Towards Improving Road Traffic Data Collection: The Use of GPS/GIS

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SUMMARY

Conventional means of manual collection and measurement of Road Traffic data is usually time consuming, cost prohibitive and prone to human error. A new method of collecting traffic congestion data that is based on the integration of Global Positioning System (GPS) and Geographical Information System (GIS) technologies has been explored.

The measurements of this project were carried out in Kumasi, the second largest city in Ghana with a GPS receiver.

Longitude-latitude pairs and speeds were sampled at regular intervals, thus providing consistency and better accuracy in measuring travel time data. Information on starts and end times as well as trip intermediate stations were automatically recorded compared with the traditional method where the driver recorded data manually. It was established that, efficient vehicle monitoring could be obtained by integrating GPS derived traffic data such as traffic speed and vehicle direction into a GIS environment. Using the geographic components in a dataset and visualizing the results in a map provided clear picture of the traffic-state of every route in the network. For example, road sections where delays and congestion situations occurred were clearly indicated by the GPS based system.

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1. INTRODUCTION

Travel time and delay studies are mostly used to document congestion and updating of traffic cost for road segments. Most travel time study techniques involve using probe vehicles. Though these techniques seem very simple, their implementations tend to be quite labor intensive (Taylor, 2000; Wohlson & Haptipkarasulu, 2000). Normally two technicians are required in the vehicle: one of them to drive the vehicle, and the other one to record distance driven and the location and time the vehicle passes selected checkpoints. Nowadays, distance-measuring instruments (DMIs) can be used to automatically record distance, time, and speed. However, these units have several disadvantages including a need for frequent calibrations and verification of factors, which have nothing to do with the units (for example, tire pressure), and difficulty in using the resulting data in a GIS environment (Cesar Quiroga, 2005). Global positioning system (GPS) receivers have the ability to overcome these difficulties and, as a result, they are increasingly being used to conduct travel time studies (Quiroga & Bullock, 1998, Chao, C.H.,et al.,1999, Savvaidis P. et al.,2000, Ministry of Roads and Transport, Ghana, 2004.) GPS receivers record location in latitude-longitude pairs. However, GPS data files tend to have huge numbers of records, particularly if data is collected at short time intervals, for example every one second. As a result, formal procedures for linearly referencing, storing, and retrieving the GPS travel time and speed data efficiently become essential. One way to overcome the GPS data storage problem involves aggregating the GPS data into highway segments or links so that only segment (or link) travel time and speed data are stored in the database. One of the drawbacks of this approach is that the rich detail of the original data is lost because only segment data are stored in the database (the original GPS files may still exist, but they are not really usable unless they are retrieved and processed from scratch). Some of the information contained in the original GPS data include acceleration and deceleration patterns, control delay, and stopped delay, all of which occur regardless of any highway segmentation scheme considered. In order to access this information it is necessary to store all GPS point data in the database and provide a linear reference to each GPS point before attempting any GPS data aggregation.

The most important technical issue that must be addressed before using GPS to perform travel time studies is the development of a systematic and efficient data model. The following sections describe how this was overcome.

2. THE FIELD OBSERVATIONS

The probe vehicle was mounted with a Trimble GPS antenna and a receiver capable of logging in positional and time data and later downloaded onto a laptop computer in the vehicle for post processing in the office as in fig.1.

Fig 1. The vehicle with the GPS receiver used in the measurements

An interesting question about the system is the accuracy of the measurements. But in this project, a GPS receivers (a real time DGPS system) that provides a high accuracy in point positioning was used. The base station was mounted in the office and in this way it was possible for more vehicles to be used and more traffic data to be collected in a shorter period of time. In addition, it was possible to undertake a continuous updating of the travel-time database of the road network to be undertaken.

The system was used for the determination of traffic condition (congestion data) in a pilot project covering the central business district (CBD) and the area within the ring road but outside the CBD part of the city of Kumasi. Recent studies allude to the fact that more than 60% of all trips undertaken in Kumasi starts or ends at the Kejetia Lorry Park. (Afranie, S, Afukaar F.K et al, 1993). The vehicle travelled along major roads, with the city center (Kejetia/CBD) as the origin or destination of all the journeys. The vehicle was driven floating in the traffic stream following the general traffic flow at two different time zones in the day, so as to capture the expected traffic conditions in the morning as well as in the afternoon for a total of seven days. The road network was divided into segments starting and ending at predetermined intersections of the roads. For each segment, the travel time between the starting and ending node 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 computed. The overall speed for the route was also computed based on the time and distance.

A total of about 30 travels per road segment were accomplished in the time period of the project. A comparison of the positional data measured with the GPS to the digital map of the area gave very good results for most of the roads travelled. In almost all of the cases, the position of the vehicle given by the GPS receiver was well within the road edge lines. In a few cases no position could be computed due to the limited availability of satellites at narrow road segments between tall buildings or dense leafage of trees. Even in such cases there were positional data measured at the crossing of roads where visibility was better so that the computation of travel times per segment was possible.

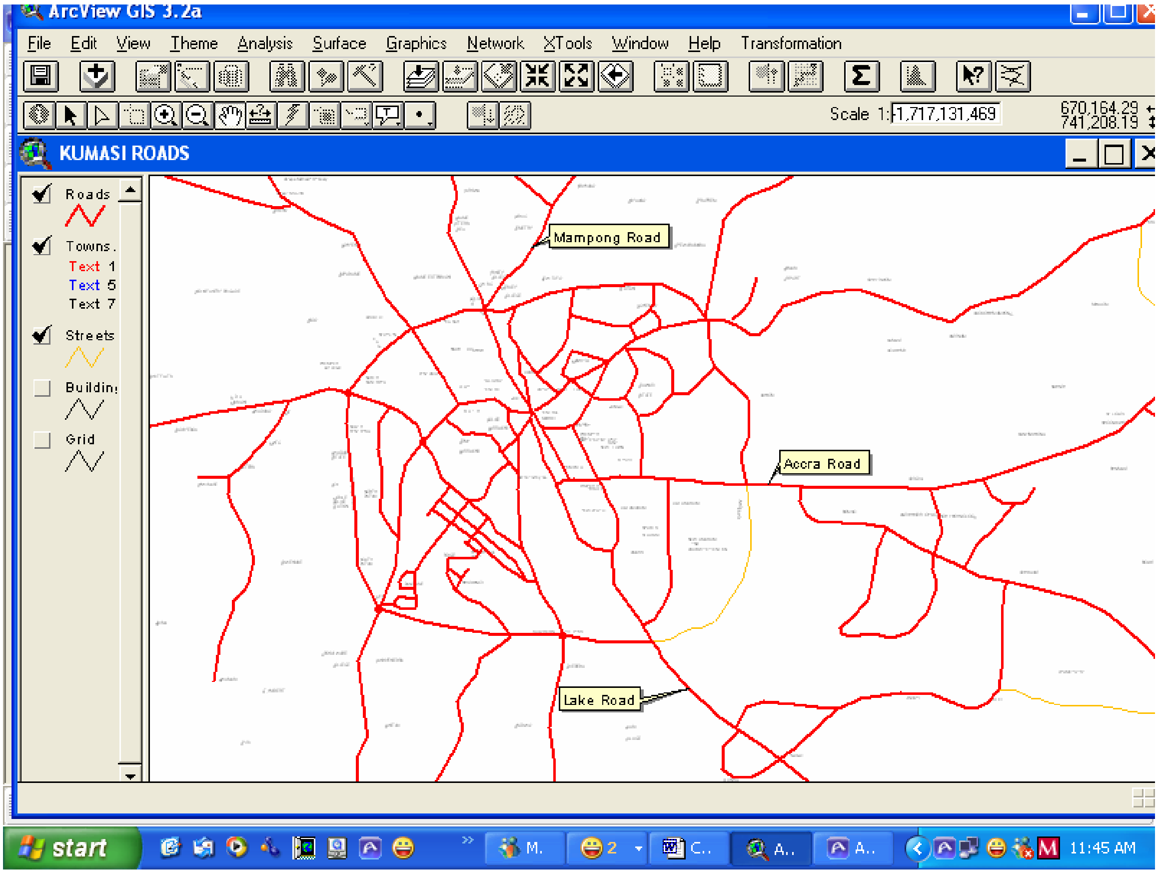

Fig. (2) Road Map of the Study Area showing the area within the CBD and outside.

3. DATA PROCESSING AND REDUCTION

Following the field measurements, the captured data were driven into a computer program for the automatic computation of travel times for each road segment fig. The program used an algorithm to find the measured GPS points nearest to the start and end node of each segment with given coordinates. In this project, traffic times computed included also delay times due to red traffic lights and queues as this was considered a realistic approach of the true traffic conditions. After the determination of the two (start and end) measured points the travel time for the road segment was computed as well as the mean travel speed from the travel time and the known length of the segment.

Fig. 3 GPS base station together with the computing and processing units.

3.1 Spatial Model

In order to linearly reference GPS data efficiently, GPS-derived network maps, which is a more accurate approach, was constructed and used for processing GPS travel time data. This was done by driving a GPS-equipped vehicle to survey both directions of travel, as well as the cross streets at signalized intersections and other physical discontinuities. The resulting GPS data was used to generate a directional centerline highway network map in the GIS. In the process, checkpoints were located at all major physical discontinuities and the map was linked to a relational database by assigning unique identification numbers to each link (Figure 3). The resulting map was then ready for mapping GPS travel time data to the network.

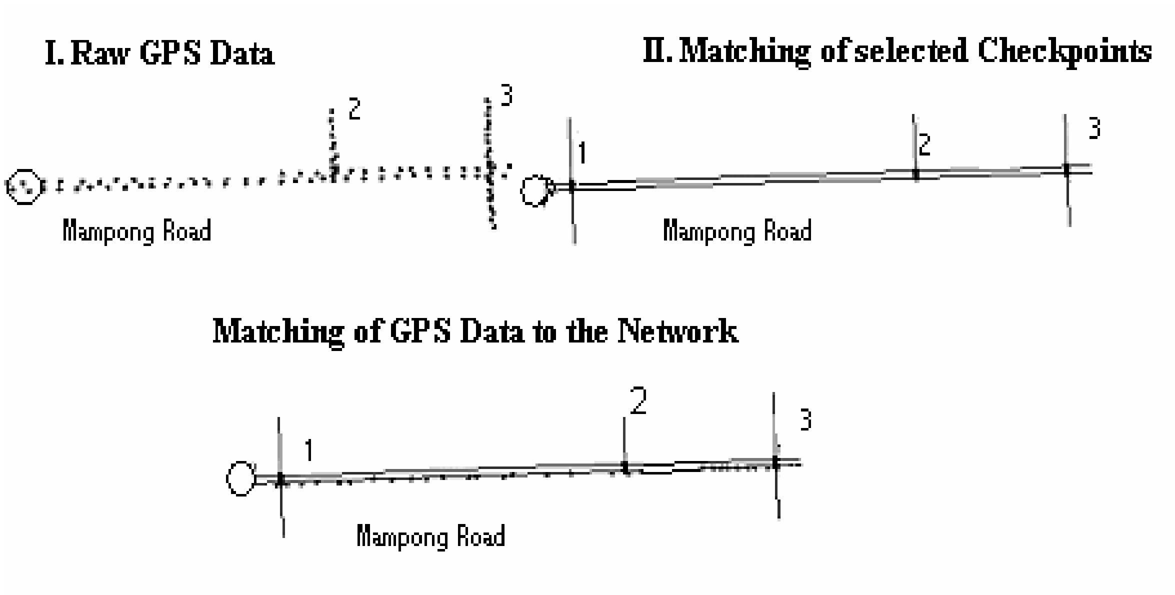

Fig.4. Sample network map geocoding and segmentation for a short section of Mampong Road

3.2 Data reduction

With the directional centerline map in place, 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. Other relevant parameters for the travel time studies such as travel time delay, maximum and minimum link speeds were also computed using the Travel Time with GPS file (TTG).
Figures 4&5 present the results of speed/distance profile from the GPS file.

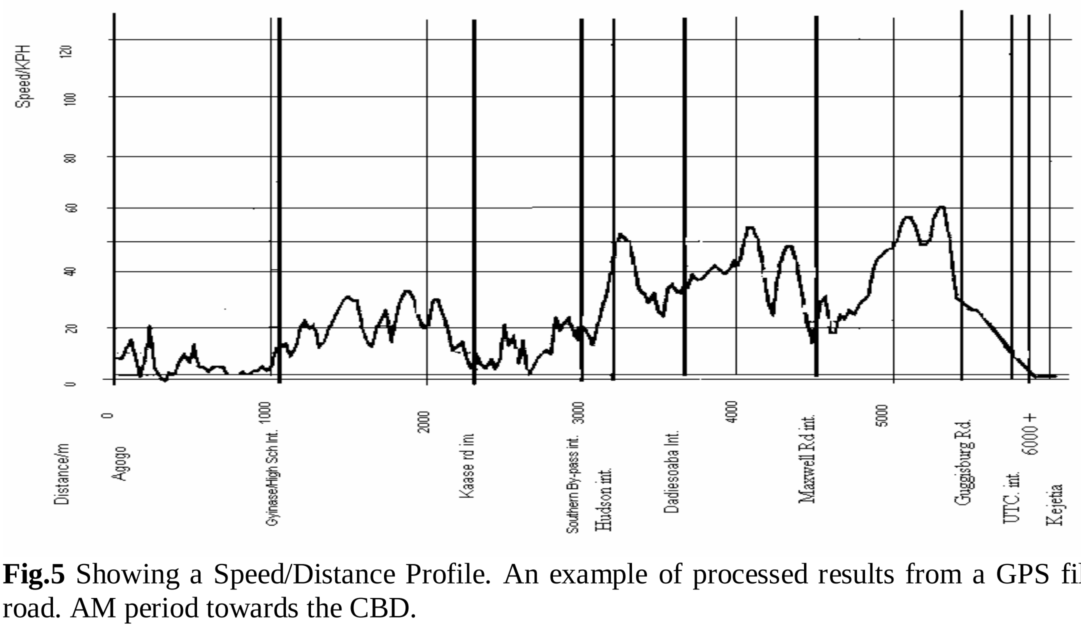

Fig.5 Showing a Speed/Distance Profile. An example of processed results from a GPS file for Lake road. AM period towards the CBD.

Locating critical interchanges as indicated on the graph accurately is essential for computing various performance measures like traffic delay, control delay, stopped delay, running speed and average speed. Example from Fig. 4 Though the mean speed was 45kph, there were sections where maximum speed was about 60kph and somewhere it was virtually zero. It also gives localized detailed speeds for the various sections.

4. RESULTS

Route Section	**Length (km)**	**Average Travel time (min)**	**Average Speed (km/h)**	**Average Impedance (min/km)**	**Level of service**
Agogo stn – Gyinase jn.	1.1	16.1	4.1	14.6	F
Gyinase jn – Kaasi Rd int.	1.3	8.0	9.8	6.1	F
Kaasi Rd int.- southern by-pass	0.6	6.4	5.6	10.7	F
Southern By-pass-Hudson int.	0.3	0.8	22.6	2.5	D
Hudson int.- Dadiesoaba int.	0.4	0.6	38.9	1.5	B
Dadiesoaba int- Maxwell Rd	0.8	1.6	30.4	2.0	B
Maxwell Rd- Guggisberg Rd	1.3	2.1	36.9	1.6	B
TOTAL	5.8	35.6	9.8	6.1	F

Table 1: Summary of Average Travel speed for the various sections selected for the Lake road

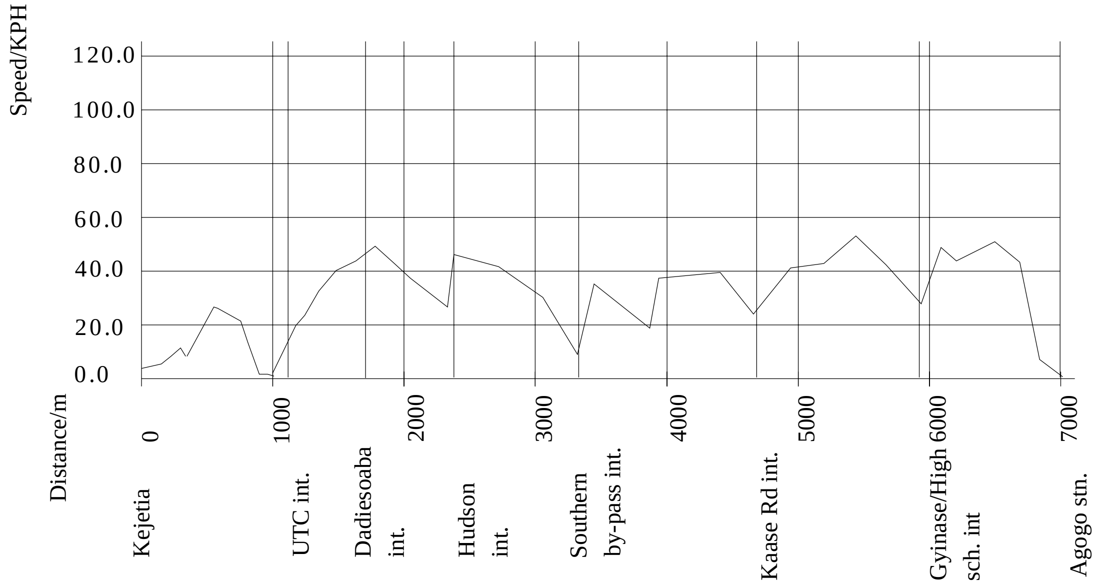

Fig. 6 Showing a Speed/Distance Profile. An example of processed results from a GPS file for Lake road. AM period from the CBD.

Table 2: Summary of Average Travel speed For Some selected Routes

Route Description	Length (km)	Period of Day	Direction	Average Speed (km/hr)	Average impedance (min/km)	Level of Service (LOS)
Lake Road	7.1	AM	Atonsu Agogo Taxi Station – Kejetia	9.8	6.1	F
			Kejetia – Atonsu Agogo Taxi Station	21.7	2.8	D
		PM	Atonsu Agogo Taxi Station – Kejetia	29.5	2.0	C
			Kejetia – Atonsu Agogo Taxi Station	12.3	4.8	F
Mampong Road	5.0	AM	Tafo market –Kejetia	6.6	9.1	F
			Kejetia – Tafo Market	25.9	2.3	C
		PM	Tafo market – Kejetia	16.2	3.7	E
			Kejetia – Tafo Market	22.6	2.7	D
Sunyani Road	5.8	AM	Tanoso Market - Kejetia	10.3	5.8	F
			Kejetia - Tanoso Market	29.1	2.1	C
		PM	Tanoso Market - Kejetia	23.1	2.6	D
			Kejetia - Tanoso Market	12.5	4.8	F
Offinso Road	6.1	AM	Kronom. – Kejetia	16.6	3.6	E
			Kejetia –. Kronom	31.2	1.9	B
		PM	Kronom. – Kejetia	29.7	2.2	C
			Kejetia –. Kronom	15.7	3.8	E

Table 3: Summary of average travel speed for the selected routes during the AM and PM periods.

	AM PEAK		PM PEAK		
ROAD NAME	**To Kejetia (km/hr)**	**From Kejetia (km/hr)**	**ROAD NAME**	**To Kejetia (km/hr)**	**From Kejetia (km/hr)**
LAKE ROAD	**9.8**	**21.7**	**LAKE ROAD**	**29.5**	**12.3**
MAMPONG	**6.6**	**25.9**	**MAMPONG**	**22.6**	**16.2**
SUNYANI	**10.3**	**29.1**	**SUNYANI**	**23.1**	**12.5**
OFINSO	**16.6**	**31.2**	**OFINSO**	**29.7**	**15.7**

Generally, traveling towards the city center (Kejetia) in the morning registered lower speeds (7-17Km/hr) than when traveling in the opposite direction (22-31km/hr).

Congestion was rife on most of the road sections when traveling on most of the road sections when travelling towards kejetia in the morning resulting in the low average speeds. The speed trend reversed in the evening, experiencing congestion when traveling out of the CBD to the outskirts. A tidal flow situation is thus being experienced in Kumasi, where travelers encountered delays in the morning when entering the CBD, but it reversed in the evening and except the situation for Mampong road where it is directional.

5. CONCLUSIONS

The application of GPS technology in data collection gives detailed study of traffic conditions and also provided numerical data for all the road segments in the study area. The GPS technology makes the task of database building more manageable and cost effective.

Furthermore, the technology not only guarantees data accuracy and precision but also allows staff to assess and process data in a more timely manner, thus overcoming the mechanical and human errors that have prevailed in the manual traffic data collection method.

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BIOGRAPHICAL NOTES

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