Urban Traffic Speed Management: The Use of GPS/GIS

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SUMMARY

The prevailing traffic speed at any section of a roadway affects the quality of traffic at the time. Whereas excessive speeds affect the severity of road traffic accidents, crawling speeds in the urban environment is also indicative of congestion. One of the key elements in speed management planning is the functional classification of roads by speed. For example, 30km/h has been designated for residential areas and 60km/h and above for major arterial roads. Nowadays, efficient vehicle monitoring can be achieved by integrating Global Positioning System (GPS) derived traffic data such as vehicle speed and direction of traffic flow into a Geographical Information System (GIS) environment.
This GPS-GIS integrated system provides real-time meaningful location and status of the vehicles in the network. The system has been used to show the second-to-second positional changes in speed and directions of vehicles travelling in Kumasi, the second largest city in Ghana. Using the geographic components in a dataset and visualizing the results in a map provided a clearer picture of the traffic-state of every route in the network. The GPS has clearly indicated the road sections where speeds are unacceptable and driver behaviour is affected giving transport planners the option to choose the desired speed management technique to improve the traffic system.

1. INTRODUCTION

Speed management is simply a way of adopting various methods such as legislation, road layout measures, enforcement, campaigns or advanced technology to help in regulating the speed of vehicles. Speed management is not necessarily about reducing speed, but to a considerable extent it is about planning and designing the road layout and the road network in such a way that an appropriate speed is obtained (Greibbe et al, 1999). It has become necessary that speed management techniques be applied to all kinds of urban roads, from residential roads (where the techniques are widely used) to arterial roads. The most commonly used technique in speed management is known as 'Traffic Calming'. This technique has mainly been used in local areas so as to reduce the speed or the traffic flow. This can be done via various speed management techniques, e.g. road design, visual effects, legislation, regulation or signing and marking.

In order to get a picture of the current traffic and safety situation, relevant data is usually collected to cover the *road geometric parameters*, *accidents*, *traffic flow*, *surrounding*, and *opinion of road-users and transporters.* The data obtained is then processed and mapped. The information obtained can subsequently be used to create a database in Geographical Information System (GIS) to help in decision making for any planning process including a speed management program (Greibbe, *et al*, 1999). The advantage in using Global Positioning System (GPS) is that mapping of the relevant parameters can easily be done in a GIS environment. This makes it possible to make a pre-evaluation of various measures related to the local targets and which usually proves to be conclusive.

Finally, traffic speed management forms a foundation on which one can assess the actual trends or pattern of traffic and environmental-related problems, and a premise for a sufficiently good evaluation of the speed management technique adopted.

2. THE FIELD OBSERVATIONS.

2.1 GPS Tracking - A vehicle mounted with GPS equipment is integrated with telemetry or GSM transmission. Where a GPS receiver is used instead, locations and speeds are recorded automatically at regular sampling periods. The wireless GPS tracking system provides fast and easy access to the time and travel information that is needed. The vehicle's position is recorded every second. When the positions have been recorded, the GPS data is transported through the telemetry system to a traffic control where the data is matched with a road network database. The travel times and speeds for specific roads can subsequently be obtained. The process is as shown in figure 1.

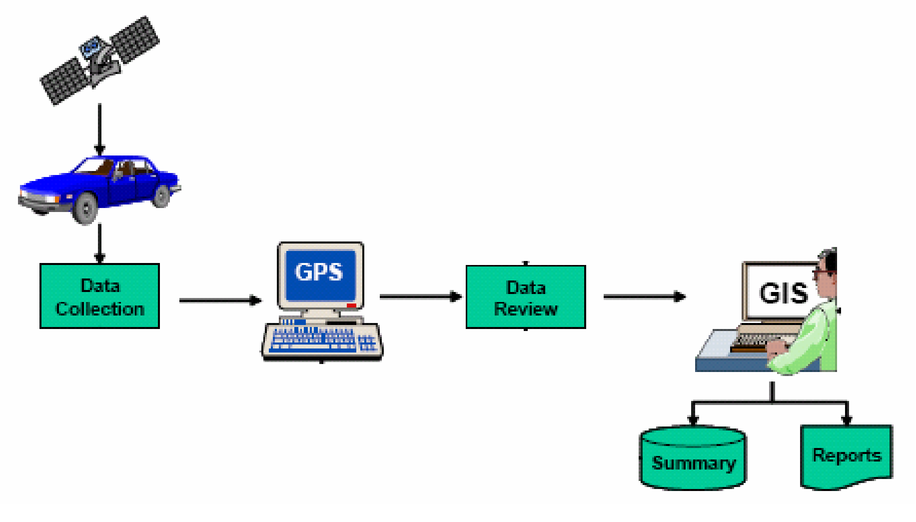

Fig. 1: The processes involved in GPS tracking.

To overcome the problem of systems accuracy for the measurements, the GPS receivers (a real time DGPS system) which provides a high accuracy in point positioning was employed. A base station was also used to correct the data collected from the city road network. The corrections were adequate, since the distances from the base station were short.

2.2 Field Speed Measurements

A full scale project using the GPS receivers was undertaken in Kumasi city for the central business district (CBD) and the area adjoining the CBD but lying within the ring road portion of the city. The road network was divided into segments starting and ending at predetermined intersections of the roads. In keeping with recent studies which allude to the fact that more than 60% of all trips undertaken in Kumasi starts or ends at the Kejetia Area (Afranie S; Afukaar FK; et al, 1993) the test vehicle for the traffic management study, used the city centre (Kejetia/CBD) as the origin or destination of all the journeys. The vehicle was driven floating in the traffic stream by following the general traffic flow during different time periods of the day. This enabled information to be gathered on the expected traffic conditions in the morning as well as in the afternoon for a total of seven days. For each route segment, the travel time between the starting and ending nodes was computed from the GPS time data. Knowing the distance between the nodes and the respective travel time, the speed of the vehicle along the particular road segment was then computed. The overall speed for the route was also computed based on the time and distance dataset.

2.3 Road network data and Traffic sign Inventory Data Collection

GPS was used as the primary data collection tool for mapping the overall road network and traffic sign inventories for the study area. To accomplish the data collection activities, ArcMap was used to query the data collector for sign attribute information. The GPS unit determined the position of the sign while the data collector entered the attribute information into a laptop computer which forms part of the GPS unit. At the end of each data collection day, the data was downloaded to the PC and further processed in the office. Any other unique signs were collected separately using a digital camera.

3. DATA PROCESSING AND REDUCTION

3.1 GPS Processing.

Following the field measurements, the captured data were keyed into a computer program for the automatic processing of the positional data, speed and travel times of the vehicle for each road segment. The computer software called Total Trimble Control (TTC) was used for the automatic processing of the GPS data to derive the travel times for each road segment.

3.2 Background map preparation

An existing digital map containing road network of the study area was used as a background on which GIS related results were displayed since one of the key successful components for real-time GPS mapping is a background map. After all the GPS data had been corrected and combined, it was then converted into a block format (jpeg files) with the Total Trimble Control software. Data recorded by the GPS receiver was according to the World Grid System of 1984 (WGS84) reference system. Therefore the image data was first geo-referenced in the ArcMap to the world transformation system. The ArcMap then gave the possibility to visualize, explore, query, and analyze data spatially and to carry out a network analysis.

3.3 GIS application

The GPS captured data is now transformed into several views in ArcMap. For example, one can have the spatially mapped road link theme and also the attributes data in a tabular format. Additional themes such as road sections, speed variations and other background information can be loaded on for spatial visualization and for query purposes. Other tabular data such as dBase files of the network can also be loaded into the view and joined with the existing GPS map attributes. After joining, all the tabular data can then be displayed geographically. It is obvious that a map with spatial data will allow the user to accomplish different tasks (Paul Hsu, 2005**)** including:

- To find the attributes of any feature.
- To select features according to their attributes.
- To select features based on their proximity to other features.
- To carry out a network analysis.
- To track any vehicles position on the network.
- To layout a map and print it.

3.4 Data reduction

Several runs were carried out for each time period to provide acceptable permitted errors in the estimate of the mean speeds. Each run resulted in a GPS file, which contained time, speed and coordinate pairs data. This was used in generating the speed/distance profiles for the various routes and other relevant parameters for the travel time studies such as travel time delay, maximum and minimum link speeds and the like.

4. RESULTS

4.1 Speed profiles

The average speeds of the moving test vehicle in traffic at any given location along the designated routes for given periods of time of the day have been presented as the speed profiles. Figs. 2 and 3 show typical speed profiles for the Harper Road and Western By-pass/Antoa Road during the AM period for the direction towards the CBD. The speed profiles showed the locations of peaks and troughs in the speed distributions along the routes. The peaks depicted sections of the route with high speeds whilst the troughs indicated sections with low speeds. In general, the average traffic speeds on the Western By-pass/Antoa Road was about 30 km/hr whilst that on the Harper road was 15 km/hr. In comparison, the level of service (LOS) enjoyed by the travelling public on the Western By-pass/Antoa road in the morning towards Kejetia, the CBD, was higher than the Harper road towards the CBD in the morning.

The speed profiles in Figs. 2 and 3 also indicated sections along the route where traffic speeds were very low (i.e below 20 km/hr) and the level of service (LOS) was unacceptable and where speeds were considered averagely high (greater than 30 km/hr) with acceptable LOS. Sections of the route where traffic speeds were below 20 km/hr presented traffic congestion and bottlenecks in the road network.

4.2 Mapping of speeds

A map showing the average traffic speeds for the various routes for the AM peak period is shown in Fig.4. Different colour codes have been used to represent different categories of speed classes on the routes and at a glance, sections where traffic speeds are unacceptably low and present bottlenecks in the road network can be readily seen.

4.3 Distribution of congested route sections

Table 1 shows a summary of the percentage distribution of the congested sections of the routes under the study. In proportion, the heavily congested routes were Harper road (52%) and Lake Road (33%). The Okomfo Anokye Road, Western By-pass and 24th February Road were the least congested routes, presenting more than 75% of the road sections with average traffic speeds higher than 30 km/hr.

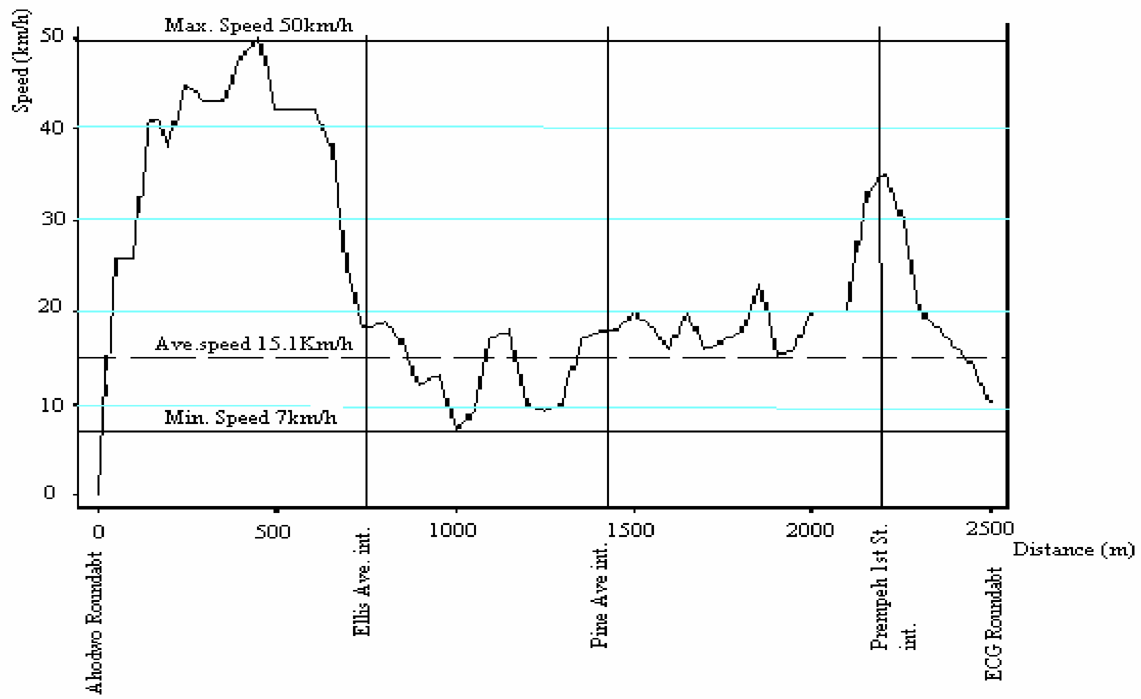

Fig.2 Speed Profile from a GPS file for Harper road during AM period towards the CBD.

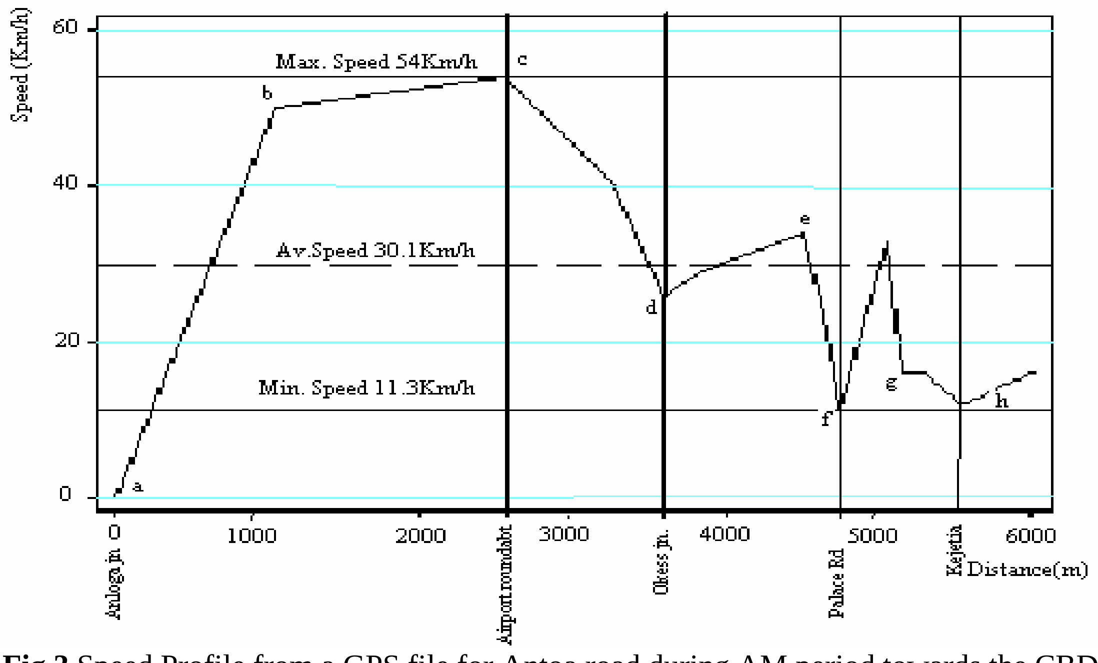

Fig.3 Speed Profile from a GPS file for Antoa road during AM period towards the CBD.

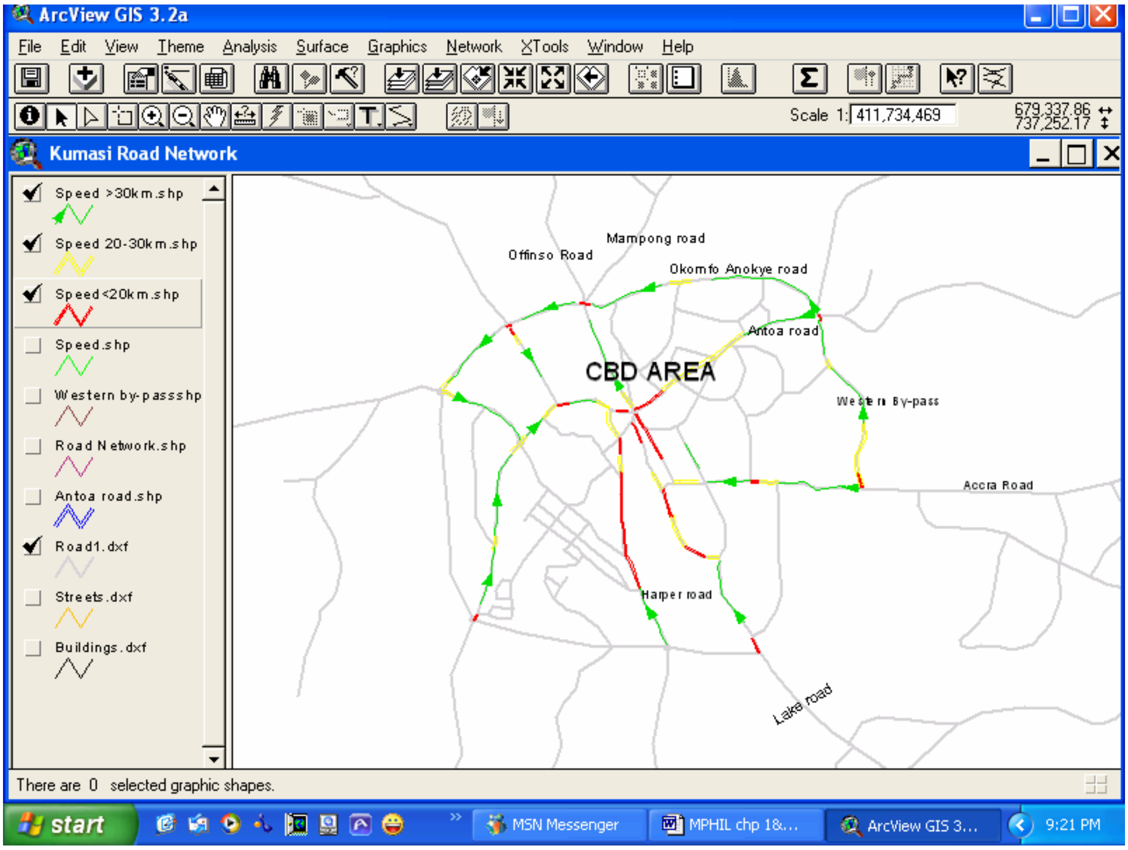

Fig. 4 Observed speed distribution during the AM Peak period.

Legend

1. Red= speed < 20km/hr.
2. Yellow=speed 20-30km/hr
3. Green=speed>30km/hr

Table1: Percentage distribution of congested sections on typical routes during AM period within the ring road in Kumasi, Ghana.

Route Name	**Length (km)**	**Carriage-way Status**	**<20km/hr LOS=E, F**	**20-30km/hr LOS=C, D**	**<30km/hr LOS=A, B**
Harper Road	2.5	Single	52%	25%	23%
24th February Road	3.4	Dual	6%	16%	78%
Bekwai Road	5.2	Single	15%	65%	20%
Lake Road	3.2	Single	33%	43%	24%
Antoa Road	5.7	Single	17%	52%	31%
Western By-Pass	3.6	Dual	8%	12%	80%
Okomfo Anokye Road	5.9	Dual	4%	9%	87%

DISCUSSIONS.

Generally, travelling within the city centre (CBD) in the morning is more difficult as a result of increased vehicular volume, dense pedestrian interference coupled with a number of hawkers occupying portions of the roadway. Such activities tend to limit the road capacity and also affect vehicle travel speeds. From the speed map in Fig.4, it is observed that few metres towards the CBD, all the road sections are heavily congested. This is explained by the mixed traffic activities and trading which take place on the pavements at the Kejetia area.

Vehicles are said to be crawling if travelling speeds are less than 20 km/hr, but in an urban area traffic speeds are generally considered acceptable if they are more than 30 km/hr. The speed profiles for the various routes become handy in establishing sections along the routes where there are bottlenecks by delineating them on the speed-distance graphs. These sections can then be examined more critically for the appropriate traffic management decisions to be taken.

The use of the GPS/GIS has the advantage of eliminating guesswork as to which routes require attention since routes with crawling speeds present to the travelling public unacceptably low level of service. In general, the dual carriageway routes presented higher traffic performance than the single carriageway roads. The later depict roads under stress which require immediate attention.

CONCLUSIONS

Vehicular traffic speeds in the urban environment can effectively be managed by the application of the GPS and GIS. Mapping of the situational road traffic speed at any given time brings out the desired geographic patterns and relationships which are fundamental decision making tools for the management of the urban traffic system by the Urban Planner.

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BIOGRAPHY

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