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Effect of Speed Limit Compliance on Roadway Capacity of Indian Expressways

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Abstract

Expressway is an arterial highway for motorized traffic, with divided carriageways for high speed travel, with full control of access and usually, provided with grade separators at location of intersections. Higher design speeds, restriction on slow moving vehicles, varied traffic composition with high amount of cars and no strict lane-discipline characterize these roads. This study aims to evaluate the change in roadway capacity with increasing driver compliance levels within a posted speed limit. It has been found that with increasing driver compliance level for a roadway along with a marginal decrease in the travel times at flow levels nearing capacity. The results of the study may be useful in underlining the importance of driver compliance to a designed speed limit along with its enforcement.

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1. Introduction

Expressways deserve to be treated separately from other categories of roads as these facilities carry only relatively large vehicles such as cars, buses and trucks. Traffic flow on Indian expressways is quite interesting to be studied due to two reasons. First, the traffic is multi-class with vehicles such as cars and pickups with their high maneuverability and heavy vehicles such as trucks and buses. The speeds of these vehicles may vary from 20 to over 100 km/h. Second, in spite of absence of vehicles such as two-wheelers and three wheelers that can clog the traffic during congestion, driving in expressways is said to be quasi-lane disciplined, with some vehicles following a lane-based driving and many others not.

Such a lack of lane discipline can be attributed to combination of factors viz. enforcement and education. Consequently vehicles tend to take any lateral position along the width of roadway, based on space availability. Hence, expressways remain as a partially heterogeneous traffic characterized by poor lane discipline.

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The present study is focused on the impact of driver compliance on the roadway capacity with different posted speed limits. Many parts in Europe and North America are currently using variable speed limits (VSL) systems in which the system senses adverse weather or traffic conditions and then reduces the posted speed limit. The efficacy of these systems is largely dependent on the driver compliance level with the posted speed limit. Currently, these systems are deployed in countries, where traffic conditions are characterized by fairly homogeneous traffic conditions and lane-based behavior, which is significantly different from the traffic conditions, prevailing on Indian Expressways. Although, there is little evidence to suggest that VSL increases capacity flow and safety benefits may be achieved at the expense of increasing travel times. Still, there is an increasing interest in North America and Europe to deploy VSL on freeways with more advanced control strategy and efficient enforcement laws. India is on its path of rapid expansion of its national road network and hence many multi-lane expressways have recently come into existence. So, it becomes important to analyze the efficacy of such systems under Indian Traffic Conditions, as due to the non-lane based driving behavior, the impact of such a system may be entirely different. In this context, the impact of driver compliance on the effectiveness of VSL is particularly important. Currently, there is a very less amount of research literature available on these facilities in India. It is timely to augment research literature on these facilities with many of them already existing and many others coming up. Hence, in this paper to start with an attempt has been done to study the effects of change in driver compliance levels on roadway capacity and travel times near capacity level volume, using simulation model, namely, VISSIM. In the simulation model the posted speed limit is fixed i.e. it doesn’t change dynamically with traffic or weather conditions as in VSL system, on the driver compliance levels are changed. After the accomplishment of the model calibration and calibration process, the simulated model has been used to estimate the roadway capacity for the observed conditions and the hypothetical scenarios of different driving compliance levels at different posted speed limits. Thereafter, the roadway capacity values are compared to study the impact of driving compliance. In the last section, the effect on the travel times for the big cars has been studied at different driving compliance levels.

2. Literature Review

It was found from the review of research literature that there are very few works on the operation of expressways in India despite their evident differences from other facilities in operational speed, access control and vehicle class distribution. All of the present literature available is mostly from North America and Europe. Ulfarsson et al. (2005) evaluated the impact of variable speed limits posted on I-90 near Snoqualmie Pass, Washington State, by using empirical data. The study concluded that using variable speed limits significantly reduced mean vehicle speeds, but no consistent impact on variation on speed was found. Furthermore, driver response to this VSL system is not likely transferable to general VSL systems, given the unique nature of the Snoqualmie Pass geometry, terrain, and weather. Park and Yadlapati (2003) conducted a simulation study of VSL in work zones in Virginia by using VISSIM. They considered three different levels of speed compliance in which 70, 80, or 100% of the vehicles complied with the posted speed. No evidence was given to indicate which of these three compliance levels is most likely to be achieved in practice nor was the distribution of speeds associated with a given posted speed limit described. Lee and Abdel-Atty (2008) used a driver simulator to examine the behaviour of 86 participants as they drove an 8-km freeway section along which they encountered variable message signs (VMS) warning of downstream speed changes implemented via VSL. The study showed that the presence and type of message displayed on the VMS had a significant impact on the level to which drivers complied with the downstream speed. The researchers [For example: Matsuhashi et. al. (2005)] used simulation model, VISSIM, for assessing the benefits of different transportation systems and management. For modelling traffic flow simulation has been recognized as one of the best tools under homogeneous as well as heterogeneous conditions. Fellendorf and Vortisch (2001) presented the possibilities of validating the microscopic traffic flow simulation model VISSIM, both on a microscopic and a macroscopic level in
homogeneous flows. Hossain (2004) calibrated the heterogeneous traffic model in VISSIM to match saturation flows measured by video at an intersection in the city of Dhaka, Bangladesh. Ishaque and Noland (2009) demonstrated the feasibility of modelling vehicle-pedestrian interactions using VISSIM.

Mathew and Radhakrishnan (2010) presented a methodology for representing non-lane-based driving behaviour and calibrating a micro-simulation model for highly heterogeneous traffic at signalized intersection. Calibration parameters were identified using sensitivity analysis, and the optimum values for these parameters were obtained by minimizing the error between the simulated and field delay using genetic algorithm. Velmurugan et al. (2010) studied free speed profiles and plotted speed-flow equations for different vehicle types for varying types of multi-lane highways based on traditional and microscopic simulation model VISSIM and subsequently estimated roadway capacity for four-lane, six-lane and eight-lane roads under heterogeneous traffic conditions with reasonable degree of authenticity. Bains et al. (2012) modelled the traffic flow on the Mumbai-Pune Expressway using simulation technique (VISSIM) and estimated the passenger car equivalents (PCE) of different vehicle types. Though, it is very clear that not much literature is available regarding the impact of driver compliance on roadway capacity, under prevailing conditions in India, the importance and the future application of such system cannot be ignored. High driver compliance with posted speed limits may have following positive effects: (i) Reduction in pollution due to increased flow efficiency; (ii) Studies have indicated the increase in road safety with increasing compliance levels [Hellinga and Mandelzys (2011), (iii) Very Useful in adverse weather conditions; (iv) Increase in life of the road, and (v) Increment in roadway capacity.

3. The Simulation Model

Simulation is one of the well-known techniques to study traffic flow and its characteristics. Simulation gives us the advantage of being able to study how a validated simulation model behaves dynamically over time and space for a given duration. Traffic characteristics on roads as a system vary with time and space, with considerable amount of randomness and simultaneous interactions. Given this, the results obtained through a validated simulation model can be equally accurate as obtained through analytical techniques. Traffic data in the form of videos collected from the selected study stretch was analyzed and this information was used for building the simulation model in the software VISSIM 5.40. Then, the model was calibrated and validated for rendering it suitable for replicating the observed conditions at site. Using this validated simulation model, roadway capacity was estimated for various scenarios of driver’s compliance levels.

3.1 Model Calibration and Validation

Model calibration is an iterative process of comparing the model to reality, making adjustments (or even major changes) to the model, comparing the revised model to real conditions, making additional adjustments, comparing again, and so on. The comparison of the model to reality is carried out by tests that require data on the system’s behaviour plus the corresponding data produced by the model. The input data required for the above-mentioned heterogeneous traffic-flow model are related to four aspects viz. road geometrics, traffic characteristics, driver reaction time and vehicle performance. The power of simulation as a tool for the study of traffic flow lies in ability of the model to include the effect of the random nature of traffic. Hence, the random variables associated with traffic flow such as headway distribution are expressed as frequency distributions and input into the simulation model. These data pertaining to one direction of traffic flow, was collected at a selected stretch of an expressway for model calibration and validation purposes.

Study Stretch: The road stretch selected for the study is Mumbai-Pune Expressway in Western India. The location for data collection is located near km 9/100 from Pune city. The study stretch was selected after conducting a reconnaissance survey such that it satisfies the following conditions: (1) The stretch should be fairly straight, (2) Width of roadway should be uniform and (3) There should not be any direct access from the adjoining areas. The study stretch is a six lane divided road with a central median of 5.0 m width. The width of
main carriageway in one direction of traffic flow is measured as 10.5 m and the paved shoulder width is measured as 1.5 m.

**Data Collection:** The field data input required for the model were collected at the above location with the help of a digital video camera for capturing the traffic flow movement for a total duration of one hour. The video was then analyzed at a speed one-eighth of the actual speed to enable recording and measurement of data. For the study hour, the traffic volume observed was 1087 vehicles per hour whose composition is given in Column (2) of Table 1. The speeds of the different categories of vehicles were measured by noting the time taken by the vehicles to traverse a trap length of 30 m. The free speeds of the different categories of vehicles were also measured for the traffic under free-flow conditions.

The observed maximum, minimum and mean speeds of various classes of vehicles and the corresponding standard deviations are shown in columns (3), (4), (5) and (6) respectively of Table 1. The overall dimensions of all categories of vehicles are shown in columns (7) and (8) of Table 1. Any vehicle moving in a traffic stream has to maintain sufficient lateral clearance on the left and right sides with respect to other vehicles/ curb/ median to avoid side friction. These lateral clearances depend upon the speed of the vehicle being considered, speed of the adjacent vehicle in the transverse direction, and their respective vehicle categories.

The minimum and maximum values of lateral-clearance share, adopted from study by Arasan and Koshy (2005), are given in columns (9) and (10) of Table 1, respectively. The minimum and the maximum clearance-share values correspond to zero speed and free speed conditions of respective vehicles respectively. The acceleration values of the different categories of vehicles over different speed ranges used for simulation are shown in Table 2.

Table 1: Input data for heterogeneous traffic flow conditions.

| Vehicles | Composition | Observed Speeds(km/hr) | Vehicle dimension(m) | Lateral clearance share(m) |
|----------|-------------|------------------------|----------------------|---------------------------|
|          |             | Max. Speed (3) Min. Speed (4) Mean speed (5) Std. Deviation (6) Length (7) Width (8) Min. (9) Max. (10) |
| Truck    | 4.60        | 69 48 60 9.36 8.5 2.5 0.4 0.8 |
| Bus      | 3.80        | 93 64 79 17.25 11.4 2.5 0.4 0.8 |
| Small Car| 42.68       | 97 69 81 12.40 4.4 1.6 0.3 0.7 |
| Big Car  | 43.51       | 102 78 90 11.70 4.9 1.9 0.3 0.7 |
| MAV      | 1.90        | 62 40 53 12.53 8.0 3.0 0.4 0.8 |
| LCV      | 3.40        | 80 63 73 8.67 6.0 1.9 0.3 0.7 |

Note: MAV - Multi-Axle vehicles LCVs – Light Commercial Vehicles

Table 2: Acceleration Values for different vehicle categories

| Vehicle Type | 0-30km/hr(m/s²) | 30-60km/hr(m/s²) | Above 60km/hr(m/s²) |
|--------------|----------------|-----------------|-------------------|
| Small Car    | 2.20           | 1.90            | 1.20              |
| Big Car      | 2.50           | 2.10            | 1.40              |
| Bus          | 1.10           | 0.70            | 0.50              |
| Truck        | 1.00           | 0.58            | 0.34              |
| LCV          | 1.30           | 0.90            | 0.60              |
| MAV          | 0.80           | 0.60            | 0.30              |

Note: MAV - Multi-axle vehicles LCVs – Light Commercial Vehicles

### 3.2 Simulation Model Development

A model which accurately represents the design and operational attributes of the study stretch in the simulation software is known as the ‘base model’. The design attributes can be road configuration (carriageways, medians & shoulders), horizontal curvature and vertical gradient. Operational attributes can be the vehicle or driver characteristics and the traffic flow data. When the base model is calibrated and validated to replicate the actual or
ground conditions, such models can be used to study different characteristics that were not defined by the user as an input. For example, the width of the road can be defined and in turn the capacity of this road could be measured. The validated base model can also be used to develop a simulated scenario which is desired to be known. The base model development involves the following steps: (i) Development of Base Link/Network, (ii) Defining Model Parameters, (iii) Calibrating the Network, and (iv) Validating the Model.

(i) Development of Base Link/Network: Development of a link/network that accurately depicts the physical attributes of a test site is an important stage in the modelling process. The basic key network building components in VISSIM are links and connectors. In the present simulation model, for the purpose of calibration and validation, unidirectional three lane test section link spanning 100.5 m was created representing the study stretch located on the Mumbai-Pune Expressway as explained above. Additionally, extra links of length 200 m each were provided at the beginning and end of the main stretch for buffering process. The test section and the buffer links were joined using the connectors. The buffer links provided the spatial warm up sections for vehicles entering and exiting the test section thereby ensuring accurate results. After the validation, the length of the link was increased to 1000 m for estimating roadway capacity.

(ii) Defining Model Parameters: Vehicle model, deals with defining the dimensions of each vehicle types, which are plying on the test stretch and hence, considered for the simulation. It is also used to define the acceleration values of vehicles. The dimensions, namely, the width and the length were considered for the present simulation model as per the description given in Table 1. The acceleration values were given as per Table 2. Desired speed distribution: The desired speed distribution for each vehicle category was given as input for the simulation model in VISSIM. The maximum and minimum values of the speeds and distribution between these values were defined in the model. The desired distribution curve for any vehicle category is generally an ‘S’ shaped curve. Adequate care was taken to ensure that the speed distribution defined in VISSIM represented the values observed in the field.

Vehicle composition and Vehicle Flow: Vehicle composition and vehicle flow based on field observations was given as an input to simulation model for the given time interval.

Driving behaviour characteristics: The driving behaviour characteristics mainly include these three features viz. car following behaviour, Lane Change and lateral distance. The psycho-physical driver behaviour based Wiedermann-99 Car-following model has been used for simulating the vehicle following behaviour. The VISSIM 5.40 user manual clearly instructs to use the Wiedermann-99 Car-Following model for traffic conditions such as freeways, motorways or expressways. For defining the lateral distance between the vehicles, the location of the vehicle on a lane, minimum lateral distance at different speeds etc. were given as input. Since, many parameters of the driving behaviour differ from vehicle type to vehicle type; each vehicle type was assigned with its own driving behaviour as shown in the Figures 1a and 1b. Values for the various calibration parameters for each vehicle types driving behaviour were given based on information from earlier studies, observation from video recording from the site and trial and error method. Description for the same is given below under calibration of the simulation model.

(iii) Calibration of the Simulation Model: In the present simulation model, the outputs were the hourly average speeds of the vehicles and 5 min average stream speeds for 10 different random seed values. All the simulations were run for a total time of 3900 seconds including a temporal warm-up period of 300 seconds to ensure accurate simulation results. As explained above, a different driving behaviour was considered for each vehicle type to account for heterogeneity in the traffic. There was no strict lane discipline among the vehicles was as observed from the video. Under the ‘Lateral Behaviour’ tab of the Wiedermann-99 Car-following model, firstly by ticking the options ‘Keep Lateral Distance to Vehicles on next lane’, by which vehicles also consider the lateral position of vehicles that are travelling on adjacent lanes and keep the minimum lateral distance. For this purpose, they even adjust their own lateral position in their own lane by drawing aside. The simulation also regards the exact position of the rear ends of vehicles during or after lane change to adjacent lanes. And then option of ‘overtaking is allowed from either side’ is ticked. And lastly Minimum Lateral distances for vehicles passing each other within the same lane and for the lateral distance to vehicles in the adjacent lane are defined for each vehicle class to be passed (Figure 1b). The values for the minimum lateral distance were adopted from an earlier study by
Arasan and Koshy (2005). All these parameters under ‘lateral behaviour’ in combination help to model the non-lane based behaviour accurately.

Under the ‘following’ tab the minimum look-ahead and look-back distance which defines the distance a vehicle can see forward in order to react to vehicles in front or to the side of it set to a value of 40 m was found to be appropriate for the present situation. VISSIM (PTV, 2011) user manual, recommends values of at least 20-30 m for the minimum look-ahead distance and for corridors with higher speeds this value is further increased. It was found via trial and error that 40m value worked well for the traffic conditions mentioned in this work. Values for CC0 and CC1 under the following tab decide the average safety distance of a vehicle in following behaviour. CC1 is the parameter which has a major influence on the safety distance and thus affects the saturation flow rate. Values for these 2 parameters for each vehicle type were estimated by carefully observing the video and taking references from previous studies [(Arasan and Koshy (2005); Mathew and Radhakrishnan, (2010)]. Mostly trial and error was done within a range of values for a certain vehicle type. It was observed during the simulation that the overtaking behaviour of cars was not in proximity with what was seen in the video so under the ‘Lane Change’ tab, only the safety distance reduction factor, which reduces the required safety distance during overtaking depicting aggressive behaviour during overtaking/Lane Changing was reduced from 0.6 to 0.5 for Small Cars and Big Cars which produced overtaking manoeuvres similar to as observed on the site. Thus, reducing the safety distance required for overtaking/lane changing to 50% of the value calculated from the values CC0 and CC1 under the ‘car following’ tab. The other values were chosen as per the defaults considered in VISSIM which produced the observed conditions with required accuracy. The estimated values and the observed values were compared and the error was computed. If the error is within the limits, the calibration process was stopped or otherwise the parameters were modified and simulation runs were carried out again. This process is repeated and the simulation runs were made till the error was within the satisfactory limits. The calibration process in the form of a flow chart is shown in Figure 2.

(iv) **Validation of the Simulation Model:** Validation is the process of checking the results obtained from the calibrated model in terms of simulated values against field measurements for parameters such as average speeds. The observed traffic volume and composition was given as an input to the simulation process. Average hourly speeds of all vehicle types and 5-min average stream speeds, were calculated from 10 simulation runs with different random seeds. The inter-arrival time gaps of the heterogeneous traffic flow (similar to headway of homogeneous traffic) of vehicles was assumed to follow negative exponential distribution (Arasan and Koshy, 2003) and the free speeds of different categories of vehicles, based on the results of an earlier study (Velmurugan
et al. 2010), was assumed to follow normal distribution. To check for the validity of the model, the hourly vehicle speeds simulated by the model were compared with the field observed speed values for each vehicle category as shown in Figure 3 and 5-min average stream speeds of all vehicle types were compared with the field observed values as shown in Figure 4. It can be seen that the simulated speed values are quite closer to the speeds observed from the field for all the vehicle categories. A paired t-test yielded (for figure 4) the calculated value of t-statistic (t0) as 0.535. The critical value of t statistic for a level of significance of 0.05 for 5 degrees of freedom obtained from standard t-distribution table is 2.571. And a paired t-test (for Figure 5) yielded the calculated value of t-statistic (t0) as 0.598. The critical value of t statistic for a level of significance of 0.05 for 4 degrees of freedom obtained from standard t-distribution table is 2.201. This implies that there is no significant difference between the observed and simulated speeds.

4. Model Application

In this study, the application of the model is to study the variation in the roadway capacity of Indian Expressways for the traffic flow (comprising of six vehicle categories), under varying speed limits (80 Km/h, 70 Km/h and 60 Km/h) and different driver compliance levels (10%, 30%, 50%, 70% and 90%). The above speed limits were chosen to take into account varying traffic, roadway and weather conditions, which may require lowering the speed limit. To implement the driver compliance model in VISSIM, duplicate vehicle classes were created for all
vehicle classes with scenarios: (a) desired speeds which are greater than the hypothetical posted speed limit (for non-complying driving behaviour), and (b) desired speed decisions were created with speeds less than the given posted speed limit (for complying driving behaviour).

Then, when assigning composition to the model, percentage of vehicles not complying with the posted speed limit are assigned the desired speed (scenario-a) as per its vehicle class and the percentage of vehicles complying with the posted speed limit are given the desired speed decision (scenario-b) according to the posted speed limit. For example: If compliance level is 50% and composition of Big Car is 44% then 22% for Big Cars were assigned desired speeds according to scenario (a) and the rest 22% of Big Cars (the duplicate vehicle class) were assigned desired speeds according to scenarios (b). Separate vehicle classes are created to obtain results separately for drivers complying and not complying within a same vehicle class. The methodology for calculating results is shown in the form of a flow chart in Figure 5.

![Figure 5: Flowchart for studying the Impact of driver compliance](image)

4.1 Speed-Flow relationships and Capacity

In this study, roadway capacity was estimated from speed-flow relationship using the validated simulation model for a heterogeneous flow with vehicle composition and roadway conditions same as that observed in the field and for scenarios with different posted speed limits and driver compliance levels, the comparisons of which are shown in figures 6a, 6b and 6c. The average speed of the stream was plotted for different simulated volumes, starting from near-zero to the capacity of the road. The following procedure was adopted for finding the capacity of the facility for developing the above speed-flow relationships. An example of a speed-flow relationship thus developed is shown in the Figure 6d for speed limit of 60 km/h with different driver compliance levels of 10%, 30%, 50%, 70% and 90%. It is clear from the figures that the curves follow the established trend and the roadway capacity generally increases with increasing driver compliance levels for all speed limits. The values of the change in capacity obtained using the simulation for the above mentioned scenarios are given in Table 3.

| Speed Limit 60 Km/hr | Speed Limit 70 Km/h | Speed Limit 80 Km/h |
|----------------------|----------------------|----------------------|
| DC                   | C                    | X                    | Y                    | C | X | Y | C | X | Y |
| 10% 5635             | -0.74                | 5603                 | -1.32                | 5623 | - | -0.96 |
| 30% 5685             | 0.14                 | 5588                 | -1.59                | 5549 | -1.32 | -2.30 |
| 50% 5753             | 1.34                 | 5596                 | -1.44                | 5620 | -0.05 | -1.01 |
| 70% 5897             | 3.88                 | 5696                 | 0.34                 | 5816 | 3.43 | 2.39 |
| 90% 6037             | 6.34                 | 5861                 | 3.14                 | 5975 | 6.26 | 4.99 |
| CO 5676              | -                    | 5676                 | -                   | 5676 | - | - |

Note: DC – Driver Compliance Level, C – Roadway Capacity (vehicles/hour), X – Percentage change in capacity with respect to Compliance level 10%, Y – Percentage change in capacity with respect to Observed Conditions, CO – Estimated Roadway capacity in observed traffic conditions (Vehicles/hour)

For calculating travel times, the travel time function of VISSIM was used, in which a travel time section of length 1000 m was coded in the network for evaluation. Figures 7a, 7b and 7c show the variation of travel times with increasing driver compliance levels for different speed limits. It is observed that there is a marginal decrease...
in the travel times at volumes near the capacity, with increasing driver compliance levels, which is also shown in Table 4 for a vehicle type, big cars, as an example.

| DC | TT for Speed Limit 60 km/hr (sec) | TT for Speed Limit 70 km/hr (sec) | TT for Speed Limit 80 km/hr (sec) | TT for OC (sec) |
|----|---------------------------------|---------------------------------|---------------------------------|----------------|
| 10%| 84 C 80 NC 81 C 79 NC 81 C 79 NC 81 C 79 NC 81 C 81 BC | 10%| 81 C 79 NC 81 C 79 NC 81 C 79 NC 81 C 79 NC 81 C 81 BC | 10%| 80 C 78 NC 80 C 78 NC 80 C 78 NC 80 C 78 NC 80 C 80 BC | 10%| 75 C 73 NC 75 C 73 NC 75 C 73 NC 75 C 73 NC 75 C 82 BC |
| 30%| 80 C 79 NC 81 C 79 NC 81 C 79 NC 81 C 79 NC 81 C 81 BC | 30%| 80 C 79 NC 80 C 79 NC 80 C 79 NC 80 C 79 NC 80 C 80 BC | 30%| 78 C 77 NC 78 C 77 NC 78 C 77 NC 78 C 77 NC 78 C 82 BC | 30%| 80 C 78 NC 80 C 78 NC 80 C 78 NC 80 C 78 NC 80 C 82 BC |
| 50%| 80 C 79 NC 80 C 79 NC 80 C 79 NC 80 C 79 NC 80 C 80 BC | 50%| 80 C 79 NC 80 C 79 NC 80 C 79 NC 80 C 79 NC 80 C 80 BC | 50%| 78 C 77 NC 78 C 77 NC 78 C 77 NC 78 C 77 NC 78 C 82 BC | 50%| 80 C 78 NC 80 C 78 NC 80 C 78 NC 80 C 78 NC 80 C 82 BC |
| 70%| 79 C 76 NC 79 C 76 NC 79 C 76 NC 79 C 76 NC 79 C 82 BC | 70%| 80 C 77 NC 80 C 77 NC 80 C 77 NC 80 C 77 NC 80 C 82 BC | 70%| 79 C 77 NC 79 C 77 NC 79 C 77 NC 79 C 77 NC 79 C 82 BC | 70%| 79 C 77 NC 79 C 77 NC 79 C 77 NC 79 C 77 NC 79 C 82 BC |
| 90%| 75 C 73 NC 75 C 73 NC 75 C 73 NC 75 C 73 NC 75 C 82 BC | 90%| 75 C 73 NC 75 C 73 NC 75 C 73 NC 75 C 73 NC 75 C 82 BC | 90%| 75 C 73 NC 75 C 73 NC 75 C 73 NC 75 C 73 NC 75 C 82 BC | 90%| 75 C 73 NC 75 C 73 NC 75 C 73 NC 75 C 73 NC 75 C 82 BC |

*Note: DC – Driver Compliance Level, C – Travel time (sec) for Big Car Complying with speed limit, NC – Travel time (sec) for Big Car Not-Complying with speed limit, BC- Big Car, OC – Observed Condition, TT- Travel time*

Figure 6a: Change in roadway capacity – 60 Km/hr

Figure 6b. Change in roadway capacity – 70 Km/hr

Figure 6c. Change in roadway capacity – 80 Km/hr

Figure 6d. Speed-flow relationship

Figure 7a.

Figure 7b.

Figure 7c.

*Note: Figure 7a, 7b and 7c represent the comparison of travel times for complying and not complying big cars at different posted speed limits with different driver’s compliance levels with volumes nearing capacity. CL – Compliance Level*
5. Findings

The results presented in this study are based on the reasonably validated model (using best possible available traffic flow condition data observed on the selected study stretch); the outcome of the present study is to highlight the importance of having enforcement on maximum speed limit compliance. It is found that, the estimated roadway capacity generally increases as percentage of vehicles complying with the posted speed limit increases. It is also observed that for driver compliance levels more than 50%, for speed limits 70 and 90 Km/h, the roadway capacity increases as compared to the roadway capacity estimated for observed conditions used in this study. It is further found that the travel times decrease marginally with increasing driver compliance levels for volumes nearing capacity. Thus, these results indicate that the flow efficiency improves, when more number of drivers comply with posted speed limit, under the traffic conditions prevailing on expressways in India. Thus, it suggests that due to relatively lesser lane-based behaviour under Indian traffic conditions (as compared to the homogeneous traffic conditions prevailing in developed countries); non-complying vehicles are not considerably slowed down as compared to the complying vehicles. Therefore, the non-complying vehicles may tend to take up any lateral position available on the road and thus making overtaking possible on either of the sides of the subject vehicle precarious. This results in decreased travel times for both complying and non-complying vehicles at volumes nearing capacity of the road. On the contrary, as demonstrated in the present study, with increasing driving compliance levels with speed limits, vehicles may tend to make the entire traffic flow much smoother and start to follow more disciplined and safer behaviour because of the desire to drive within the speed limit. Under the traffic conditions prevailing in India as demonstrated in this study, if the non-lane based behaviour allowed, with higher driving compliance level with the posted speed limit, the capacity tends to increase and travel times tend to decrease marginally. So, the effect of maximum speed limit compliance is also optimistic under Indian conditions. This operational efficiency, coupled with its possible safety benefits; it could prove as a very useful strategy, in situations of adverse traffic and weather conditions. The research opens up a window for analysing the effect of driver compliance on roadway capacity for varying traffic composition. The concept can be extended by introducing Variable Speed Limits (VSL) based on the traffic condition and weather conditions.

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