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SPEED PROFILING ON ROADS OF NEW DELHI

Sudatta Mohanty *(Author)*
Department of Civil Engineering
Indian Institute of Technology, Delhi
New Delhi, India
sudatta.mohanty.0993@gmail.com

Anubhav Kumar *(Author)*
Department of Civil Engineering
Indian Institute of Technology, Delhi
New Delhi, India
anubhavkumar.iitd@gmail.com

***Abstract*—Study of transportation systems at various levels of organization has gained increased importance in recent times and is a rapidly advancing field in transportation engineering. With increased capabilities of Geographic Information Systems, the concept of developing a complete virtual transportation model of the entire globe has become a bright prospect. Speed profiling of data has direct applications in developing Intelligent Transportation Systems (ITS) and in analysis of efficiency of existing road networks. The prime objective of this study was to develop a speed profile map for the complete road network of the city of New Delhi. As a result of the accompanied analysis that was done on the resulting spatial database, some vital correlations were developed between Accident prone areas and peak speeds, variation of speeds with time of day, average speeds on roads classified on the basis of Right Of way and variation of rates of acceleration and deceleration near intersections. The completion of the study yielded a complete spatial database of average speeds on roads of New Delhi having a Right of Way greater than 30 m accompanied with the attributes – accidents, time of day, acceleration and deceleration rates. The database is of prime utility for any primary or auxiliary analysis relating to variation of speeds**

Keywords*- *Speed Profiling, Spatial Join, Smartphone, Accident Hotspots.

I. INTRODUCTION

A. Intelligent Transportation Systems (ITS)

Intelligent transportation systems (ITS) is an emerging field in the domain of transportation engineering which follows an integrated approach towards development of surface transportation systems in order to improve the effectiveness and efficiency of each model element through use of advanced technologies in Information Systems (Geographic and Management), Electronics and Communications and Transit Modules. An important aspect of these types of systems is the 'real-time' flow of information in a structured manner. Implementation and design of such system requires precise and exact information on the traffic behaviour, supply and demand of the target area which is constituted by modelling of the traffic conditions.

B. Transportation Modelling

Transportation Modelling is an analysis methodology wherein a virtual model of real life transportation systems is developed in a structured approach. It is an integral component of transportation planning as it provides for the basis of design and analysis of transportation systems which play a major role in affecting the economy of the country. There are three types of transportation models that are developed as a standard practice based on the requirements: Macro, Meso, and Micro. Macro models treat the entire study area as a whole and analyze on the basis of a grid or network. Meso models are somewhat more detailed where a single corridor is also treated as a separate entity. Micro models are the most detailed models where every single link and intersection is analyzed.

Collection of data for the purpose of modelling is carried out in a three layer approach. The first step constitutes a mapping of the physical features (natural and man-made) which is generally carried out through GPS or accurate positioning devices such as total stations. The second step involves the measurement of relevant parameters required for the model such as carriageway width, Right of way etc. The final step, being the most important and requiring the highest degree of accuracy is collection of real time data which involves recording cycle time at intersections, traffic load at intersections, pedestrian traffic etc. These three layers are then integrated on a virtual interface and a dynamic model is made available for analysis, study and design of a new system.

C. Geographic Information Systems (GIS)

A Geographic Information System (GIS) [1] allows for visualization, analysis, query and an overall view of the data with global reference. It is of prime application in data analysis as it provides an array of spatial operations having utility in correlating information. In other words, information beyond perception in the form of tables and other data structures can be used to create a pictorial representation which is bound to depict the same information in a manner feasible for spatial operations. In context of transportation modelling, GIS database is the central storage system that allows communication and intermediate storage between the various sub-models. GIS-integrated models use data stored in relational tables to estimate and produce traffic behaviour and characteristics. These base maps are then used for further analysis depending on the requirements and the type of data available

D. Speed Profiling

E.

Speed Profiling is the process of calculating speed traces on transportation channels in a well defined study area and it's variation with parameters such as Right of Way, Carriageway Width, Traffic Inflow etc. [2] These plots, generally on a visual interface, are a result of a combination of Transportation

Modelling and application of Geographic Information System (GIS). There are two main categories of speed profiling that are carried out. The first type involves plotting the speeds of individual vehicles over a specified path. In the second method, these individual profiles are averaged over many such individual profiles for the same stretch and an average speed plot is obtained. Care needs to be taken that this averaging out is carried out with data obtained under identical physical (external) conditions. In terms of spatial database, a speed flow curve is obtained on a road link defined with relevant attributes.

The data represented by this exercise is of great significance in design and redesign of transportation systems, estimated time of travel calculations between two nodes and measuring the degree of congestion is segments of roads. It can also be used to discover various patterns in driver behaviour and responses to certain specific stimuli. [4]

II. METHODOLOGY

A. Data Collection

This module consisted of collection of primary speed data on major road of New Delhi. Six volunteers were selected through an unbiased process. It was kept in mind that the sample set depicted variation in both gender and age in order to incorporate maximum possibilities. Smart-phones were provided to volunteers for the purpose of speed measurement. The smart-phones were pre-installed with android based software capable of recording the following data at intervals of 1 second:

- Latitude and longitude
- Date and Time
- Speed
- Eco-Drive Score

The Eco-Drive score was allotted to each driver governed by some implicit rules coded in the software.

The length of the observation period was about 45 days and the survey was conducted in the months of May and June 2012.

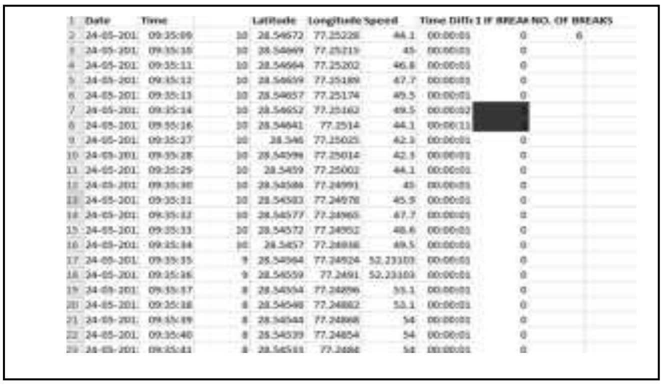
A secondary data source having the same format as that of the fresh data collected was also made available for analysis. [3]

B. Data Refinement

After handing over of phone by the volunteers, the data was extracted from the phones in the form of Comma Separated Values (.csv) files. The files were then converted to the excel format (.xls) for refinement. The following Modifications were done to the raw data:

i. Fields were labelled and initial and final data records with zero values of speeds were removed from the respective files.
ii. Discontinuity of data due to loss of signal was encountered for volunteers of all regions in Delhi and this led to breaks in time intervals (ideally to be equal to 1 s). The Breaks were first detected by an iterative algorithm (run in excel) and the fields with such breaks were highlighted using conditional formatting tools. The irrelevant data was eventually removed selectively

Figure 1. Excel Sheet highlighting breaks in original data



1	Date	Time			Latitude	Longitude	Speed	Time Diff	1 IF BREAK	NO. OF BREAKS
2	24-05-201	09:35:09		10	28.54672	77.25228	44.1	00:00:01	0	6
3	24-05-201	09:35:10		10	28.54669	77.25215	45	00:00:01	0	
4	24-05-201	09:35:11		10	28.54664	77.25202	46.8	00:00:01	0	
5	24-05-201	09:35:12		10	28.54659	77.25189	47.7	00:00:01	0	
6	24-05-201	09:35:13		10	28.54657	77.25174	49.5	00:00:01	0	
7	24-05-201	09:35:14		10	28.54652	77.25162	49.5	00:00:02	[illegible]	
8	24-05-201	09:35:16		10	28.54641	77.2514	44.1	00:00:11	[illegible]	
9	24-05-201	09:35:27		10	28.546	77.25025	42.3	00:00:01	0	
10	24-05-201	09:35:28		10	28.54598	77.25014	42.3	00:00:01	0	
11	24-05-201	09:35:29		10	28.5459	77.25002	44.1	00:00:01	0	
12	24-05-201	09:35:30		10	28.54586	77.24991	45	00:00:01	0	
13	24-05-201	09:35:31		10	28.54583	77.24978	45.9	00:00:01	0	
14	24-05-201	09:35:32		10	28.54577	77.24965	47.7	00:00:01	0	
15	24-05-201	09:35:33		10	28.54572	77.24952	48.6	00:00:01	0	
16	24-05-201	09:35:34		10	28.5457	77.24938	49.5	00:00:01	0	
17	24-05-201	09:35:35		9	28.54564	77.24924	52.23103	00:00:01	0	
18	24-05-201	09:35:36		9	28.54559	77.2491	52.23103	00:00:01	0	
19	24-05-201	09:35:37		8	28.54554	77.24896	53.1	00:00:01	0	
20	24-05-201	09:35:38		8	28.54548	77.24882	53.1	00:00:01	0	
21	24-05-201	09:35:39		8	28.54544	77.24868	54	00:00:01	0	
22	24-05-201	09:35:40		8	28.54539	77.24854	54	00:00:01	0	
23	24-05-201	09:35:41		8	28.54533	77.2484	54	00:00:01	0	

iii. Excel sheets having number of breaks in excess of 100 were classified as unsuitable for further analysis and were removed from the database.

C. Speed Profile Plots

The general speed profile plots required speed data from all parts of Delhi. Hence, excel data was collected from TRIPP IIT Delhi, presenting "Car-Speed Functions". These refined excel files were then imported to ArcMap 10.0 module of the ArcGIS software from the excel format in the form of datasheets. These datasheets had attributes labelled Latitude and Longitude and the display function was used to plot these points on a layer. This layer was then assigned a projection system in ordinance with the base-maps to be used.

For further analysis to be carried out, it was important that the assigned projection system be embedded on to the plotted point's layer. This was assured by converting the layer to a 'shape file' and saving it with the projection system of the basemap. This process provided us with a file that had a point distribution of data points on various types of base-maps. A subset of this file was also created which depicted change in speed values with the help of colour gradients using "symbology" function in ArcMap software. Further, "queries" were made to analyze the areas recording maximum idling (Speed <5 Km/hr) and overspeeding (Speed >60Km/Hr) points.

D. Spatial Joins

The final step to obtain the required spatial database was to conduct the "Spatial join" operation for pairs of layers. It is a type of table join operation in which fields from one layer's attribute table are appended to another layer's attribute table based on the relative locations of the features in the two layers. In our case, the features being speed profile plots and base map characteristics. For this purpose also, the "Car-Speed Functions" data was imported. The following pairs of layers were generated:

i. Speed Profile layer with 'All Roads of Delhi' base-map
ii. Speed Profile layer with 'Roads having Right of Way

30 m' base-map

iii. Speed Profile layer with 'Roads having Right of Way 45 m' base-map

iv. Speed Profile layer with 'Roads having Right of Way 60 m' base-map

v. Speed Profile Layer with 'Accident hotspots in Delhi' base-map.

The spatial join output layers had combined attributes of both the layers taking part in the spatial join operation and hence made it possible for data analysis to take place.

E. Driver Behavior Plots

This segment of the study was performed completely on Microsoft Excel 2007. It used the data collected by smartphones from volunteers. It consisted of three kinds of data plots:

i. Rates of acceleration and deceleration were plotted near intersections for all six volunteers at the same time of day and same location. This enabled us to compare driver behaviour near intersection with respect to age and gender.

ii. Average Speeds on a stretch of road varying with time of day was plotted for all six volunteers as well in order to observe the effect of office hours and other factors.

iii. For a combined data of all volunteers, pie charts of speed (for different Right of Ways) were obtained to see general fluctuation in speeds and deviation (variance) from the average value speed.

III. RESULTS AND DISCUSSIONS

A. Average Speed with time of day

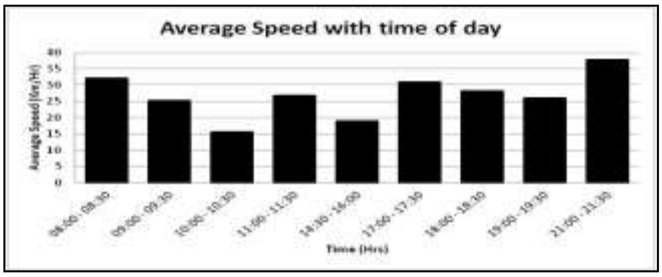


Figure 2. Plot of average speeds recorded at different time slots in the day

TABLE I. SPEEDS MEASURED AT DIFFERENT TIMES OF DAY

Mean and Standard Deviation of Speeds at various times of day		
Time (Hrs)	***Mean(Km/Hr)***	***Standard Deviation(Km/Hr)***
14:30-16:30	18.95	20.30
17:00-17:30	30.25	21.30
10:00-10:30	15.55	17.11

The chart displayed above depicts the variation in average speed with time of day for one volunteer. However, a similar pattern has been observed for nearly all volunteers at different corridors. Therefore, common inferences that can be drawn from this data representation are as follows:

- Average speed decreases from 33 Km/hr at 8:30 am to 16 Km/hr at 10:30 am. This phenomenon can be attributed to an increase in traffic flow during office opening hours.
- There is increase in average speed to around 26 Km/hr by 11:30 am because of a reduction in office-bound traffic.
- However, a reduction in average speed to 18 Km/hr can be noted during afternoon hours. This can be ascribed to many office-goers heading for lunch along with increase in signal cycle time.
- At around 5:30 pm, few office-workers start returning in relatively free roads. Hence, higher average speed (around 30 Km/hr) is observed. This speed decreases as density of traffic starts increasing.
- The maximum average speed (around 38 Km/hr) is recorded at night, when traffic density is minimal.

The standard deviations calculated for the same sample set of data show very little fluctuations and thus, verify the consistency of data with respect to time. However, it is observed that the standard deviation values are distinguishably large and hence, the reliability of data is not so high. It is to be noted that this parameter is largely beyond the control of experimental conditions and its effect can be diluted by taking a large sample size for our convenience.

Another feature of the GIS database obtained is the availability of query mode for finding out the speed plots of the entire city at a particular time.

B. Overall Speed Variation on all roads of New Delhi

i. Overall Analysis

As stated previously, speed profile plots of entire city of Delhi were fashioned. A part of the plot is shown below for analysis:

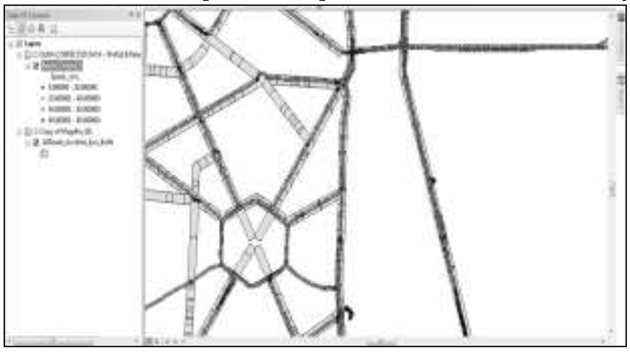


Figure 3. Speed profile plot of India Gate, New Delhi

The figure above depicts variation of speed profile near "India Gate" using colour variation as identifying feature. Here, points shown "red" represent speeds < 20 Km/hr, points shown "yellow" represent speeds between 20-40 Km/hr, points shown "light blue" represent speeds between 40-60 Km/hr and points shown "deep blue" represent speeds between 60-80 Km/hr.

Speeds are generally less while approaching the monument. However, higher speeds were recorded on the parallel road due to fewer interruptions.

ii. Idling (Speed < 5 Km/Hr): Case Study

The points representing speed < 5 Km/hr were demarcated using query.

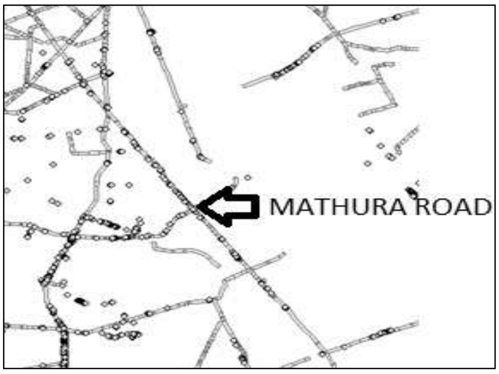


Figure 4. Plot showing points of idling on Mathura Road, New Delhi

The corridor identified having maximum number of such points was along or near Mathura Road. The reason for this observation can be attributed to lot of heavy vehicle traffic and poor condition of roads.

Apart from this corridor, most points were mapped near intersections.

iii. Efficient Transport Channel (Speed > 60 Km/Hr) : Case Study

The points representing speed > 60 Km/hr were demarcated using query.

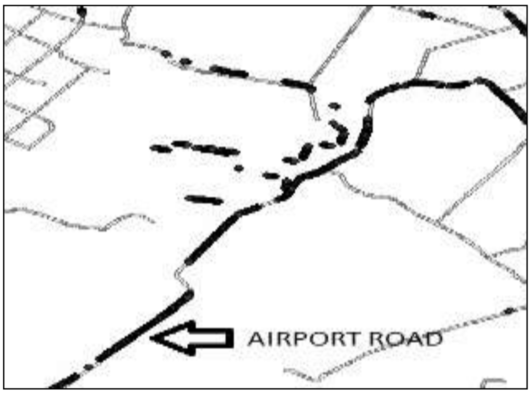


Figure 5. Plot showing points with speed >60km/hr on Airport Road

Airport Road recorded maximum points having such high speeds. The speed limit in this corridor is high due to less density of traffic and wide carriageway.

Apart from this observation, other high speed points were noticed at long stretches of roads.

C. Speed Variation with Right of Way

The points plotted for speed profile were overlayed on layers containing roads classified according to the 'Right of Way' attribute. Spatial Join operation was carried out to obtain a combined attribute table for observation of trends.

The average speeds on categories of road classified are tabulated as follows

TABLE II. SPEED VARIATION WITH ROW

Mean and Standard Deviation of Speeds at various ROW		
ROW(m)	***Mean(Km/Hr)***	***Standard Deviation(Km/Hr)***
30	26.59	14.98
45	30.08	15.73
60	28.70	14.48

The average speeds across various Right of Ways don't vary to a great extent. This can be attributed to the fact that even though an increase in the Right of Way value leads to some increase in the carriageway width, it is to be kept in mind that each road has been individually designed to cater different levels of traffic and encounters a different traffic demand every day. Another plausible explanation put forward is that the traffic on roads with higher Right of Way increases to a greater extent due to settlement in its locality.

On further analysis, the minute variation in speeds across the roads with different Right of Way is advantageous to smooth flow of traffic. As can been seen through a simple analogy, if two roads under different classification intersect at a point and carry traffic at vastly different speeds, congestion is bound to occur at any such node

D. Accident Hotspots with Peak Speeds: Case Study [5]

For analyzing the impact of high speed on number of accidents on a road, the layer containing data on accidents was overlayed and spatially joined to the layer representing speeds above 60 Km/hr

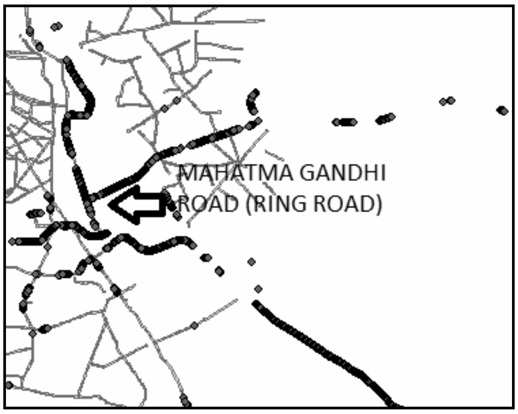


Figure 6. Combined plot of accident hotspots and speeds>60 Km/Hr

From the resulting layer conclusion was drawn that Mahatma Gandhi Road along Ring Road recorded maximum number of high-speed accidents.

These accidents have the highest probability of being fatal. Hence, precautions should be taken accordingly.

E. Variation of Deceleration and Acceleration Profiles near intersections

The deceleration and acceleration profiles of different volunteers were found to vary depending on age and gender.

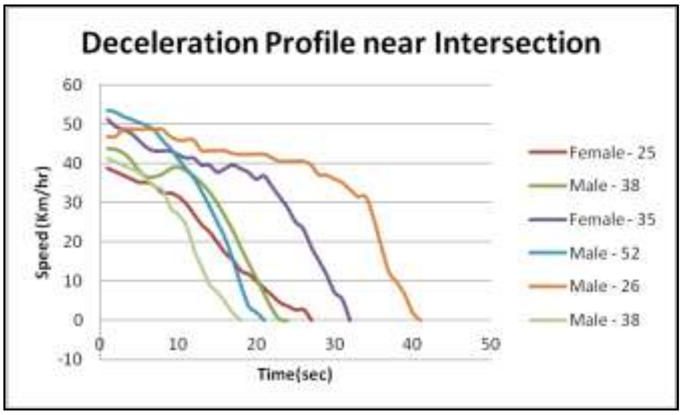


Figure 7. Deceleration profile near intersections for both genders and various ages

The deceleration plots provided the following interpretations:

•Females have a tendency to decelerate more gradually than males. This is evident from the gentle slope of the deceleration profiles of females as compared to males.

•Younger males tend to start decelerating much later as compared to their older counterparts.

However, all males have relatively sudden stops represented by steep curves. This might be unsafe near certain intersections.

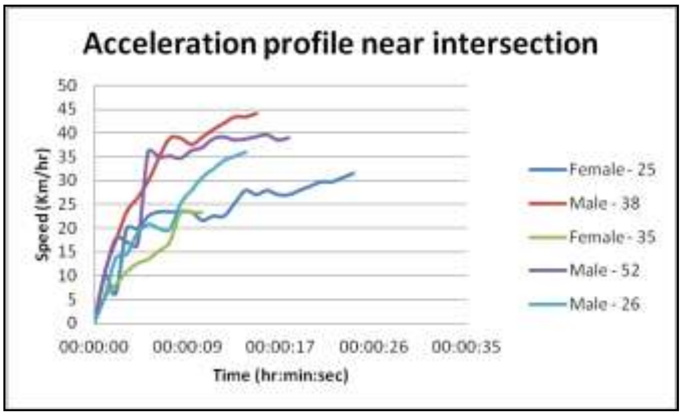


Figure 8. Acceleration profile near intersections for both genders and various ages

The acceleration plots provided the following interpretations:

• The acceleration profile of female drivers after intersection showed more gradual variation in speed as compared to males. The time taken to achieve peak speed is thus longer (around 20 seconds).

• The acceleration profile of males was found to be "jerky" and they reached peak speeds at around 12 seconds.

• There were fewer variations with age as compared to the variations in deceleration profile.

In a city, there may be drivers of different ages and genders driving on the same lane at any time. Hence, non-compatibility between deceleration and acceleration behaviour near intersection may lead to accidents.

IV. CONCLUSION

The study conducted for the city of New Delhi presents five important aspects of transportation modelling and responses to the existing transportation system. Average speed analysis with time of the day infers that average speed during normal traffic hours varies between 15km/hr to around 40km/hr subject to traffic density and signal cycle time. A database was created for overall speed profile on roads of New Delhi. Specific case studies presented corridors where idling and smooth-flowing traffic are prevalent. Accident study was conducted and high-speed accident prone zones in the city were identified. Right of Way (ROW) analysis showed that the current design allows uniform average speeds of around 25-30 km/hr in roads irrespective of carriageway width. This is necessary to avoid congestion at intersections. Finally, driver behaviour analysis was carried out by plotting acceleration and deceleration speed profiles near intersections. It was observed that female drivers had a more gradual and smooth speed variation near intersections as compared to males. Time taken during braking and accelerating was also longer in the case of female drivers. This variation must be analyzed in detail to avoid incidents near intersections in the future.

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