridor attributes include name or ID, facility type, geometry, capacity, restrictions, and material characteristics. Dynamic or time-dependent attributes include traffic volumes, deterioration conditions, and construction/maintenance activities. Spatial attributes include capacity, operational hours, and personnel/equipment information.

Information about transportation features can be stored as links to CAD drawings, aerial photographs, digital orthophotos, video images, and other multimedia formats. The spatial features regarding the existing transportation system include those relate to connectivity and continuity of the network and other link attributes (i.e., highway/street names, travel directions, number of travel lanes by direction, posted speed limit, and highway functional class).

Implementation of linear referencing systems (LRS) to GIS has been complicated as a number of different methods are employed by various jurisdictions. One of the aims of GIS and computer technology is to automate data input; hence, it is critical that linear referencing methods (LRMs) are clearly understood. Linear features commonly use an arc-node model where a node is an intersection where two or more arcs meet. For planning purposes, a single line is usually appropriate for representing a road with traffic in both directions. Divided highways are sometimes captured as two separate lines at very large scales (1:1000) or for purposes that require a separate feature for each direction of traffic. Nodes exist where roads intersect other roads, political and administrative boundaries, railroads, utility lines, water features, and canals. It is important to pay attention to the scale of the features. Two nodes, or intersections, may be mapped as one if they are too close to be distinguished at a small scale (Figure 13).



(a) (b)

Figure 13 (a) Real world situation. (b) Possible map representation

Linear referencing is the means of referring to and identifying a location on a linear feature. LRS use a name, direction, and a distance measurement from a known and marked location as the address for an object or an event. Different LRMs include route mile point, route reference post offset, street address, and dynamic segmentation. The route mile point method measures the distance from a known point, such as the place where the route crosses a county boundary, to the reference location.

Locations are listed with the name of the route or road, a direction, and the mileage from the known point. The route reference post-offset method uses posted signs to indicate known locations. Distances are measured from the reference posts and are recorded with the reference post number and a distance offset. Link-node models are similar to the reference post method but use intersections and other "node" areas such as the beginning of a bridge or a dead end as the reference points.

The above methods are very helpful to identify the attributes of any transportation corridor such as the direction, number of lanes, type of lane (e.g., normal, bus lane, carpool lane, etc.), pavement material and condition, and speed limit. But these characteristics vary for different road sections. Several methods have been developed for segmenting a transportation system into discrete roadway sections. One method is to store attribute data in fixed lengths of road. Characteristics of these segments reflect average or representative values in the section. Another method defines segments by a unique combination of roadway features. If an attribute changes, a new segment is created that includes the changes and the existing attributes from the old segment. Figure 14 explains what types of spatial attributes are required while analysing the existing transportation system.

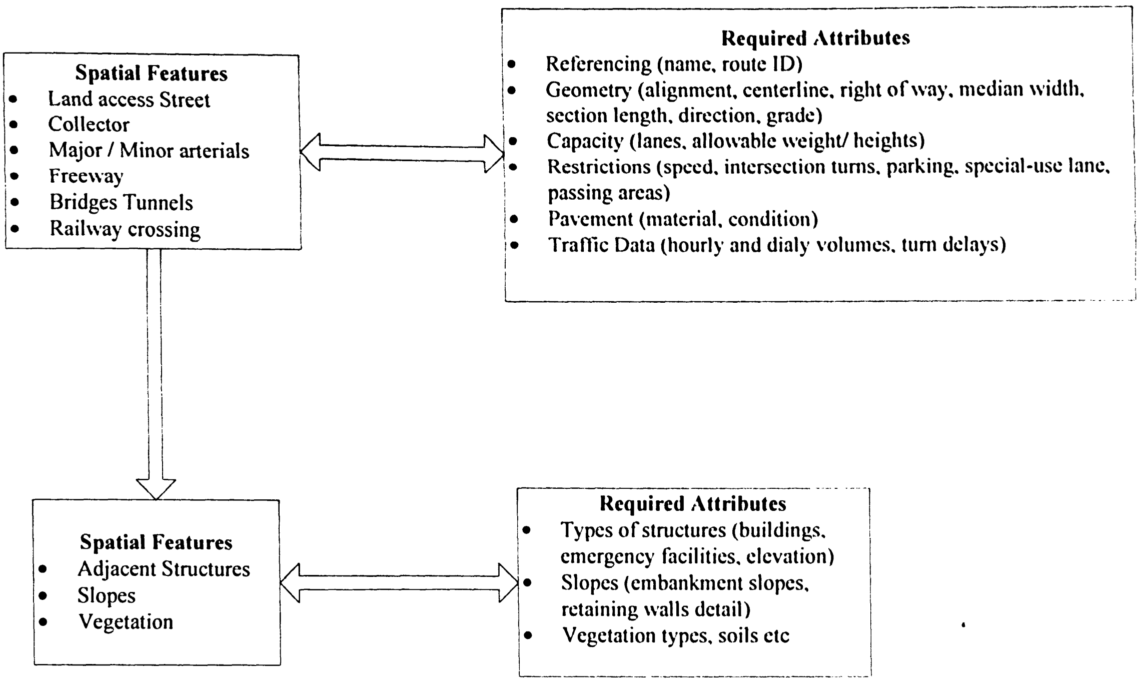


Figure 14 Existing transportation corridor and its spatial features

Dynamic segmentation in GIS involves the division or segregation of network links into segments that are homogeneous for the specified set of link attributes. The segmentation is dynamic because it is created in response to the current attributes of the network. If the attributes are changed, then "dynamic segmentation" will create a new set of homogeneous segments. The process first creates a route system that only contains to and from nodes, the length of the arc, unique ID, road name and address information. Descriptive or attribute information is associated with the route system by referencing distances from the starting point of each route. This is an event drive process that dynamically segments the roadway according to the natural breakpoints of the attribute in question. Dynamic segmentation has been introduced into GIS software in order to integrate and analyze link based transportation system attributes. For example in pavement management, the highway base map may be initially "dynamically segmented" by bituminous versus concrete pavement type so that each network segment only contains bituminous pavement or only concrete pavement. Specification of both pavement type and number of lanes as attributes for dynamic segmentation would result in network segments with the same number of lanes for each pavement type.

GIS based, multi-modal transportation application provides with an efficient and user-friendly storage, retrieval, maintenance, and updating system for the extensive existing transportation system within the corridor. Once the datasets are developed, these datasets provide a base map for performing transportation analyses and developing GIS applications.

4.3 GIS FOR EXISTING AND PROJECTED LAND USE CONDITIONS IN THE CORRIDOR

In any transportation corridor planning land use is critical especially for long-term forecasting and planning. Land use influences the magnitude and pattern of travel demand and travel demand influences future land use therefore it is impossible to separate land use from travel demand. Currently, the Lowry and related models, mathematical programming, multisector models and urban economics models are being developed for corridor planning.

Task 3.1 Land use and other Characteristics of the Region

The information is gathered about the region served by the corridor, in terms of its current and planned land uses and historical, cultural, environmental, social, and economic features. As this information can be used to identify issues that could impact corridor improvements. And also, land use, demographic and business data are the basis for demand forecasting analyses that help planners assess the need for transportation facilities. Urban planning is interconnected with transportation planning, and datasets such as zoning, property value, property vacancy, population, and travel statistics help produce current and projected population estimates for short- and long-term transportation planning.

Animations allow the urban spatiotemporal dynamics to be visualized and explored at varying levels of spatial and temporal resolutions. One of the rapidly emerging frontier that can greatly enhance the realistic quality of land use corridor model visualizations in 3-D GIS. This ability to create natural depictions of the urban environment at the human scale allows analysts and decision makers to assess and convey the human scale experience in an urban future. Users could manipulate virtual representations of themselves interacting and even interactively manipulate design elements in the urban environment.

Figure 15 given below provides the conceptual model for corridor 3-D GIS system.

Arrows indicate data and information flows. The system integrates data from traditional sources such as analog maps, GIS coverage, satellite imagery and aerial photography. Computer-aided design (CAD) software maintains 3-D architectural and urban design data. A semiautomatic classification process maps these data to the level-of-detail hierarchy. Thus the output from a GIS-based land use modelling system can be enhanced and visualized as a three-dimensional scene using CAD data representing current or imagined future architecture and design elements. This includes photo-realistic 3-D views with superimposed thematic data generating from analysis and modelling.

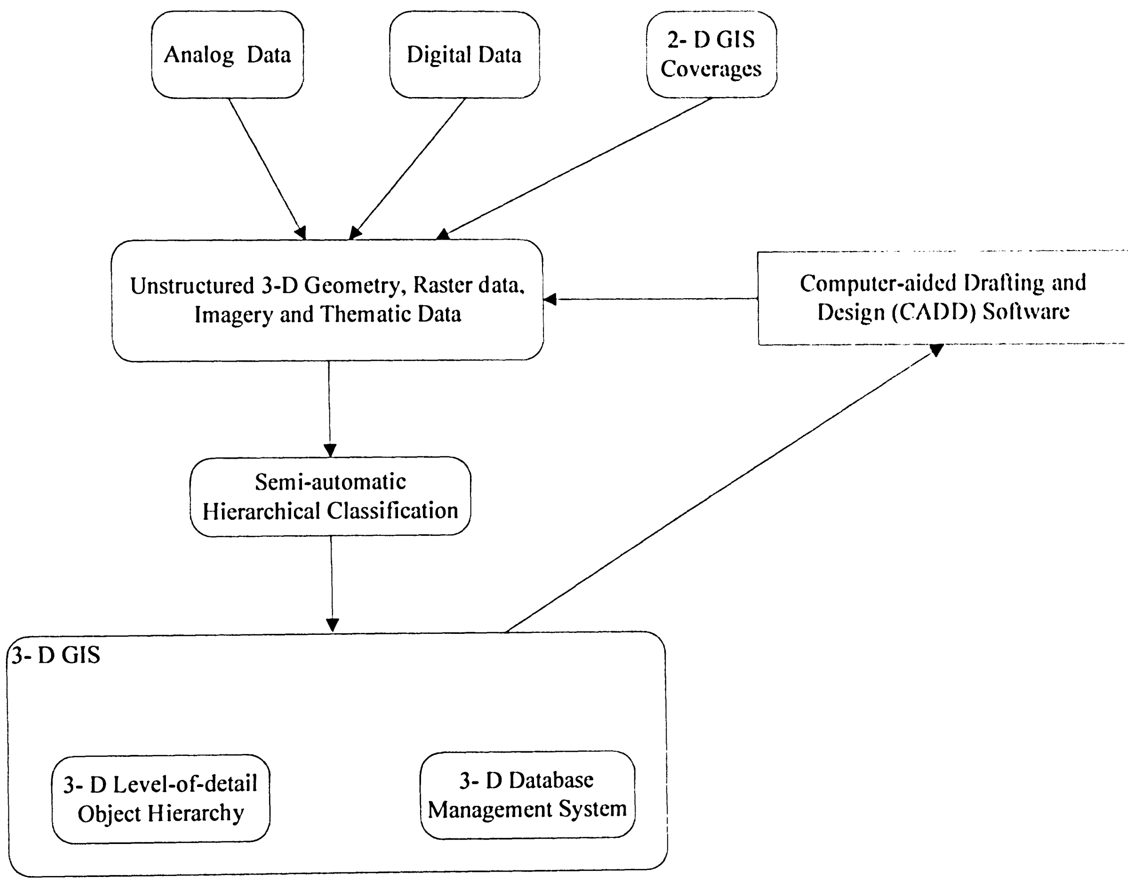


Figure 15 Conceptual design for a 3-D GIS

Basically, a GIS has the following functions which can support the analysis of any land-use transportation model;

- Visualizing and editing spatial data
- Creating and editing transportation networks with topology
- Analyzing spatial data using search and query tools

First, a GIS can be a useful database management system which can display and edit spatial data. Because most of currently available GIS use relational database technologies, it is easy to understand that a GIS can be an effective data inventory system in land use transportation corridor modelling. Sometimes necessary data acquisition becomes the most critical problem for land use transportation corridor modelling; adopting a GIS will alleviate a great deal of data inventory problems.

Second, GIS can alleviate the difficulties of transportation network generation. For a land use transportation corridor model, generating a transportation network is essential. However, conventional methods require very time consuming procedures. If a modeller desires to simulate a network in various ways by modifying an original network, conventional methods will be too slow to generate all the necessary networks for his/her models. Therefore, using a GIS as a network generator is very desirable in land use transportation corridor modelling.

Third, a GIS can be a successful spatial data analysis tool. A land use transportation corridor model produces a variety of outputs including future origin destination tables, link costs, volume per capacity (V/C) ratios, and so forth. Therefore, querying and searching functions are essential to analyze such abundant outputs in an efficient manner. Visualizing the results is the primary tool for spatial data analysis, and querying and searching functions are the secondary ones. In addition, it is obvious that an electronic map, which can be queried and searched, analyzes the outputs better than typical outputs of land use, which are usually in non-graphical, numeric forms.

GIS technologies can directly support the land use transportation corridor modelling by alleviating the labour intensive data preparation stage, i.e., data acquisition and management. Maintaining topology is another advantageous feature of GIS. By using the topological data structure, it becomes possible to implement the iterative partitioning technique for the TAZ generation subsystem in land use. One of the generic GIS functions, visualization function, is still valuable for many purposes. Eventually, GIS will be not only a database management tool, but also could be the base of the system integration, including required land use transportation corridor functions.

4.4 GIS FOR FUTURE TRAVEL DEMAND IN THE CORRIDOR

This is important phase of transportation corridor planning assessment of travel demand. Since demand is the basis for i) identification of suitable technology, ii) working out the supply requirement and iii) deriving various other components such as financial feasibility, system sustainability etc. Emphasis is given in this work to assess the travel demand. Future travel demand modelling is the utilization of a computer software package to replicate the "real world" transportation system around us (roads, intersections, traffic control devices, congestion delays, use of a transit system, etc.).

Future travel demand forecasting is a state-of-the-art analysis tool used in the transportation corridor planning process. Main objective is to simulate the current traffic volume and to forecast the future traffic volume on a transportation network. Travel demand modelling typically consists of the following tasks;

- Defining traffic analysis zones (TAZs) based on land-use characteristics
- Building the transportation network
- Collecting traffic data for calibration
- Performing the four-step traffic demand modelling process of trip generation, trip distribution, mode choice and trip assignment

Task4.1 Estimating Future Transportation Travel Demand in the Corridor

Travel demand models are used to predict changes in travel and utilization of the transportation system in response to changes in land-use, demographics and socio-economic conditions. In the conventional transportation corridor planning process, data collection is a major part of the work and converting them from different scales to the required scale is a time consuming process. The available data are in paper format with different departments and organizations; and, most of the time they do not meet the requirements due to variations in format. This problem is prevalent in most of the organizations. GIS is a preferred platform, because the data attributes are associated with topological object (point, line or polygon). In GIS, information is identified according to their actual locations. The graphical display capabilities allow visualization of different locations of traffic generators, network and routes. The use of GIS in transportation corridor planning will enhance the visualization aspect and facilitate the development of decision modules for use by the corridor planners.

Input data in GIS for travel demand modelling include a transportation network, TAZs, TAZ centroids, and centroid connectors. GIS can help build a transportation network from different data sources, such as road networks maintained by provincial or local transportation agencies.

TAZs usually follow available census data boundaries, such as census tracts, block groups, or blocks, so that data collected in the decennial census can be used with minimal manipulation. However, these census data boundaries are sometimes not well suited for analyzing proposed development sites. Tracts or blocks must then be split by community plan boundaries, zip code boundaries, and/or planned roadways.

The required spatial features also include the transportation network and related traffic data, zonal boundary files such as census tracts and blocks and associated socioeconomic data, and other layers on land use, hydrography, soil, and elevation. Increasingly, image data, such as digital orthophotos and satellite images, are most commonly used for TAZ in transportation corridor planning. GIS can help create a TAZ map interactively or automatically by overlaying the necessary boundary files and performing query and analysis of socioeconomic and land use data. To connect the transportation network with TAZs, it needs centroids and centroid connectors. Again, GIS packages offer commands and macro programming capabilities that can automatically define centroids and centroid connectors. GIS can be used to maintain and manage all map layers and their attribute data related to transportation corridor planning as long as the map layers are geo-referenced.

GIS also allows integration of data from different sources and different scales. It can also aggregate forecasted traffic data and produce cross-reference files between different levels of geography. The potential outcome from this process can be used as displaying tool for transportation data and model results. The graphic presentation is important for effectively communicating the results of any transportation model to the public and elected officials. GIS's query capabilities make it possible to quickly respond to questions that arise during meetings, and to focus attention on affected areas.

4.5 GIS FOR GENERATING ALTERNATIVES TO MEET THE CORRIDOR GOALS

Route alignment planning for a new highway corridor 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 transportation link and the evaluation of socio-economic and environmental impacts of different alternatives.

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 does not allow them to argue against political decisions. The generation of alternatives mainly involves two tasks described as follows:

Task 5.1 *Generating Preliminary List of Alternatives*

It is often desirable that the set of alternative corridor locations be spatially dispersed. Otherwise, the alternatives may not be judged substantially different by decision makers and stake holders. Methods for generating a good set of spatially dispersed alternative corridor locations using surface shortest path techniques include the iterative penalty method and the gateway shortest path problem.

A potential problem with finding alternative corridors using basic surface shortest path techniques is that the resulting corridors may not be physically feasible e.g. the geometric configuration of the corridor may prohibit vehicle travel due to sharp curves, steep inclines and so forth.

Another technique for generating multiple alternatives for the corridor is genetic algorithm. With the help of this technique we can generate a set of diverse but well-performing solutions to a problem rather than a single best solution. Combining genetic algorithm with multi criteria ranking techniques can be helpful to solve corridor right of way problem. Figure 16 shows criteria for generating alternatives for any corridor in general.

GIS allows evaluation of alternative corridors using buffer, overlay, interpolation and visualization techniques for summarizing and communicating solution attributes. The technique of surface shortest path problem can be used for generating alternative in transportation corridors. As this technique solves for a minimum cost path through a surface that often represent geographic space. We can solve this problem at a computational level using polygons or the regular square grid (RSG) and triangulated irregular network (TIN) surface models. One strategy is to generate solutions based only on cost and use multicriteria decision making. We could also incorporate other attributes at this stage by using suitability mapping with proper scaling to generate a pseudocost for each location, i.e., higher score implies lower suitability.

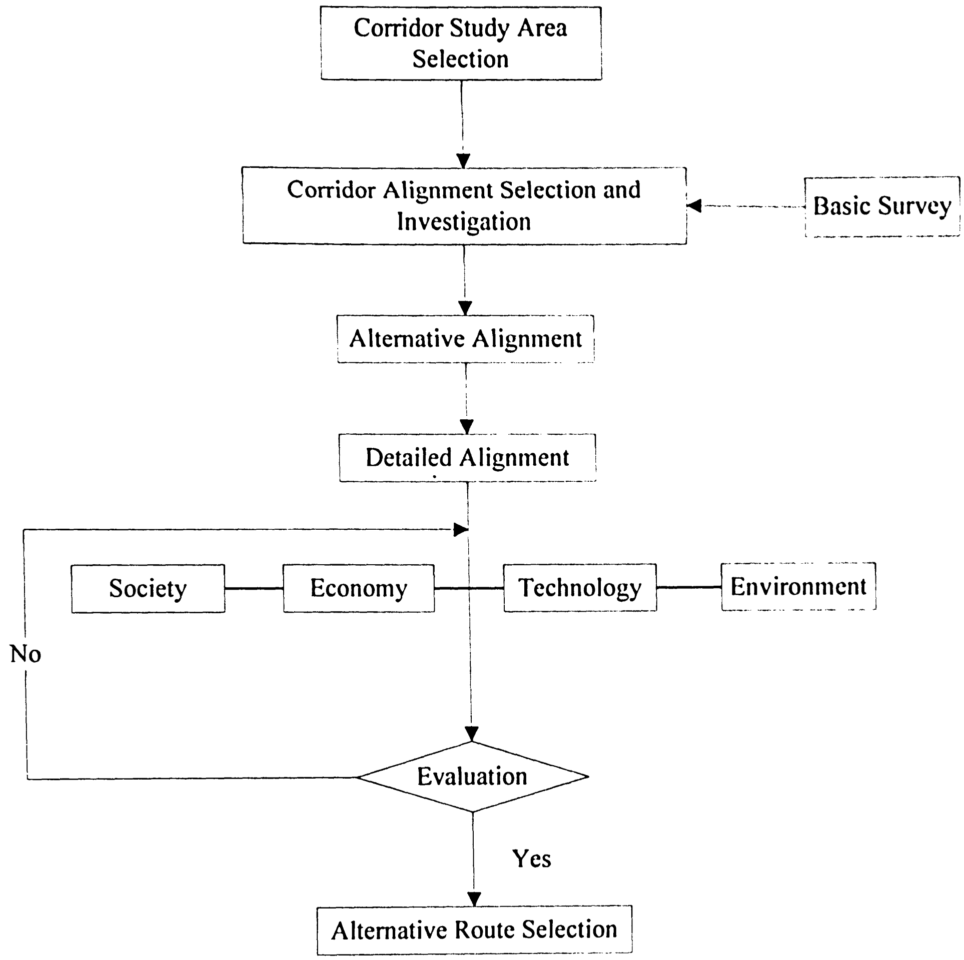


Figure 16 Generating various alternatives for corridor route plans

Task 5.2 Preparing Conceptual Maps of Potential Road Alignments

After developing various alternatives conceptual map for each alternative can be generated using displaying capacity and plotting function of various GIS commercial software.

4.6 IDENTIFYING FEASIBLE ALTERNATIVE USING GIS TECHNIQUES

The problem of selecting suitable highway corridor and the use of GIS as a decision-aid platform has been addressed by a number of practitioners and researchers; however, the number of criteria and the approaches they have adopted vary widely. For instance, it also depends on corridor priorities (e.g., traffic congestion, road safety, etc.)

Task 6.1 Screening Criteria

A decision-aid tool for route planners requires a comprehensive body of information. This information should be prepared in digital format, as a base model for the region of interest. The flowchart in Figure 17 describes the first phase of any GIS project: building the database. The data collection and digitization process is a critical and time-intensive stage. The database requirements are set as one of the objectives of the project at hand. The objectives include a definition of the study area boundary, the required data layers (coverages), the features required in each coverage, the attribute data needed for each feature type, and how to code and organize these attributes. Furthermore, a scale and base map projection are adopted for the whole dataset. It is evident that creating a geographically referenced database for a given region would require different types of data coverages depending on the type of analyses and applications anticipated. The GIS model can be thought of as a geographically referenced base consisting of data layers of various types (graphical features and attributes or associated descriptive properties). The required layers of information are application specific (engineering, agricultural, health science, and so on). The greater the number of data layers, the more complete the model is. However, for transportation corridors various route alignments, the important coverages are; political/administrative, existing roads, existing structures, land cover, land use, topography, rivers/streams, geology, soil, and depth to water table.

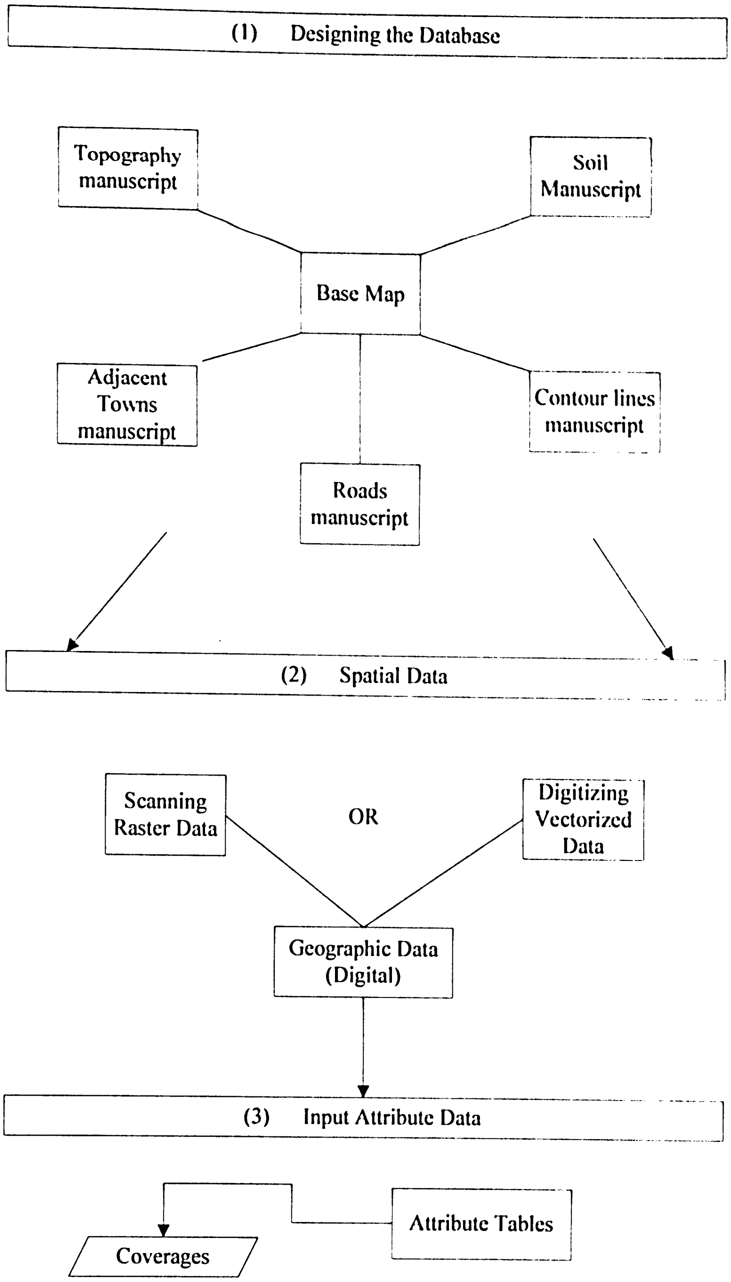


Figure 17 Process of building database

The database developed using the coverages specified earlier could be used to support a large number of transportation corridor applications. This tool provides the decision makers with a matrix of various criteria associated with any given alignment of his/her choice.

This decision aid tool is built for the ArcView GIS package [by the Environmental Systems Research Institute (ESRI)], and it integrates a specialized roadway design package (AutoCIVIL, by Research Engineers). The system engine and the interface environment is ArcView (ESRI).

The resulting analysis procedure can be broken down several distinct phases/steps. The user only needs to define the road alignment on the GIS model of the study area (by defining a series of points, interactively, using the mouse or by assigning particular coordinates). The rest of the analysis is automatically run. Once the alignment has been defined then final report is generated by itself. The following steps are required during this process;

- Identify the successive geology and soil formations underlying the road alignment selected by spatially intersecting the defined road alignment coverage with the geology and soil coverages.
- Perform cut and fill analysis using the proper Digital Terrain Model and the pertinent highway section geometry.
- Qualitatively interpret the data by classifying the generated cut and fill volumes into the various soil/geology functions.
- Identify, evaluate, and highlight potential slope stability problems along the road alignment at both edges of each cross section/station.
- Finally, a summary report table is produced.

GIS spatial analysis helps in locating the least-impact corridor between origin and destination, based on a minimization of the environmental impact defined in terms of population, fauna, flora, soil, water, air, and climate. It also helps in selecting the least risky route in the transportation of hazardous materials.

5. CONCLUSION

It was proposed in the beginning of this degree project (as described in Chapter 1) that the study was to: a) investigate the utilization of latest GIS tools documenting, control, and modelling of conceivable overall transportation corridor planning process; and b) show the potential and the possibilities to further improve transportation corridor planning process by applying GIS. Study was focused on Phase 1 and Phase 2, and in this context GIS was especially referred to eight steps in corridor planning process. From the project research, it has been observed that GIS can be helpful for some of the corridor planning process stages. The usage of GIS for these various steps is described in detail in Chapter 4 and the concluding remarks are summarized in the following.

Geographic Information System (GIS) represents a new paradigm for the organization of information and design of information systems, the essential aspect of which is the use of the concept of location as the basis for the structuring of information systems. The application of GIS has relevance to transportation corridor due to the essentially and spatially distributed nature of transportation corridor related data, and the need for various types of network level analysis, statistical analysis, spatial analysis and manipulation. Most transportation corridor impacts are spatial. In a GIS platform, the transportation corridor network databases can be generally extended by integrating many sets of its attributes and spatial data through its linear referencing system. Moreover, GIS can facilitate the integration of all other socio-economic data with transport network databases for a wide variety of planning functions.

The main advantage of using GIS is its ability to access and analyze spatially distributed data with respect to its actual spatial location overlaid on a base map of the area of coverage that allows analyses not possible with the other database management systems. The main benefit of using the GIS is not merely the user-friendly visual access and display, but also the spatial analysis capability and the applicability to apply standard GIS functionalities such as thematic mapping, charting, network-level analysis, buffering, simultaneous access to several layers of data and the overlayment of same, as well as the ability to interface with external programs and software for decision support, data management, and user-specific functions.

Combining the data collection, data analysis, and data presentation capabilities in GIS enables the transportation planners to share a collection of alternative improvement scenarios for transportation corridor. Traditionally, the non-spatial database does not allow the user to manipulate, access, and query it other than in a very limited way. The user is limited to textual queries only and the selection and viewing of crossing attribute data with respect to spatial and topological relationships is not possible. Data, such as land use, population, and the road network characteristics of the area in the crossings vicinity, cannot be accessed in the non-spatial database. The data integration ability of GIS, along with the analysis and final presentation of results on digital maps, allows the user a better perception of the problem, enables better decisions, and allows a better understanding of what is to be achieved in a broader sense.

Furthermore, the ability of most GIS software to provide many basic transportation models and algorithms may also be useful in specific situations. The ability to link to external procedures and softwares also provides flexibility, as these procedures can access data within the GIS and present the results of analysis to the GIS for viewing and analysis.

The geographic information system could be used as a tool for transportation infrastructure management in a way similar to its current applications in land-based information. GIS procedures provide a coordinated methodology for drawing together a wide variety of information sources under a single, visually oriented umbrella to make them available to a diverse user audience. GIS tools can be applied to aid technical and administrative specialists both in managing costly and intensively used resources and in supplying information to decision-makers.

6. REFERENCES

Arampatzis, G., Kiranoudis, T., Scaloubacas, P. and Assimacopoulos, D., *"A GIS-based decision support system for planning urban transportation policies"* European Journal of Operational Research 152 (2004) 465–475

Apparicio, P., Shearmur, R., Brochu, M. and Dussault, G., *"The Measure of Distance in a Social Science Policy Context: Advantages and Costs of using Network Distances in Eight Canadian Metropolitan Areas"* Journal of Geographic Information and Decision Analysis 2003, Vol. 7, No. 2, pp. 105 – 131

Alterkaw, M., *"Application of GIS in Transportation Planning: The Case of Riyadh, the Kingdom of Saudi Arabia"* GBER Vol. 1 No. 2 2001 pp 38-46

Arnstein, S. *"The Ladder of Citizen Participation"* Journal of the Institute of American Planners Vol. 35, No.4. 1969, pp. 216-224.

Agrawal, L. and Dikshit, K., *"Significance of Spatial Data and GIS for Environmental Impact Assessment of Highway Projects"* Indian Cartographer, 2002

Allen, E. and Morgan, H., *"Web-Based Public Editing of Spatial Scenarios: The 'Paint the Region' Experience"*

Banger, S., *"Integrating GIS with web for public participation"* Map Asia 2002
Schroeder, P., *"GIS in Public Participation Settings"* University Consortium for Geographic Information Science (UCGIS) June 15 - June 21, 1997

Bailey, K. *"AMIS: Development and Application of a GIS/Multicriteria Corridor Evaluation Methodology"* Map Asia Conference 2003

Bates, C. and Schwetz, T., *"The Key to a High Quality, Sustainable GIS"*

Beimborn, E., *"Land-Use and Environmental Considerations"* Transportation Research Circular E-C015: Statewide Transportation Planning, Centre for Urban Transportation Studies, University of Wisconsin-Milwaukee

Budic, N., *"Geographic Information Science Implications for Urban and Regional Planning"* URISA Journal, Vol. 12, No. 2, Spring 2000

Blaschke, T., *"Participatory GIS for Spatial Decision Support Systems Critically Revisited"*

Boile, P., *"Intermodal Transportation Network Analysis – A GIS Application"*

Balamohan, N., *"Enterprise GIS approach for urban transportation planning"* GIS development 2001.

Balamohan, N., and Matwi, A., *"Travel Desire between Municipalities and Doha"* ESRI 1999 Vol. 14, pp 109, ESRI, USA.

Ceccato, A., *"Adapting GIS Technology to the Needs of Local Planning"*

Charkraborty, J., Schweitzer, L. and Forkenbrock, D., *"Using GIS to Assess the Environmental Justice Consequences of Transportation System Changes"* Transaction in GIS, 1999, (3): pp. 239-258

El-Shair, M. *"GIS and Remote Sensing in urban transportation planning: A case study of Birkenhead, Auckland"* Map India Conference 2003

Evaluation of Alternatives *"Alternatives Analysis and Draft Environmental Impact Statement for I-285 Corridor"* The Atlanta Regional Commission Report, April 2004

Feeney, B., *"Corridor Planning in Wisconsin: A Work in Progress"* Wisconsin Department of Transportation

FHWA *"Transportation Case Studies in GIS: Portland Metro, Oregon –GIS Database for Urban Transportation Planning"* Publication No.FHWA-PD-98-065

FHWA (a), Transportation Case Studies in GIS, *"Maine Department of Transportation Statewide Travel Demand Model"* September 1998 No. 4

FHWA (b), Transportation Case Studies in GIS *"SANDAG's Multiple Species/ Habitat Conservation Programs and Transportation Planning"* November 1998 No.5

FHWA Priority Technology Program, *"Transportation Planning GIS"* Publication No. FHWA-PT-96-IA (01) February 1997

FHWA, TCSP Program: Report July 21, 2004

Francek M. and Frankovich J., *"Using GIS Technology to Help Plan Future Growth in Union Township, Michigan"* The Great Lakes Geographer, Vol. 8, No. 1, 2001

"GIS Solutions for Urban and Regional Planning Designing and Mapping the Future of Your Community with GIS" A Report by ESRI Solution

Grossardt, T., Bailey, K. and Brumm, J., *"Structured Public Involvement: Problems and Prospects for Improvement"* Transportation Research Board, Washington, D.C., 2003 Annual Meeting

Gupta, P., Jain, N., Sikdar, K. and Kumar, K., "Geographical Information System in Transportation Planning" Map Asia Conference 2003

Haklay, M. and Harrison, C., *"Public Participation GIS in the UK and the USA: A Cross Cultural Analysis"*

Harrison, C., *"The Potential of Public Participation GIS In UK Environmental Planning: Appraisals by Active Publics"*

Harris, T. and Weiner, D., "*GIS and Society: The Social Implications of How People, Space, and Environment are represented in GIS*" NCGIA Technical Report, Santa Barbara, California, 1996

Husdal, J., "*The vulnerability of road networks in a cost-benefit perspective*"

Idaho Transportation Board "*Idaho Corridor Planning Guidebook*" 1998

Kaufman, L. and Cain, C., "Public Involvement: Paving the Way to Success"

Keeney, R., "*AMIS: Least Cost Path Analysis for Transportation Planning*"

Khatib, Z., Ou, Y., and Chang, K., "*GIS and Transportation Planning*"

King, L. and O'Hara, G., "*A Synthesis of Remote Sensing Applications for Environmental Assessment*" National Consortium on Remote Sensing in Transportation - Environmental Assessment

Klosterman, E., "*The What If? Collaborative Planning Support System*" Environment and Planning and Design Conference, 1998, pp. 393-408

Krek, A., "*Rational Ignorance of the Citizens in Public Participatory Planning*" Conference proceedings of CORP 2005, Vienna

Liu, R., Cheng, P., Liu, K. and Zou, S., "*Core Techniques and Products of Digital Photogrammetry and Remote Sensing for Urban Infrastructure*" IAPRS, Volume XXXIV, Part 2, Commission II, Xi'an, Aug.20-23, 2002

Maine Department of Transportation, "*Maine DOT Statewide Travel Demand Model*"1998.

Miller, H.J. and Shaw, S., *"Geographic Information Systems for Transportation: Principles and Applications"* by Oxford University Press (ISBN 0195123948), 2001

Miller, H.J. and Storm, J.D., *"Geographic Information System Design for Network Equilibrium-Based Travel Demand Models"* Transportation Research Record, Vol. 4, pp. 373-389, 1996

Miller, H.J., Hung, M. and Wu, Y., *"A GIS based Decision Support System for Analysis of Route Choice in Congested Urban Road Network"* Transportation Research Record, 2001(3) pp. 3-24

NCHRP, Guidebook for Transportation Corridor Studies: *"A Process of Effective Decision-Making"* Report 435.

North Metro I-35W Corridor Coalition Subregional Growth Study *"Land Use and Transportation Analysis"* June 2002

Obermeyer, J., *"PPGIS: The Evolution of Public Participation GIS"* Transportation Research Board, Washington, D.C., 2000Annual Meeting

O'Hara, G. and King, L., *"Digital Data Libraries of Geospatial Data and Information Products for Transportation Assessment and Planning"* National Consortium on Remote Sensing in Transportation and Environmental Assessment

O'Hara, G. and Hearne, P., *"Remote Sensing and Spatial Information Technologies for Transportation Decision Making"* Remote Sensing in Transportation and Environmental Assessment Mississippi

Papacostas, S. and Cliffs, E., *"Fundamentals of transportation engineering"* N.J: Prentice-Hall, c1987.

Papacostas, S. and Prevedouros, D., *"Transportation engineering and planning, Third Edition"* Upper Saddle River, NJ: Prentice Hall, c2001.

Raza, S. and Darren, J. "Spatially Enabled Pipeline Route Optimization Model" International Pipeline Conference Proceedings 2004, Alberta, Canada

Sadek, S., Bedran, M. and Kaysi, I., *"GIS Platform for Multicriteria Evaluation of Route Alignments"* Journal of Transportation Engineering April 1999

Schulte, J., *"Utilizing GIS to Facilitate Public Participation in Access Management Issues"* National Planning Conference 1999

Schuman, G., Strauss, T., Gieseman, D. and Souleyrette, R., *"Iowa Department of Transportation Statewide Coordinated GIS"* 1998 Transportation Conference Proceedings

Souleyrette, R. and Anderson, D., *"Developing Small Area Network Planning Models Using Desktop GIS"* Journal of Urban Planning and Development / June 1998

Talaat, A., *"Towards a Spatial Decision Support System for Route Alignment Planning In Egypt"* 42nd Congress of the European Regional Science Association (ERSA), Dortmund, August 2002

Uddin, W., "Evaluation of Airborne *LIDAR Digital Terrain Mapping for Highway Corridor Planning and Design"* Land Satellite Information Commission Conference 2002

Vermal, A. and Dhingra, L., *"Optimal Urban Rail Transit Corridor Identification within Integrated Framework Using Geographical Information System"* Journal of Urban Planning and Development, ASCE / June 2005

Weiner, D., Harris, M. and Craig, J., *"Community Participation and Geographic Information Systems"*

You, J. and Kim, J., *"An Integrated Urban Systems Model with GIS"* Journal of

Geographical Systems, 1999, p: 305-321

Zhang, X., *"Using Genetic Algorithms to Generate Alternatives for Multi-Objective Corridor Location Problems"*