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NEEDS FOR TRANSPORTATION PLANNING AND MANAGEMENT IN NIGERIA USING GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT: *Transportation is the act of transporting or the state of being transported; conveyance; often of people, goods, etc, while planning stands as the act of formulating of a course or courses of action, or of drawing up plans or programes for future events or activities. Geographic information system is a survey tool used to capture, store, query, analyze, manage and display geographic information/data (Kang-Tsung Chang, 2002). Geographic information system (GIS) technology has the ability to integrate common data base operations such as query and statistical analysis with unique visualization and geographic analysis. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting out comes and planning strategies. The objective of this article is to articulate the success of geographic information system applications in transportation planning. The methodology applied was the administration of questionnaires by stratified sampling to major stake-holders in GIS and transportation technology such as surveyors, traffic warden staff, road safety staff, police, some members of the national union of road transport workers, some staff of the Ministry of Transport (including the vehicle inspection officers), Staff of State Security services (SSS) and transportation planners. Secondary information were also obtained from books, journal articles and conference papers. The use of computer and some software made the research simpler. The results of the observations and analysis show that the centralized traffic control room can be made use of, to effectively manage the traffic. Information about the number of vehicles on each road, where there are jams and alternative roads can be displayed on electronic signboards installed at important traffic road junction. The discussions so far show that the use of GIS for transportation management is ideal and has come to stay universally, and so should be adopted in Nigeria.*

KEYWORDS: Transportation, Management, Geographic Information System, Traffic.

INTRODUCTION

In a broad sense a Geographic Information System (GIS) is an information system specializing in the input, management, analysis and reporting of geographical (spatially related) information. Among the wide range of potential applications of GIS transportation, issues have received a lot of attention. A specific branch of GIS applied to transportation issues, commonly labeled as GIS-T, has emerged.

Geographic Information Systems for Transportation Planning refers to the principles and applications of applying geographic information technologies to solve transportation problems (Didigwu, 2010)

GIS application for transportation planning research can be approached from two different directions. While some research focuses on issues of how GIS can be further developed and enhanced in order to meet the needs of transportation planning applications, other research investigates the questions of how GIS can be used to facilitate and improve transportation studies. In general, topics related to GIS transportation studies can be grouped into three categories:-

(i) **Data representations:** How can various components of transport systems be represented in transportation planning?.

(ii) **Analysis and Modeling:** How can transport methodologies be used in a GIS transportation?.

(iii) **Applications:** What types of applications are particularly suitable for transportation planning?.

Data Representations

Data representation is a core research topic of GIS. Before a GIS can be used to tackle real world problems, data must be properly represented in a digital computing environment. One unique characteristic of GIS is the capability of integrating spatial and non-spatial data in order to support both display and analysis needs. There have been various data models developed for GIS. The two basic approaches are object-based data models and field –based data models.

(i) An object-based data model treats geographic space as populated by discrete and identifiable objects. Features are often represented as points, lines, and/or polygons.

(ii) On the other hand, a field-based data model treats geographic space as populated by real-world features that vary continuously over space. Features can be represented as regular tessellations (e.g., a raster grid) or irregular tessellations (e.g., triangulated irregular network – TIN).

GIS transportation studies have employed both object-based and field-based data models to represent the relevant geographic data. Some transportation problems tend to fit better with one type of GIS data model than the other. For example, network analysis based on the graph theory typically represents a network as a set of nodes interconnected with a set of links. The object-based GIS data model therefore is a better model for such transportation planning applications. Other types of transportation data exist which require extensions to the general GIS data models. One well-known example is linear referencing data (e.g. highway mileposts). Transportation agencies often measure locations of features or events along transportation network links (e.g. a traffic accident occurred at the 52.3 milepost on a specific highway). Such a one-dimensional linear referencing system, that is linear measurements along a highway segment with respect to a pre-specified starting point of the highway segment) cannot be properly handled by the two-dimensional Cartesian coordinate system used in most GIS data models. Consequently, the dynamic segmentation data model was developed to address the specific need of the transportation planning. Origin-destination (O-D) flow data are another type of data that are frequently used in transportation studies. Such data have been traditionally represented in matrix forms (i.e. as a two-dimensional array in a digital computer) for analysis. Unfortunately, the relational data model widely adopted in most commercial GIS software does not provide adequate support for handling matrix data. Some GIS transportation software vendors therefore have developed additional file formats and functions for users to work with matrix data in a GIS environment. The above examples illustrate how the conventional GIS approaches can be further extended and enhanced to meet the needs of transportation planning applications.

In recent years, developments of enterprise and multi-dimensional GIS transportation data models also received increasing attention. Successful GIS deployments at the enterprise level (e.g., within a state ministry of transport) demand additional considerations to embrace the diversity of application and data requirements. An enterprise GIS transportation data model is designed to allow “each application group to meet the established needs while enabling the enterprise to integrate and share data”. The needs of integrating 1 dimensional, 2 dimensional, 3 dimensional and temporal data in support of various transportation planning applications also have called for the implementation of multi-dimensional (including spatio-temporal) data representations.

In short, one critical component of GIS is how transportation-related data in a GIS environment can be best represented in order to facilitate and integrate the needs of various transportation applications. Existing GIS data models provide a good foundation of supporting many GIS transportation applications. However, due to some unique characteristics of transportation data and application needs, many challenges still exist to develop better GIS data models that will improve rather than limit what we can do with different types of transportation studies.

Geographic Information System Transportation Analysis and Modeling

GIS transportation applications have benefited from many of the standard GIS functions (query, geo-coding, buffer, overlay, etc) to support data management analysis, and visualization needs; like many other fields, transportation has developed its own unique analysis methods and models. Examples include shortest path and routing algorithms *e.g. traveling salesman problems, vehicle routing problem), spatial interaction models (e.g. gravity model), network flow problems (e.g. minimum cost flow problem, maximum flow problem, network flow equilibrium models), facility location problems (e.g. p-median problem, set covering problem, maximal covering problem, p-centers problem), travel demand models (e.g. the four-step trip generation, trip distribution, modal spilt, and traffic assignment models), and land use-transportation interaction models.

While the basic transportation analysis procedures (e.g. shortest path finding) can be found in most commercial GIS software, other transportation analysis procedures and models (e.g. facility location problems) are available only selectively in some commercial software packages. Fortunately, the component GIS design approach adopted by GIS software companies provides a better environment for experienced GIS transportation users to develop their own custom analysis procedures and models.

It is essential for both GIS transportation practitioners and researchers to have a thorough understanding of transportation analysis methods and models. For GIS transportation practitioners, such knowledge can help them to evaluate different GIS software products and choose the one that best meets their needs. It also can help them select appropriate analysis functions available in a GIS package and properly interpret the analysis results. GIS transportation researchers, on the other hand, can apply their knowledge to help improve the design and analysis capabilities of GIS transportation.

GIS TRANSPORTATION APPLICATIONS AND MODELING

GIS Transportation Applications

GIS transportation is one of the leading GIS application fields. Many GIS transportation applications have been implemented at various transportation agencies and private firms. They cover much of the broad scope of transportation and logistics, such as infrastructure planning and management, transportation safety analysis, travel demand analysis, traffic monitoring and control, public transit planning and operations, environmental impacts assessment, intelligent transportation systems (ITS), routing and scheduling, vehicle tracking and dispatching, fleet management, site selection and service area analysis, and supply chain management. Each of these applications tends to have its specific data and analysis requirements. For example, representing a street network, as centerlines may be sufficient for transportation planning and vehicle routing applications. A traffic engineering application, on the other hand, may require a detailed representation of individual traffic lanes. Turn movements at intersections also could be critical to a traffic engineering study, but not to a region-wide travel demand study. These different application needs are directly relevant to the GIS transportation data representation and the GIS transportation analysis issues discussed above. When a need arises to represent transportation networks of a study area at different scales, what would be an appropriate GIS transportation design that could support the analysis and modeling needs of various applications? In this case, it may be preferable to have a GIS transportation data model that allows multiple geometric representations of the same transportation network. Research on enterprise and multi-dimensional GIS transportation data models discussed above aims at addressing these important issues of better data representations in support of various transportation applications.

With the rapid growth of the Internet and Wireless communications in recent years, a growing number of Internet-based and Wireless GIS transportation applications can be found. People to get driving directions frequently use web sites such as Google Maps and Map quest. Global Positioning System (GPS) also are available as a built-in device in vehicles or as a portable device. With the aid of wireless communications, these devices can offer real-time traffic information and provide helpful location-based services (LBS) (e.g., finding the closest ATM location based on the current traffic conditions). Another trend observed in recent years is the growing number of GIS transportation applications in the private sector, particularly for logistic applications. Since many businesses involve operations at geographically dispersed locations (e.g., supplier sites, distribution centers/warehouses, retail stores, and customer sites), GIS transportation can be useful tools for a variety of logistics applications. Again, many of these logistics application are based on the GIS transportation analysis and modeling procedures such as the routing and the facility location problems.

GIS transportation is interdisciplinary in nature and has many possible applications. Transportation geographers, who have appropriate backgrounds in both geography and transportation, are well positioned to pursue GIS transportation studies.

GIS Transportation Modeling

There is a powerful synergy between GIS and transportation modeling systems. By using GIS with a transportation-modeling package, it is possible to extend modeling capabilities and open up new possibilities for development using, and maintaining transportation data.

Arc-Info can be used to store, edit, display, and plot a simulation network, both before assignment and after. Before a simulation is run, Arc-Info can make maintaining simulation networks easier in many ways. Using software such as the Arc-Tools, Arc-Info can manage a whole range of simulation networks by maintaining a base network and tracking projects that will change that network over time. By maintaining one network rather than many, problems of network tracking, documentation, and consistency are eliminated. Also, Arc-Info provides a range of powerful network editing tools that are simply unavailable in most modeling packages. Arc-Info also provides a powerful way to display model results. Since you are not limited to using straight-line approximations of street geometry, it is possible to combine modeling data with existing GIS data and annotation utilizing Arc-Info's rich set of cartographic tools. Also, it is possible to conduct further analysis of transportation data in Arc-Info using the Network and GRID modules. For example, you can develop a comprehensive urban air quality model combining both stationary and mobile emission sources to highlight areas of potential violation of air-quality standards.

It is because of the complimentary strengths of transportation models and GIS systems that it is only logical to use them together to create a powerful set of modeling tools. Once established, such a system can simply network maintenance and reduce errors while at the same time extending both the analytical and display capabilities of existing travel forecasting models.

Several State Departments of Transportation have begun to utilize Arc-Info and Arc-View with transportation models. In some cases the GIS is simply used to display the model results with other GID datasets as a backdrop. In more sophisticated applications, such as the **Southern California Association of Governments**, Arc-Info is used to update and manage the network as well as display the model results. In SCAG, the model networks are integrated with the Thomas Brothers Street centerline files so that assigned flows are displayed on real streets. This helps the modelers to validate model output and identify local inconsistencies, caused by network coding errors or the wrong location of zone centric connectors.

GIS can also play a useful role in organizing inputs to other stages in the travel demand forecasting process; examples include compiling data in Traffic Analysis Zones for trip generation, formatting the zonal data into trip tables for trip distribution modeling and organizing mode choice data by geographic area as part of mode split analyses.

Arc-Info does not provide off-line-shelf application tools for transportation modeling and most applications require the user to develop their own application bridges between the GIS and the simulation model. Most users have found Arc-Info 9.2 the best environment to develop these tools with Arc-View as a GUI to display the results with other data for non-GIS specialist staff.

The burgeoning number of vehicles in the country, especially in an urban setting that are choking the cities in Nigeria is the **main concern of the Government as well as the Urban transportation Planners.** The reasons for this are many.

With the education and technical know how of many Nigerian citizens the large Nigerian middle class has that extra money to afford 'necessities' (vehicles being one of them) which was considered as a 'luxury' not very long ago but today an essential service.

However every care has to be taken to see that these 'necessities' do not become a bane in day-to-day life. This calls for an effective transportation management in an urban setting. Since 'Transportation Management' is a spatial phenomenon, **GIS can be used as an effective tool in Managing and Planning transportation.**

This article gives a comprehensive insight as to how GIS can be used effectively to manage and plan transportation and make commuting easier (if not pleasure) in an Urban setting.

Reasons for GIS Transportation Management

The growth of any urban area is driven by two factors. Firstly being the establishment of businesses which open up tremendous employment opportunities, and secondly 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.

On an average an urban commuter in Lagos spends about 2-3 hours everyday on the roads to reach the work place, school or home where as a decade back the same distance would have been covered in about half the time as that of now. Considering the exponential growth of the number of vehicles and the ever-increasing population the situation is bound to reach alarming levels in the near future. At the same time all the Technical advancements made in various fields of Science and Technology provide effective tools to check, manage and plan the 'Vehicular traffic'.

Challenges of Use of GIS in Transportation Management

The challenges in effective Transportation Management are many. The number of vehicles for example in major cities like Lagos, Abuja, Enugu, Kaduna, Kano, Port-Harcourt etc on the roads are steadily increasing whereas the roads and the land available for building new roads is very limited. Managing, redirecting and decongesting the traffic within the existing roads and space are indeed a challenging task.

Methods of Overcoming the Challenges

Geographical Information Systems (GIS) in the recent past has acquired tremendous importance in various applications. In general, any application, which has a spatial phenomenon, can leverage the GIS technology.

By the use of Geographic Information System (GIS) and Global Positioning Systems (GPS), it is possible to continuously track the location of vehicles at any given point of time. So far this Technology, which is very popularly referred as Automatic Vehicle Location (AVL), is being effectively used for fleet management and is provided by AVL service providers. This technology with its high cost of implementation and specific use has been limited as many companies owning large fleet of vehicles to track their vehicles. However, with all the advancements made in the fields of GIS and especially the decreasing size and cost of GPS it is possible to use the same AVL technologies, to track any vehicle that is just out of the assembly line. All the trucks, cars and even two wheelers can be fitted with a GPS which is as small as a chip and which gives an accurate position of the vehicle in terms of latitude and longitude.

Once the vehicles are fitted with the GPS a centralized traffic control room, which has all the necessary equipments to view and analyze the location of every vehicle on the road, can be made use of. 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 also can be built as an intelligent system, which is capable of generating alternative routes if there is a jam at any point of time. The system can be used to know the average number of vehicles plying on each road on a daily basis. The same data can be stored in a database and later mined which can be very useful in various activities of traffic planning and management.

Application of GIS in Transportation Management

The question is how a person like you and I can make use of this intelligent system when in the middle of the road battling the traffic. The results of the analysis put together by the Centralized Traffic Control room can be made use of to effectively manage the traffic. All important data like the number of vehicles on each road, information about the roads where there are jams and the details of alternative 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 sometime intervals as popularly suggested by the stakeholders in transportation planning through the stratified sampled results.

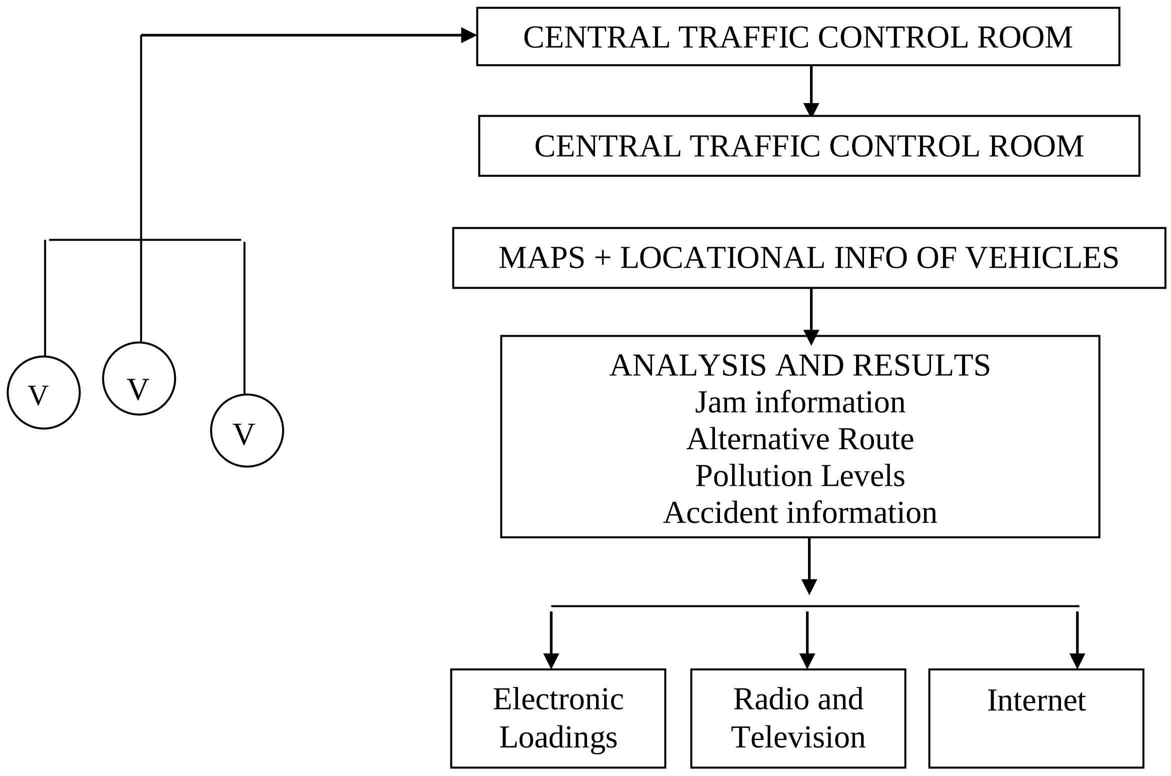

Fig. 5.2: Locational Information of vehicles in latitude and longitude.

BENEFITS OF EFFECTIVE TRANSPORTATION MANAGEMENT.

Transportation management being a spatial phenomenon can be managed effectively using the GIS technology. The benefits of effective transportation management are:

- Ease of traffic movement.
- Lesser time on roads.
- Reduced tempers while driving.
- Increased Personal Safety.
- Effective transport planning.

The examples of its applications are:

Rail – Rail system operators use GIS to keep accurate inventories of facilities and report safety and performance statistics.

Public Transport - GIS is an excellent tool for analyzing service revenue, patterns, and usage by population demographics.

Aviation - Use GIS for managing airport facilities, regulating use of airspace, and noise modeling.

Water – Transportation - GIS helps engineers build and manage port facilities and helps planners accommodate community and environmental constraints more easily.

Transportation professionals in developed world have discovered and embraced GIS as an important tool in, planning, evaluation, construction, management and maintenance of transportation system.

GIS for transportation is used for a wide range of applications including:

- Modeling travel for future transport infrastructure planning using census analysis.
- Analyzing annual capital improvement plans based on network usage and condition.
- Identifying, analyzing and presenting airport noise violation.
- Improving transport services throughout rejuvenated urban centers.
- Evaluating environmental impact of new construction schemes.

Vehicle Routing Problems (VRPs) are widely investigated class of problems in combinational optimization, and include many transportation tasks (e.g. Parcel services). In general, a VRP consists of a set of customers that must be served via a fleet of vehicles, each of which leaves from and returns to a central depot. The type of VRP determines whether customers have good delivered to them, are transported from one location to another, or are served in some other way.

Use of GIS for Real-World Input Data

In research, most solution techniques for this class of problem are designed and tested by means of synthetic problem structures. However, the tackling of real-world VRPs requires a thoroughly elaborated data basis in order to provide reasonable outcomes. If this is not the case, even the best solution techniques are of no use for practical applications.

Essential input data for real-world VRP is gathered by using Geographic Information System (GIS). Whereas most researchers use Euclidean distances between customers and depots for their optimization algorithms, a GIS can provide real distance information derived from a digital road network.

To get distance information of sufficient quality, the most detailed street network commercially available for the considered region should be used. In Nigeria today, the road marshal use radio houses to communicate to vehicle road users the location of vehicle routing problems, and alternative routes to take at that point in time. Most security organizations use the combination of GIS and GPS application to track criminals with stolen vehicles.

Unfortunately static distance information from a digital road network does not correlate directly with real travel times because of dynamic influences like traffic jams, road works and weather conditions. Travel times also depend on parameters such as driving style and vehicle type, which are particularly hard to quantify.

Empirical Evaluation of Travel Times in Eastern Austria

In a project carried at Austria, the quality of calculated driving times was evaluated by comparing them with actual driving times for 91 trips within a range of 20 to 250 kilometers in Eastern Austria. The average, maximum, minimum and standard deviation of actual minus calculated driving times in minutes recorded by tacho-graphs is given in Table 6.1.

Table 6.1: Deviation of driving times in minutes.

Deviation	Minutes
Average	0.6
Minimum	-32
Maximum	24
Standard	10.3

This analysis comprised trips in more than forty locations carried out by more than twenty drivers on several days and at all times of day. All the vehicles were of the same type and were able to exceed the allowed speed limit on all the roads used. These results enable us to specify safety margins that are suitable to counteract these observed variations in driving time. The results of this evaluation were used to define reasonable buffer values for optimization procedures in order to achieve highly robust solutions for use in practical scenarios (Berry J.K and Tomlin, C.D, 1982).

Integration of GIS and Optimization

In general, optimization algorithms are implemented in a highly separated software component and used via a well-defined interface. GIS are not only needed for input data processing but in some cases also for enclosing the user interface of a decision support system that guides decision makers by allowing them to schedule vehicles visually. In the following example, GIS plays an integrating role by handling user interactions as a graphical user interface on the one hand and managing communication between all other required software components on the other (Estes,J.E, 1992). A typical example of system architecture is depicted in Figure 6.2.

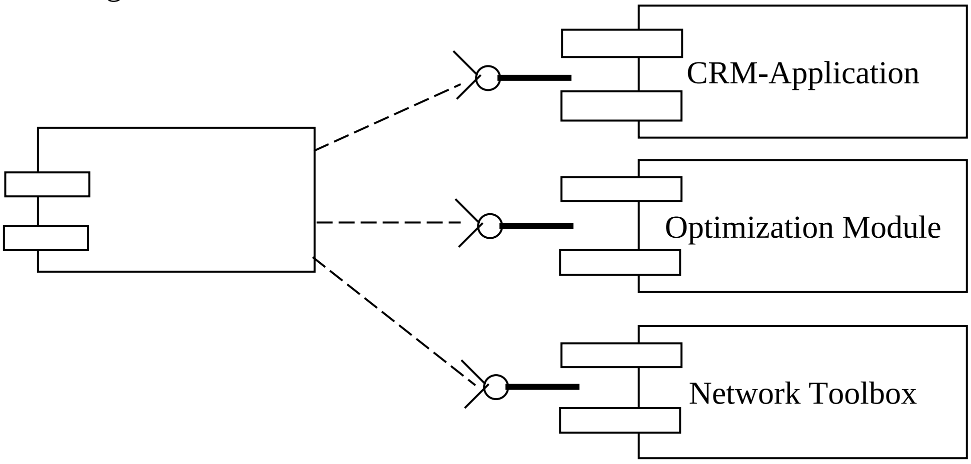

Figure 6.2: Component diagram.

The system works as follows: after retrieving customer coordinates and other relevant data from the CRM-Application, the Front-End uses the Network Toolbox to obtain a distance matrix containing travel times for all possible customer pairs. The Front-End forwards all information to the Optimization Module, which applies the optimization algorithm. Resulting tours are returned to the Front-End and given a geographical representation using the Network Toolbox.

Finally, a complete list of travel plans including customers, street paths and visiting order for the requested period of time may be generated and presented to the application user.

Implementation of the Optimization Algorithm

In general, the computation time for solving a VRP increases exponentially with the overall number of customers. Even execution times for heuristics and meta-heuristics suffer from this effect. For optimization problems of a certain size only the development and implementation of highly parallel algorithms may achieve reasonable execution times. Optimization algorithms are usually implemented in Fortran due to the high-performance compilers that are available for these languages. Next to efficiency, additional criteria such as programming convenience, adoption of technology and availability of tools could also justify the use of C++ as a programming language.

Real World vehicle routing problem (VRP) carried out in Austria

The use of GIS for optimization in transportation planning described above was applied in a project dealing with the development of a decision support system for transportation of blood donations in Austria. The underlying optimization problem originates from the blood collection process of the Austria Red Cross blood program, where processing requirements state that all blood must be processed in one centrally located blood bank within four hours of donation, which could be reduced with problem-tailored optimization algorithms by more than 25%, as measured in total driving time. (Biyant, N.A, Zobrist A.L (1981).

CONCLUSION AND RECOMMENDATIONS

Conclusion

From the discussions in this article, it became clear that the use of geographic information system combined with the Global positioning system make the location of moving vehicle easy. That is geographic information system stands as a good analytical tool to all the system that has location, space and dimension. Public servants, businessmen, etc require good transportation management to meet up with their social and economic activities. If traffic jams can be avoided using alternative routes, it makes movement from one location to another easier.

Many GIS transportation applications have been implemented at various transportation agencies and corporations in many developed countries such as U.S.A, Britain, Austina, California, etc. They are applied in rail system, public transportation system, aviation system, and water transport system. The benefits of effective transportation management include: ease of traffic movement; shorter time on roads, reduces tempers and frustrations while driving and increased personal safety.

Recommendations

There is an urgent need for transportation planning and management in Nigeria by the application of Geographic information system because of the number of vehicle on roads at certain peak periods of the day and very limited number of good roads.

In some major cities of this country e.g. Enugu, port Harcourt, Lagos, Abuja, Kaduna etc the periods of 7.30am to 9am, and 12.30pm to 3.30pm deserve alternative routes and way out of the traffic jams. This problem can be resolved by the application of GIS, which help the road users to decide on the possible routes from his house, and or even on the road.

Government should as a matter of very important provide new roads, rehabilitate the dilapidated ones, so that they can serve the road users. There are many vehicles on the roads this time, and as a result, Government should provide sufficient roads for people's safety and easy mobility. Government should also contract GIS experts to plan and design the movement of vehicles and use of roads at specific periods.

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