King Fahd University of Petroleum & Mineral

Civil Engineering Department

(Geographic Information Systems - GIS)

Term project

USES OF GIS in URBAN TRANSPORTATION PLANNING AND MANAGEMENT

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Abstract

General purpose of GIS is extracting information/knowledge from the raw geo-data. The rawdata is collected from sensors, satellites or any other ways and stored in databases or file systems. The data goes through the filtering and rendering services and, presented to the end users in human recognizable formats such as images, graphs, charts etc. A well-known example of GIS is map viewers which process layers of geospatial data to create map images. GIS are used in a wide variety of tasks such as urban planning, resource management, emergency response planning in case of disasters, crisis management and rapid response etc.

Over the years, Geographic Information Systems (GIS) technology has been implemented for a variety of purposes within the transportation industry. With this have come many new uses, benefits, and challenges. This paper tried to show the capacity of GIS to support transportation planning and management. The objectives of this paper are threefold: (1) to describe advances in geographic information systems, (2) to discuss applications of GIS in the planning and management of urban transportation systems, and (3) to discuss requirements, applications and benefits of GIS applications in urban transportation and management.

In this project I will cover several parts. First of all I will provide an introduction to the overall topic and I will describe advances in GIS as an efficient, flexible and reliable planning method. Also, I am going to cover applications of GIS in urban transportation planning and management. In addition, I will support my paper by case studies. Finally, conclusions are presented, with a focus on how cities in developing countries can benefit from the application of GIS in urban transportation planning and management.

1. Introduction

In the context of this paper, Geographic Information Systems (GIS) is defined as "a system of computer hardware, software, and procedures designed to support the compiling, storing, retrieving, analyzing, and display of spatially referenced data for addressing planning and management problems. In addition to these technical components, a complete GIS must also include a focus on people, organizations, and standards. A similar definition is provided by the U.S. Federal Highway Administration. Canada is a world leader in early innovations in GIS. The Canadian GIS, the first known mainframe based operational system, was developed for Environment Canada in the 1960s.

Increasing number of Canadian urban areas is benefiting from GIS initiatives. Also, GIS is enabling the application of smart (sustainable) development concepts and Intelligent Transportation Systems. Most transportation agencies now use GIS and Geospatial Information Systems for Transportation (GIS-T) is one of the largest users of GIS technology. The significant innovation that GIS provides is the ability to manage data spatially in layers and then overlay these layers to perform spatial analyses. Therefore, a roads layer can be integrated with a land use layer enabling a buffer analysis of the land uses within a given distance of the road. The capabilities of GIS have improved over the past three decades, and GIS now provide a wide range of tools for data management and analysis. In the early 1990s, GIS added specific tools for linear data management of transportation data that has proved to be extremely successful among transportation organizations. These capabilities enable transit agencies to georeference their bus routes, stops, time points, and other features to a digital street centerline file, and keep all these data in synch.

This paper describes advances in geographic information systems and discusses applications of GIS in the planning and management of urban transportation systems. Additionally, it discusses requirements, applications and benefits of GIS in urban transportation planning and management in the cities of developing countries.

2. Objectives:

Generally, GIS is a new technology effective tool which can be used at wide range areas and different departments. In transportation GIS can be used in many functions. As a civil engineer (Road engineer), I am interested to know how GIS can be used and what is its applications on my field. In addition to that I am willing to use GIS in future applications in urban transportation. So, to reach my goal in using GIS, first I have to perform a search on applications of GIS in my field of interest.

The objectives of this paper are threefold:

1. To give an idea about the elementary concepts of GIS such as definition of GIS, Benefits of GIS, Urban applications of GIS, and to review GIS applications in transportation planning and management.
2. To describe advances in geographic information systems.
3. To discuss applications of GIS in the planning and management of urban transportation systems.
4. To discuss requirements, applications and benefits of GIS applications in urban transportation and management in developing countries.
5. To show the contribution and the practical application of GIS in transportation field through some case studies and discuss the main findings from each study.

3. Limitations and Constraints

Actually there are some limitations and obstacles faced me when preparing this term paper such as:-

- Applications of GIS in urban transportation planning are relatively new.
- Papers published don't give enough information; a searcher must pay money to get the best papers.
- I tried to fix the idea by making a small project but I didn't get data.
- The data is not available to do the projects.
- The field is really complicated and sometimes I faced difficulties of understanding some GIS technical terms because of my recent knowledge of GIS.

4. Methodology

As is well known GIS has acquired tremendous importance in various applications. In general GIS technology can be used in any application has a spatial phenomenon.
I will concentrate my paper on many steps as follows:

a. I will discuss the important concepts of GIS in urban transportation.
b. Submit some papers about GIS applications in transportation planning and management.
c. I will discuss the advances of GIS used in this area such as using internet GIS in transportation is also reviewed.
d. I will support my paper by case studies.
e. Each case study is followed by a discussion includes the findings from the study.

5. Literature Review

5.1 Definition of Geographic Information System (GIS)

Geographic Information Systems (GIS) is a collection of computer hardware and software for capturing, analyzing, managing and displaying all forms of geographically referenced data.

General purpose of GIS is extracting information/knowledge from the raw geo-data. The raw data is collected from sensors, satellites or any other ways and stored in databases or file systems. The data goes through the filtering and rendering services and, presented to the end users in human recognizable formats such as images, graphs, charts etc. A well-known example of GIS is map viewers which process layers of geospatial data to create map images. GIS are used in a wide variety of tasks such as urban planning, resource management, emergency response planning in case of disasters, crisis management and rapid response etc.
The advantages of GIS in data documentation and processing include.

- Quick updating of information
- Integration of information by linking spatial and attribute data
- Spatial analysis
- Automated cartography
- Production of maps at different scales and
- Visualization.

5.2. Benefits of GIS

The following are some of the GIS's benefits:

- Integrating Geographic Information for display and analysis within the framework of a single consistent system.
- Allowing manipulation and display of geographic knowledge in new and exciting ways.
- Automating Geographic Information and transferring them from paper to digital format.
- Linking location and attributes of feature(s) within the framework of one system.
- Providing the ability to manipulate and analyze Geographic Information in ways that are not possible manually.
- Automation of map making, production and updating.
- Providing a unified database that can be accessed by more than one department or agency.
- Storing Geographic Information in coincident and continuous layers.

5.3. GIS Objectives

The main objectives of the GIS are:

1- To maximize the efficiency of decision making and planning
2- Provide efficient means for data distribution and handling.
3- Eradication of the duplicated data, integration of information from many sources.
4- Analysis of queries involving geographical reference data for generation of new information.
5- Update data quickly and at the minimum cost.

5.4. Components of GIS

The components of a GIS system intended for application in urban transportation planning and management, commonly referred to as GIS-T, include: technology (hardware, software), data capture & integration, users and their requirements, and finally institutions.

The figure below shows the components of GIS.

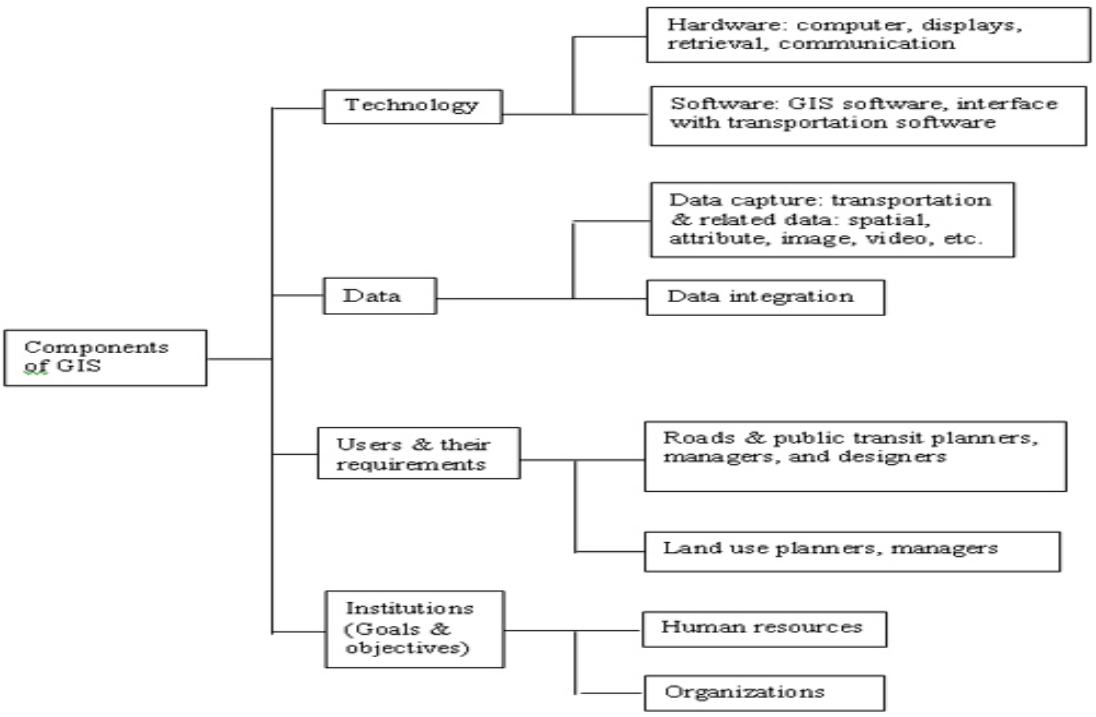

Figure (5.1): component of GIS

5.5. Factors Affecting the Use of GIS in Urban Transportation Planning and Management

The factors that affect the adoption of GIS in urban transportation planning and management include:

- The knowledge base of City employees and consultants regarding the capabilities of GIS.
- Technological advances encompassing both hardware and software.
- The cost of hardware, software and operations, and organizational factors.

The figure below illustrates the linkages between these factors and the requirements for the use of GIS in urban transportation.

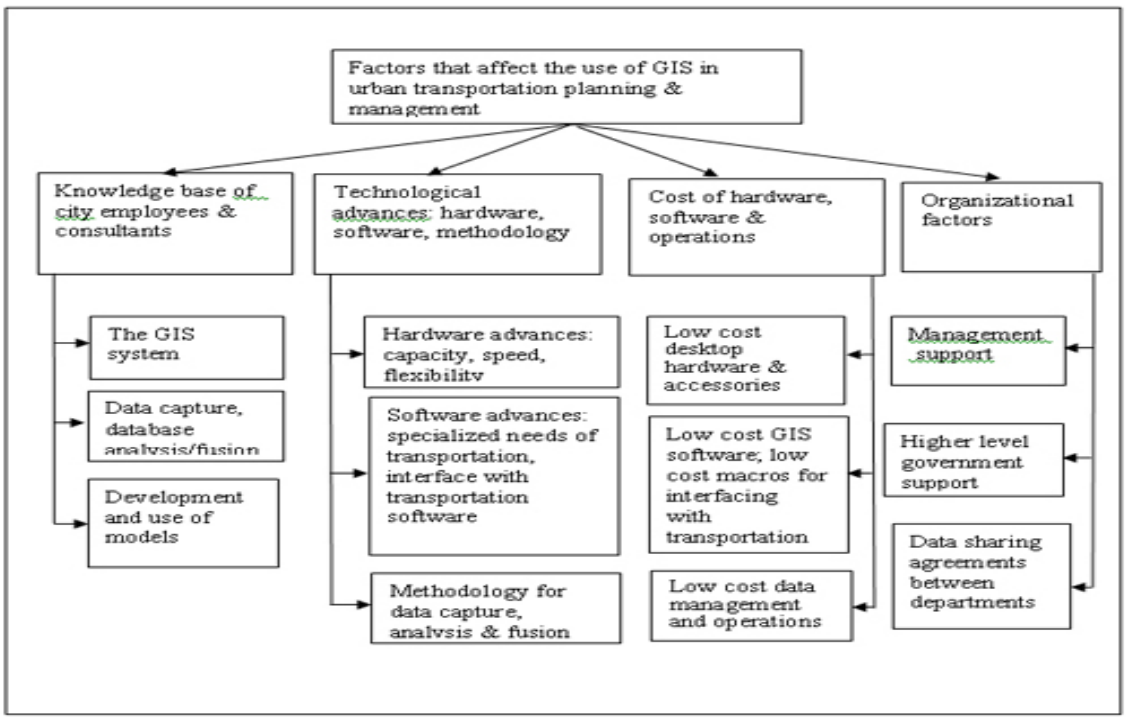

Figure (5.2): factors affecting on GIS

5.6. Advances GIS in Transportation Planning

GIS, is an efficient and cost-effective tool for planning and management. There are four components of the GIS.

- Technology (hardware, software),
- Data capture and integration,
- Users and their requirements, and
- Institutions

Over the years, there has been much progress in all facets of GIS-T, and a wide variety of applications have emerged. A number of notable GIS and related advances have paved the way to its application in urban transportation. These are:

- Data capture methods.
- Spatial integration technologies, technology platforms.
- GIS as a platform for modeling transportation systems.
- Web technologies, and organizational facilitators.

Data capture/entry involves manual digitizing and scanning, as well as the use of photogrammetric stations, coordinate geometry, global positioning system (GPS) receivers, digital cameras, satellite sensors, radar sensors, and thermal infra-red

imaging devices. The integration of disparate data is carried out in the form of direct conversion of data from one system to another, and translation of data via standardized neutral exchange file formats.

5.7. Use of GIS in Transportation Management

According to the growth number of vehicles in countries, especially in an urban country there are many problems will face the people such as, traffic jam, choking, and congestion. However every care has to be taken to see that these 'necessities' do not become a bane in day to day life. Since 'Transportation Management' is a spatial phenomenon GIS can be used as an effective tool in Managing and Planning transportation. In This paper I will focus on how GIS can be used effectively to manage and plan Transportation and make commuting easier in an urban setting.

5.7.1 Need for transportation management:

The growth of any urban area is driven by two factors. The first one is being, the establishment of Businesses which open up tremendous employment opportunities. The secondly is the large influx of people to the urban areas. This results in large number of people commuting from a large number of residential pockets, to the Central Business Districts where majority of the business establishments are located.

5.7.2. Methodology:

There are many Technologies can be used to manage the problems in the transportation.

Automatic Vehicle Location (AVL) Technology is very popularly and effectively used for fleet management.

GPS it is possible to use the same AVL technologies, to track any Vehicle that is just out of the assembly line. Also there are vehicles fitted with the GPS and has a centralized traffic control room to view and analyse the location of every vehicle on the road. This centralized traffic control room can have many computer terminals, each of them concentrating on viewing and analyzing the Vehicular traffic at the

important junctions, roads of the city which has a large flow of traffic. The system used to know the average number of vehicles plying on each road on a daily basis.

This data stored in a database and used in very activities of traffic planning and management. All important data like the number of Vehicles on each road, information about the roads where there are jams and the details of alternate roads that can be taken can be displayed on huge electronic sign boards that can be installed at important traffic junctions, roads and even on the internet. Another way of keeping the users updated is by making use of the radio with traffic updates at some time intervals. The following figure shows briefly the previous steps.

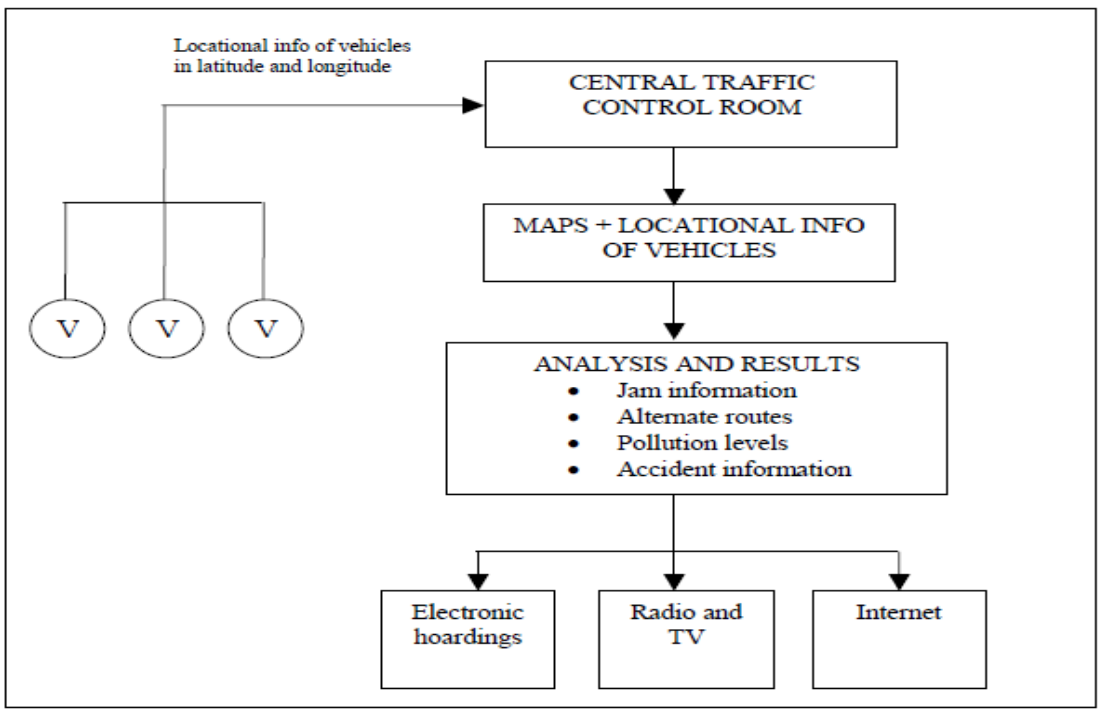

Figure (5.1): component of GIS

5.8.3. Benefits of GIS on transportation management

Transportation management can be managed effectively using the GIS technology. Following are the benefits of effective transportation management

1- Ease of traffic movement.
2- Lesser time on roads.
3- Reduced tempers while driving.
4- Increased Personal safety.
5- Effective transport planning.

6. Applications of GIS in Urban Transportation

A variety of applications of GIS in urban transportation planning and management have been reported. Some of these applications include:

- Transportation master plans and Site plans

Multimodal transportation planning (e.g., travel demand forecasting)

- Public participation and Scenario development/visioning
- Asset management systems including infrastructure maintenance management.
- Safety management including accident analysis.
- Transportation system control and management (TSC-TSM)
- Corridor preservation/right of way.
- Construction management and Hazardous cargo or overweight/oversize vehicles permit routing.
- Environmental impacts.

A GIS-T can perform a broad range of transportation planning and management tasks in a cost-effective manner. It can be used for building transportation information systems for applications such as sign inventories, accident analysis, physical distribution of goods, operations planning, etc. In the context of urban and regional transportation, GIS supports the analysis of a range of network types, including street, subway, rail, bus, highway, and multimodal networks. For example, conventional travel demand models are unable to accurately account for travel on local streets. This is a major deficiency of using such models to estimate vehicle emissions. This deficiency is overcome by the use of GIS.

7. Urban Transportation Planning

The second application of GIS-T to developing countries is urban transportation planning in a GIS environment. The key capabilities and analytical procedures of GIS-T described earlier can be used for effective transportation system analysis; including modeling .GIS-T has the ability to enhance transportation planning by supporting the development and application of travel demand models, providing tools to study demand-supply interaction, and facilitating system evaluation.

In the development of land use databases, traffic analysis zones and districts are built and information is geo-coded for manipulation within the GIS. In addition to present land use data, future projections of these information items (consisting of land zoning, population, employment, dwelling units, commercial and other buildings, etc.) can also be included in the databases. Information on existing and proposed transportation systems is also organized within the GIS-T framework.

In general, trip generation models can be estimated and applied at any spatial scale, even at the level of a parcel of land. Information can also be aggregated to the zone level. To support the modeling process, travel survey data and forecast origin destination trip tables can be geo-coded as well.

Likewise, improved modeling techniques can be supported with the GIS-T environment. In the following description of the planning process, the details of GIS development are omitted since the steps are conceptually the same as in the case of infrastructure management.

Other planning applications that relate to transportation can be developed. These are: zoning/redistricting, transit vehicle routing & scheduling, distribution logistics, site location, garbage collection, and school bus routing and para-transit service. Through the analytical support provided by a GIS-T, shortest paths can be found that minimize distance, time, or cost. In the case of dangerous goods movements, routes can established that minimize population exposure to toxic spills/fumes.

8. Case Studies

8.1. Case Study1: Application of GIS in Transportation Planning: The case of Riyadh, the Kingdom of Saudi Arabia.

This study was done by Arriyadh's Municipality to assessment the role of GIS in transportation planning in Saudi Arabia. Arriyadh is the largest city in KSA.

The main aim of this study is to identify deficient facilities (i.e., tolerable, moderate, moderate to heavy and heavy road deficiencies) in the vital area within Riyadh's ring road. The deficiency analysis process is utilized to highlight streets where demand exceeds capacity. Incorporating the link volumes resulting from the travel demand forecasting into the network attribute table in GIS. For the short range planning, it will illustrate the usage of GIS in identifying projects on the network using dynamic segmentation, and preparing network link tables for travel demand planning. Moreover, the integration of GIS into the travel demands analysis process is to identify future areas of congestion. Shortest path and travel time allocation of major activity centers analyses are also investigated.

The Figure below shows the steps of this study.

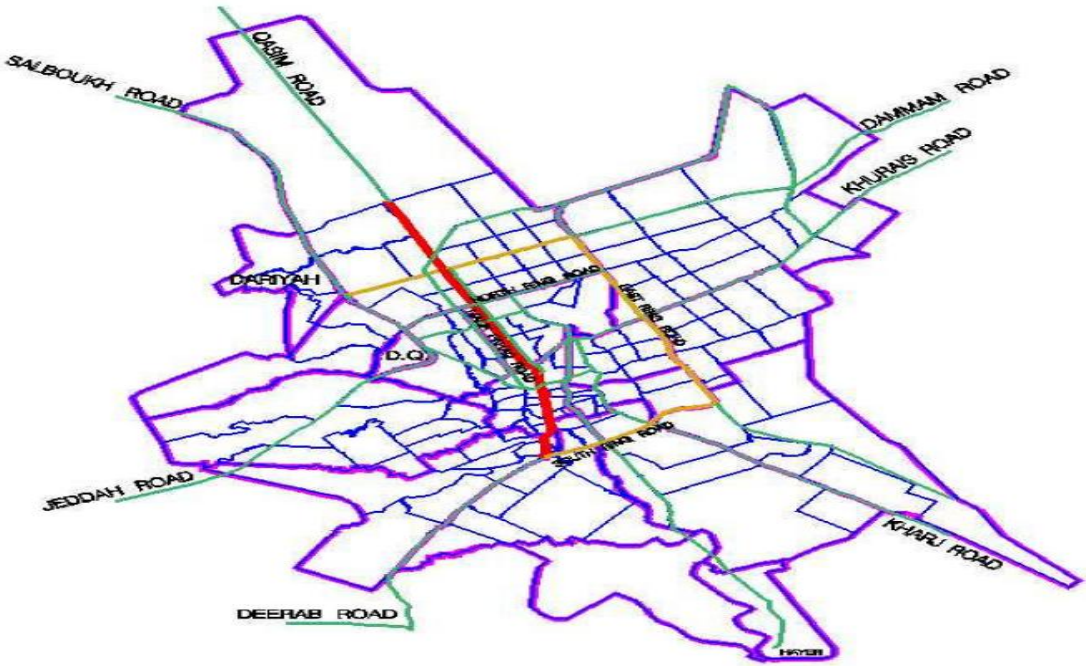

Figure (8.1): Road Network for the capital city of Riyadh

Discussion

The GIS applications in urban transportation planning have been developed in transportation agencies in Saudi Arabia, particularly in Riyadh. GIS packages have been used in Riyadh's municipality and its sub-municipalities. However, not all capabilities of GIS are utilized

The deployment of GIS applications in transportation planning has been taking its way in the transportation agencies in Saudi Arabia, particularly in Riyadh. GIS packages have been used in Riyadh's municipality and its sub-municipalities. However, not all capabilities of GIS are utilized. Therefore, still GIS application does not have major role in the transportation planning process in Saudi Arabia. Also, there is a lack of published projects that show the use of GIS in this field. Local data are not readily available; more efforts are exerted from different organizations to create their own data. Moreover, some GIS data and services are distributed on the internet. ADA has developed a site allows its visitors to brows some browsing Riyadh map, they can search for streets or locations, besides some services.

8.2. Case Study2: Analysis of Urban Planning Using GIS Techniques: the case of Hamad Town, Kingdom of Bahrain

This case study is to study the urban planning of Hamad Town by observing the town planning from the establishment till the present. The study also produced two maps showing the land use in Hamad Town for the years 1989 and 2006 to calculate the efficiency of every category. Finally the study analysed the topographic maps and the aerial photographs, in order to further investigate urban planning problems and provide suggestions and solutions for better urban planning and management.

8.2.1. Study Area

Hamad Town is located in the South of Manama Island in the Kingdom of Bahrain. It occupies an area of approximately 13.12 km2. Hamad Town was an arid land surrounded by Riffa highway and the oil pipe lines from the north, Awali highway from the east, Zallaq village and Bahrain University from the south and Dumistan from the west. It is located on high ground (30 m over the sea level). Hamad Town land is far away from the natural and artificial pollution resources. It takes the linear model from the north to the south.

8.2.2. Methodology and the use Data .

The study used the followed data:

1. Data and statistics reports, gathered from various Ministries and organizations in the Kingdom of Bahrain.
2. Old aerial photograph for Hamad Town (1989) to define the initial conditions for the study.
3. Topographic Map of Hamad Town for the years 2006.

Digital topographic map for the year 2006 in dgn format was provided by the Central Municipality. This map has been edited by using (Microstation) software to separate the land use categories into different layers. After separating every layer on this software it was possible to convert all the land use layers to the (Arc GIS) soft ware.

The aerial photographs were geo-referenced to the map. Land use features not present from the GIS attribute tables you can see the land use categories.

By using (Arc GIS) software every land use category percentage was calculated to see if the land use percentage is within the ideal percentage or not. The study also analysed the land use maps and the road network to show the efficiency of the road.

The two generated land use maps show the urban planning development of the town, as well as, the land use categories, which include:

- Housing, Roads and transport.
- Educational services.
- Infrastructure and government buildings.
- Health services.
- Historical Area and Recreational facilities.
- Religious buildings and Commercial.

8.2.3. Analysis

The proposed land uses in the study area include all land use types typically found within a town plan. The objective of this analysis was to calculate the efficiency of each category. This percentage will show if the land use category percentage is suitable or not by comparing these percentages with the percentages according to the urban planning theory. After analysing the town urban planning development, a statement can be making regarding the degree of success of the town

planning. The analysis also can measure the town planning success and suggest a future decisions and recommendations.

Urban planning of Hamad town for the year 1989 shows the following.

1. The housing percentage was small.
2. The road network was not completed in Hamad Town in 1989.
3. There were only four land use categories in the town (housing, educational services, transport network and historical area).
4. The main services in Hamad Town such as (infrastructure, recreational services, mosques and government buildings) did not as yet exist.

Urban planning of Hamad town for the year 2006 discusses the following.

1. The housing percentage is very high and over than the ideal percentage.
2. The road network was not efficient in Hamad Town in 2006 due to this the town facing the high density roads.
3. The land use categories became eight and included the main services such as (infrastructure, recreational services, mosques and government buildings).
4. The numbers of mosques is very few for this number of people.
5. The residential area has encroached the historical area.

8.2.4. Hamad Town road network analysis

The analysis of the road network is very important in urban planning analysis because if the network is not efficient it will causes environmental, economic and social problems. Hamad Town road network can be classified under the Circular Connection Network (minor arterial- as shown in figure below). In this network there are several paths that connect b to d. These paths have different lengths; however, bd is the shortest.

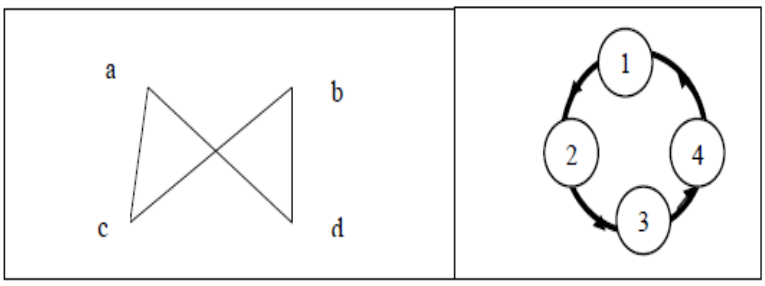

Figure (8.2): Circular Connection Network.

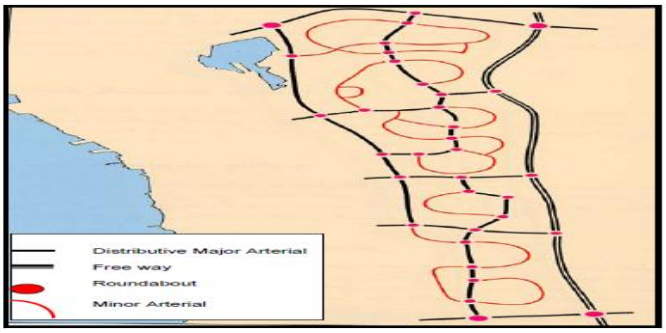

Figure (8.2): Hamad Town Road Network

8.2.5. Discussion

According to the study above and the results the following action must be taken:

a. Establish new blocks around Hamad Town to reduce the pressure on the land.
b. Evaluate of road network to improve access and establish the external and 11 circular roads. Furthermore, to advocate measures to be implemented to avoid traffic passing in the town centre.
c. Follow the proposed planning.
d. Build GIS Data Base for the town for better urban planning and management.

8.3. Case Study 3: Transportation system management for Madurai city using GIS

The transportation system management measures, needs a clear view of the flow patterns, locations to be able to analyze the attributes related to them .GIS helps to do these things effectively and efficiently.

8.3.1. Introduction

According to the lack of financial resources it becomes necessary to find data to the traffic planners. There is only one option to the traffic planner to provide improved accessibility and mobility at a satisfactory level of safety and comfort to most of the road users.

8.3.2. The Study Area

Madurai is the second largest City in Tamilnadu State. It has three National Highways namely NH-7, NH-45B, NH-49 and state highways passing through it. The study area is limited to Madurai Local Planning Area (LPA). The land use details of the urban and rural settlement of the Local Planning Area are given in Table below.

Sl.No	Land use zone	Area (ha)	Percentage of developed area
1	Residential	1817.60	74.89
2	Commercial	41.42	1.70
3	Industrial	76.76	3.16
4	Educational	99.50	4.10
5	Public and semi-public	181.79	7.48
6	Transportation	212.38	8.74

From the land use data above it show that Madurai has highly congested. The area for transportation infrastructure is less than ten percent of the developed area leading to transportation problems in the LPA .Transportation system management measures have feasibility to solve this problems during the present and the future condition of Madurai LPA road network as discussed below.

8.3.3. GIS Based TSM

8.3.3.1. Forecasting the Traffic

The traffic volume growth is forecasted according to the vehicle growth rate and the sample survey conducted at different locations. Based on the registered vehicle data collected from the Regional Transport Office Madurai North and South the growth rate of each type of vehicle is calculated. It has been taken the forecasting growth for the three National Highways during the peak hour as show below.

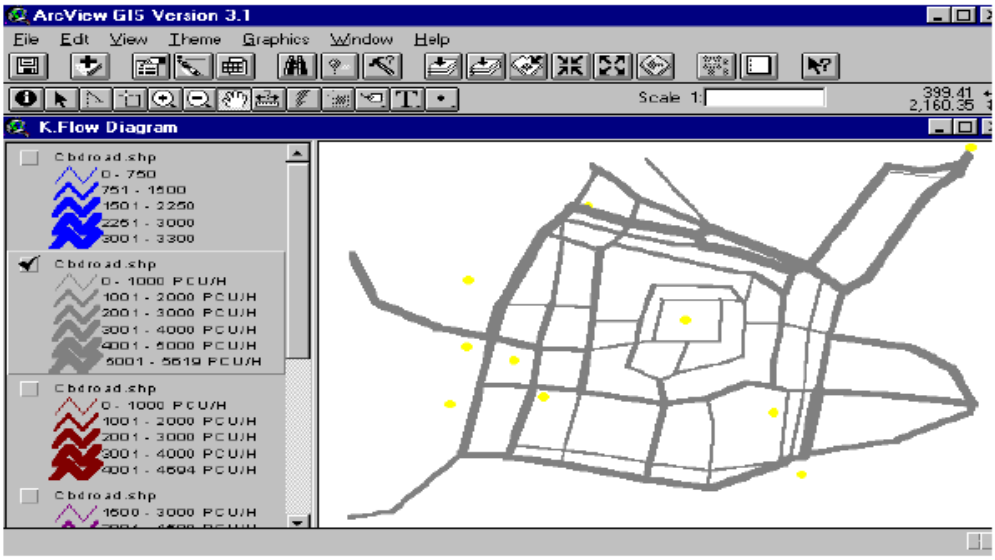

Figure (8.3): Peak Hour Traffic Flow in CBD

8.3.3.2 Conversion of One-way Streets

According to the study of traffic volume above it show that South Veli and East Veli Streets are identified as highly congested. From that the maximum peak hour composition in each direction is found out and assigned to the roads by comparing their capacities. The transportation system management has solved these problems by conversion the existing two-way streets to one-way streets.

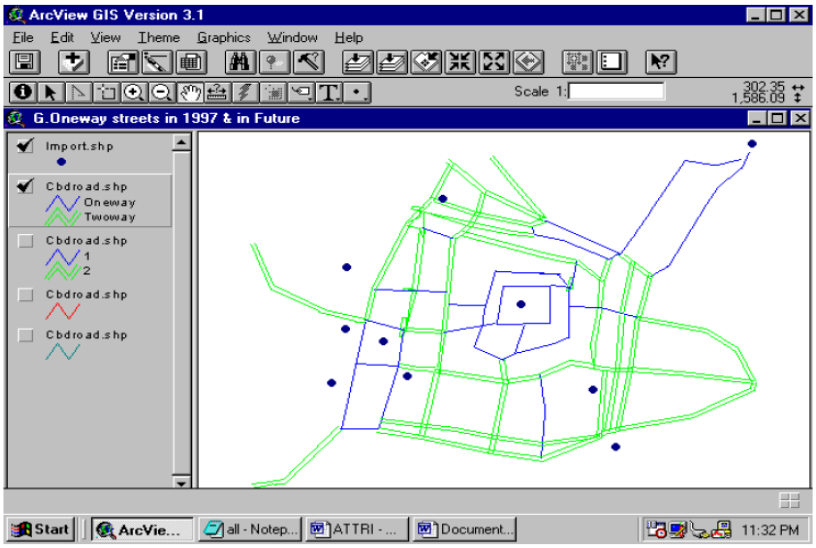

Figure (8.3): Before Introduction of One-way Streets in Madurai CBD

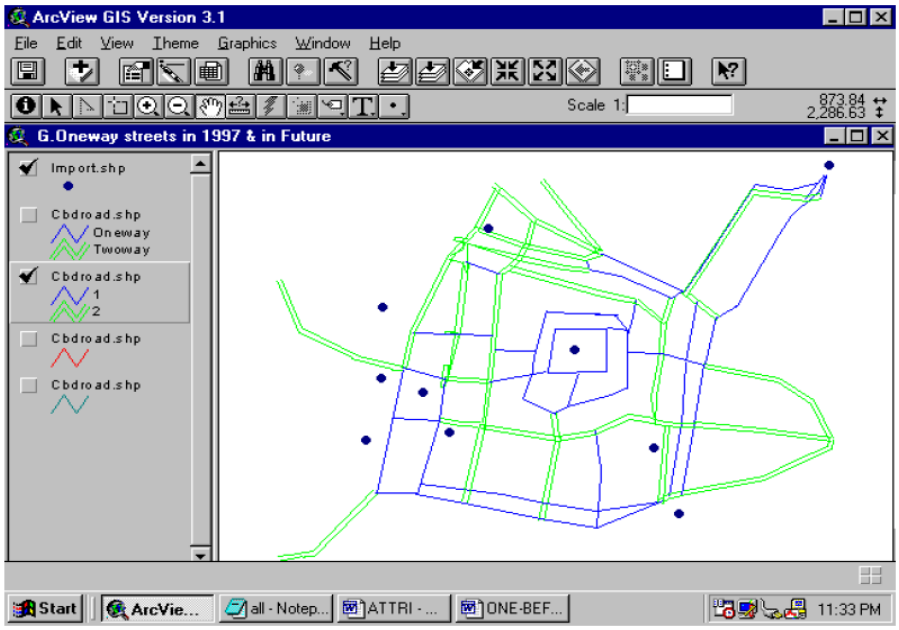

Figure (8.3): After Introduction of One-way Streets in CBD

Also, the reduction in the V/C Ratio and improvement in the whole network was studied. By running the Avenue script and selecting the required LOS from the list, the links falling under that category will be selected as shown below.

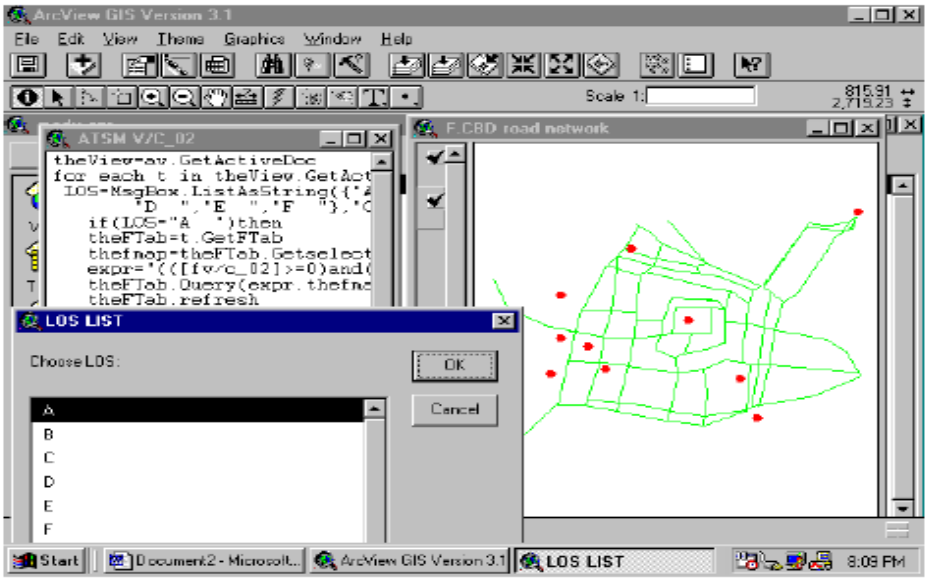

Figure (8.3): Peak Hour Traffic Flow in CBD

8.3.3.3. Other TSM Measures

There are other TSM measure should be taken in account in Madurai city for example Parking Management and diversion traffic.

The effect of V/C ratio for city road network due to One-way streets, Parking Management System and Diversion of Traffic is presented in Table below.

TSM Measures	Effect for the year 2002		Effect for the year 2007	
	Before	After	Before	After
One-way Street	0.94	0.74	1.89	1.15
Parking Restriction	1.02	0.81	2.14	1.45
Diversion of Traffic	1.24	0.80	2.74	1.79

Analysis shows that the overall V/C ratio is less than 0.81 for the present condition. But for the year 2007 the overall V/C ratio is greater than 1.15. Hence the long-term TSM measures such as widening of roads and construction new roads may be implemented to reduce the congestion in the future.

8.3.4. Discussion

From the studies a mention above TSM has used ArcView GIS 3.1 to solve the problems faced on road network .As result, ArcView GIS helps the planner to choose the roads that has to be considered for the upgrading in the present and in the future traffic conditions. Also, ArcView GIS helps to obtain clearer and accurate results. In addition, ArcView GIS reduces the amount of paper maps and data that could be used in absence of ArcView GIS.

8.4. Applications of GIS to urban planning and management: The case study in Japan

This paper tried to study the applications of GIS to Urban planning and management in Japanese local government. It shows Problems in the use of GIS in local government.

It also, discusses GIS utilization, especially focusing on urban planning and management in Japanese local government.

The writer divided GIS applications in the urban planning and management into three categories.

- Inquiry on the content of urban plan decision:
- Register management.
- Planning.

In this paper District diagnosis system using GIS performed two analyses in Ichikawa City.

1. The calculation of area and ratio for land-use.
2. The measurement of land-use purity.

GIS can calculate the degree of purity (namely occupancy rate) of specified land-use in the land-use zoning system.

Finally, this paper discuses various issues in the use of administrative GIS.

8.5. GIS a Tool for Transportation Infrastructure Planning in Ghana: A Case Study to the Department of Feeder Roads

This paper reviews the suitability of Geographical Information System (GIS) which was used as a pilot phase project in the Northern Region of Ghana to improve the decision making process in this area for better use of the available limited funds. It is also, reviews the suitability of GIS technology for managing the transport infrastructure in Ghana. This study covers many parts of using GIS in transportation management in Ghana.

9. Conclusions

Although there is a broad application of GIS in transportation, there is a lot of value to GIS that is not yet being fully explored in transportation analysis and planning .The following are some recommendations for the improvement of the GIS applications in transportation:

- GIS is becoming broader based in geospatial information systems that include the application of the global positioning system and the integration of remote sensing technology.
- The use of GIS in historical data analysis, such as trends in automated passenger counts, boarding's and lightings, and demographic analysis of transit passengers.

- The implications of data exchange standards.

GIS is becoming broader based in geospatial information systems that include the application of the global positioning system and the integration of remote sensing technology.

The benefit of GIS on transportation management as follows:

- Data analysis.
- The implications of data exchange standards.
- The costs and benefits of GIS in transportation projects are hidden and difficult to define within budgets and organizational arrangements.
- Improving communication of GIS-T programs and exchanging information about what is happening in the GIS-T sector.

10. References

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