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Simulation Study of Construction Work Zones – A Case Study

R. Vidya**, Dr. S. Moses Santhakumar, Dr. Samson Mathew
Department of Civil Engineering, National Institute of Technology, Tiruchirappalli, India

ABSTRACT

Rapid infrastructure development paves way to widening and strengthening of highways. During this process, construction work zones are encountered. Speed in the construction work zones is a vital factor to be focused upon, especially on highways. If the speed is high, fatal accidents will occur in the work zone and if it is too low, it will contribute towards the delay, followed by increased queue lengths and thereby increased vehicle operating cost (VOC). The variation of speed in different construction work zones during various stages of construction has been studied with a case study of a four-laning project of Trichy-Thanjavur section of NH-67. An attempt has been made to model the construction work zone in VISSIM, a microsimulation software. Simulation models of the work zones were generated with the entities, attributes of entities and activities within the entities involved in the work zone system. The output travel time for different components of the work zones obtained from the simulation run was analyzed and compiled. Validation is done using the travel time data observed experimentally in different work zone sections and a comparison between the observed and simulated results is presented.

Keywords: *Speed, simulation, travel time, VISSIM, work zones.*

****Author for correspondence*** E-mail: vidyarajesh123@gmail.com, Tel: + 91-9944950476

1. INTRODUCTION

The replication of operation of a system is done through a simulation model which makes it possible to study different conditions and parameters in a cost-effective manner. Simulation models are very helpful in evaluating what-if conditions and can be worthwhile especially when stochastic processes are involved. These modeling techniques may be helpful in assessing alternative work zone configurations and identifying the optimal strategy within stipulated timeframe [1].

Traffic simulation models are divided into two categories: macrosimulation and microsimulation models. Macrosimulation models assess the traffic flow as a whole without considering the interactions of the individual vehicles in the traffic stream. Microsimulation tools model the individual vehicles interactions in a car. Following logic and algorithms are incorporated to show how each vehicle moves.

Cost and planning are vital factors that affect the use of these modeling tools. Microsimulation modeling is more costly than macrosimulation and requires more time and data to complete the model and conduct the analysis. Simulation indicates the condition that reflects the actual field conditions.

Freeway lane closures were examined at work zones. The simulation study indicated that there were problems when the volumes increased the open-lane capacity [2]. A computer model QUEWZ is developed to estimate the user costs caused by lane closures [3].

Computer simulation modeling has become a powerful tool for studying the complex traffic system when empirical approach cannot adequately define the response pattern. Traffic flow modeling aims at deriving relationships based on the parameters affecting the flow, having the road capacity to depict the characteristics of traffic stream [4]. The traffic behavior at freeway work zones and at highway work zones were simulated and came up with the recommendations for the control procedures at such sites [5]. Speed flow curves suitable for work zones were developed from 30 hours of data collected from 11 work zones in order to determine the operating speed [6].

A mesoscopic-wavelet model for simulating traffic flow patterns and extracting congestion characteristics in freeways work zones was proposed [7]. A microsimulation model for freeway work zone network using VISSIM was developed [8]. The study was conducted to choose the driving behavior parameters. The VISSIM microsimulation models were used to evaluate the capacity for early merge conditions of a work zone [9].

A new simulation model, two-lane two-way highway SIMulator (TWOSIM) that could estimate capacity for various traffic and design conditions was developed [10].

An attempt has been made to model the construction work zones in highways where lane extension work is going on. The study focuses on the variation of average speed of the vehicles in different work zones of varying lengths in different stages of lane extension. This study's significance lies in deciding the critical length of the work zones which will help in minimizing the delay and congestion in that work zone.

2. CONSTRUCTION WORK ZONE

A construction zone can be defined as an area of the highway which involves the conflict of the right of use between the road users and authority responsible for the maintenance of the highway. In the construction zones, distinct zones with different features were observed. These zones were divided by manual on uniform traffic control devices (MUTCD) into four namely, advance warning zone, approach transition zone, activity (working) zone and terminal transition zone as shown in Figure 1 [11].

3. METHODOLOGY

The present study involves the survey and data collection of spot speed during different stages of widening of a highway. The variations in speed during different stages are studied, analyzed and simulated. The methodology adopted is shown in Figure 2.

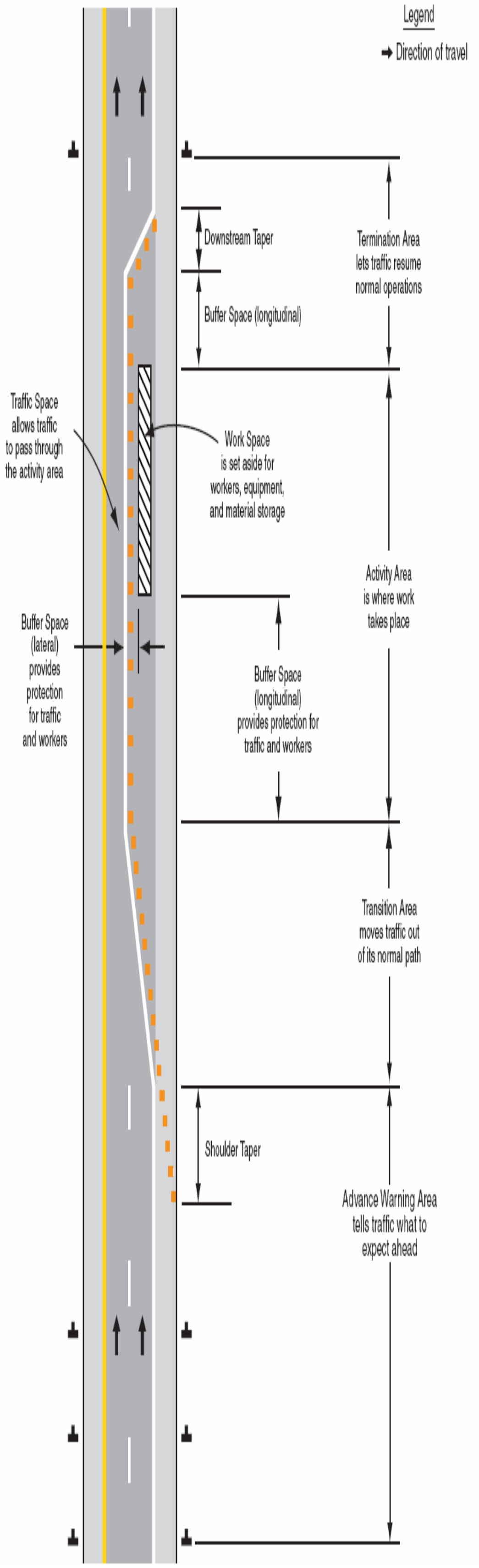

Fig. 1: Component Areas of a Highway Work Zone. Source: MUTCD (2003)

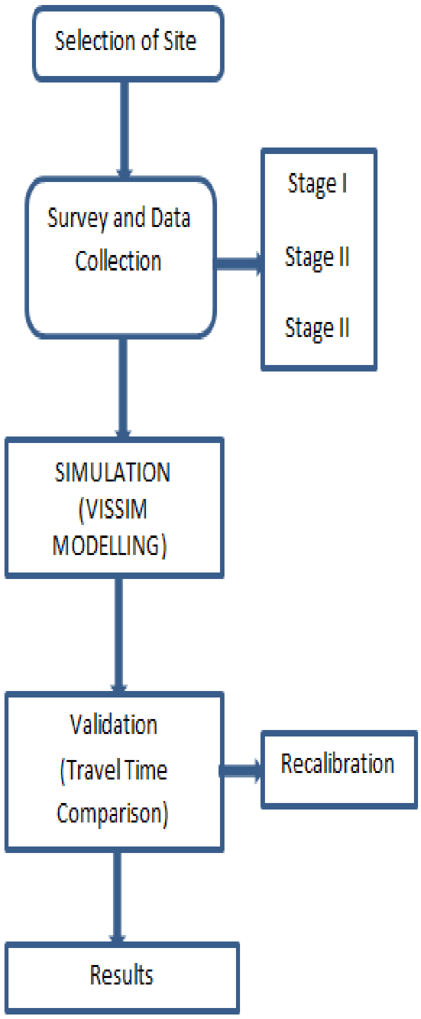

Fig. 2: Flowchart Showing Methodology Adopted for the Study.

4. WORK ZONE SIMULATION MODEL

First of all, a case study on the speed variation in work zones was conducted in the various construction zones of Trichy-Thanjavur section of National Highway-67. On the basis of the speed distribution data obtained from the case study, a work zone model was generated in the VISSIM microsimulation software. The work zone system was first defined with the entities involved in the work

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zone system, attributes of the entities and activities between entities. The strategy was then defined to find the critical length of the work zones in the construction work zones. Simulation models of varying lengths of the work zone were created in VISSIM. For each model generated in VISSIM, six simulations were run for one hour duration. The output travel time for different components of the work zones obtained from the simulation run was analyzed and compiled. The model thus generated was validated using the travel time data observed experimentally in different work zone sections on NH-67. Finally, a comparison was made between the observed and simulated results. The simulation model of a construction work zone is depicted in Figure 3. Various stages of the work zone were located in NH-67 as shown in Figures 4–7. To know the speed variation in different components of the work zones, a spot speed survey was conducted using long base method in those zones.

4.1. Modeling in VISSIM

VISSIM, which is part of the PTV vision transport modeling suite, is a powerful microsimulation tool which allows the user to display and visualize complex traffic flow in a clear graphical way. VISSIM requires different vehicle characteristics, roadway characteristics, traffic characteristics, and driver characteristics as inputs to the model. The major inputs to VISSIM for modeling the construction work zone are: (i) Simulation Parameters, (ii) vehicle characteristics, (iii) traffic composition, (iv) driver characteristics, (v) road geometrics, (vi) traffic volume, (vii) desired speed distribution of the vehicles [12,13].

O – origin; Z1 – advance warning zone; Z2 – approach transition zone; Z3 – work zone; Z4 – terminal transition zone; D – destination

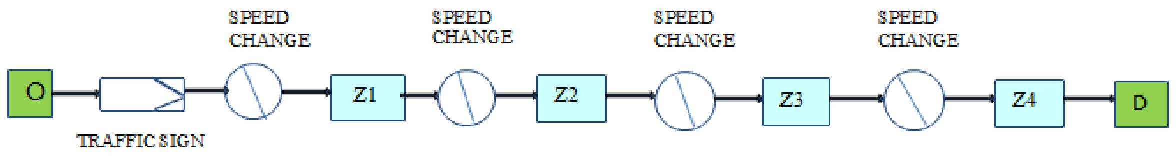

Fig. 3: *Typical Simulation Model of a Construction Work Zone.*

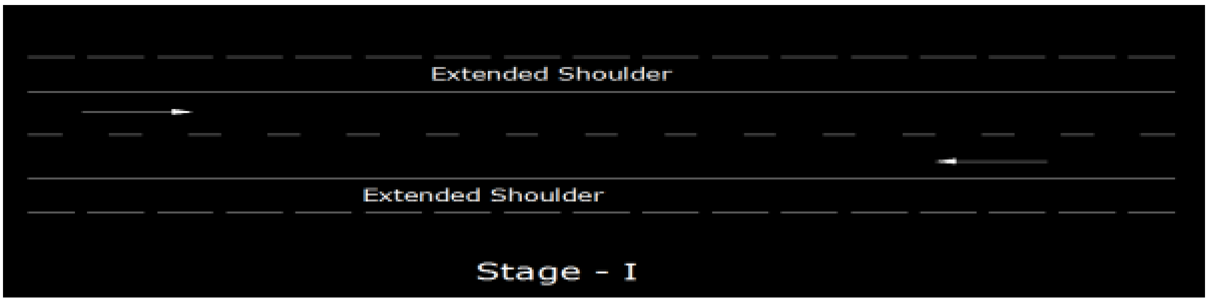

Fig. 4: *Stage-I of the Construction in Four Laning.*

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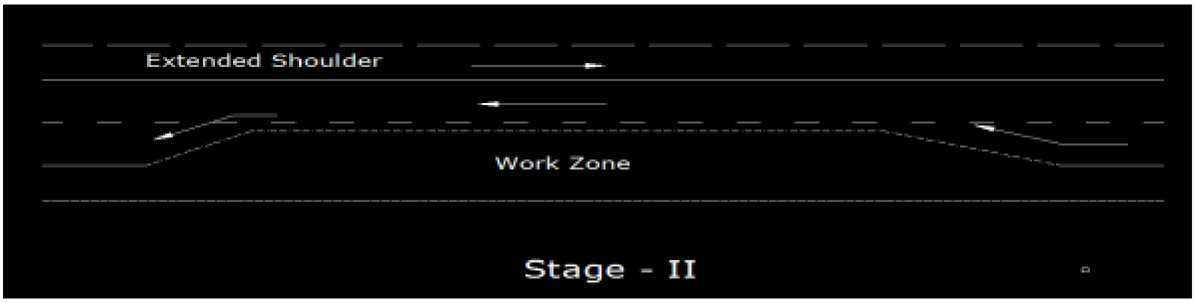

Fig. 5: *Stage-II of the Construction in Four Laning.*

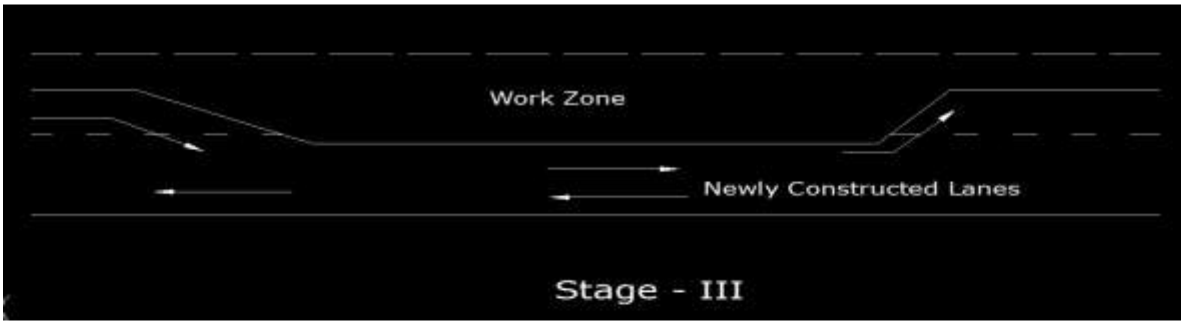

Fig. 6: *Stage-III of the Construction in Four Laning.*

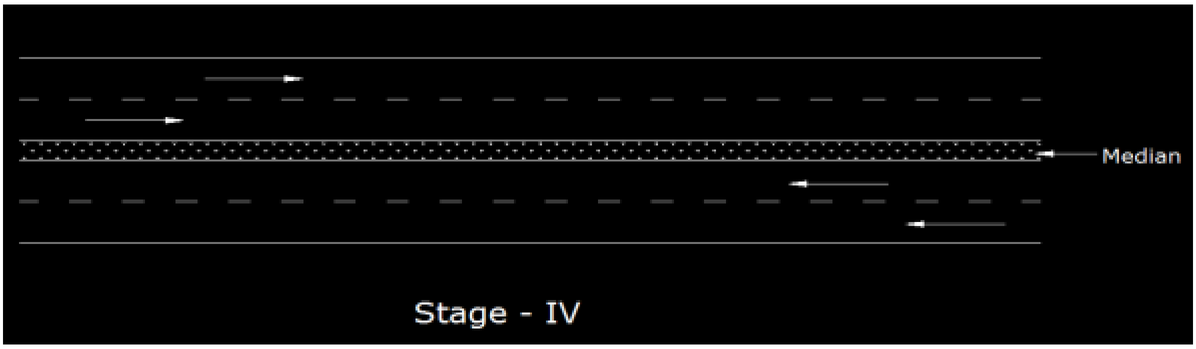

Fig. 7: *Stage-IV of the Construction in Four Laning.*

5. RESULTS AND DISCUSSION

To know the speed variation in different components of the work zones, a spot speed survey was conducted using long base method in those zones. After conducting the surveys at selected sites of rural and urban areas, the data collected were analyzed and the results obtained from the data are presented as follows.

5.1. Comparison of Speed in Different Components of Construction Zones

Figure 8 shows average speeds in different construction stages. It can be seen that speed of the vehicles drops considerably while passing through the transition area from the advance warning area.

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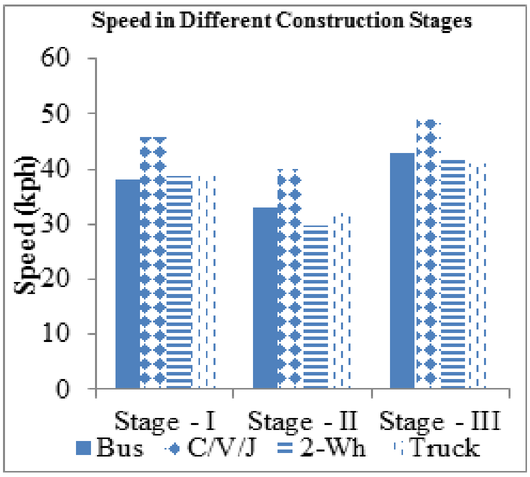

Fig. 8: *Average Speeds in Different Construction Stages.*

5.2. Comparison of Average Speed of Vehicles

There is a difference between the average speed of vehicles obtained from the spot speed survey and that obtained from the simulation run. The average speed comparisons are shown in Figure 9.

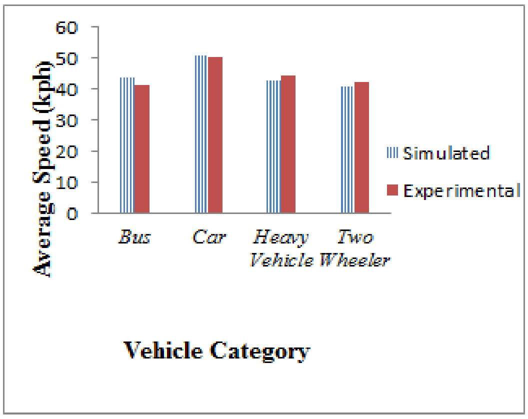

Fig. 9: *Average Speed Comparisons (experimental and simulated).*

5.2.1. Average Speed versus Length of the Work Zone

The average speed of the vehicles in a work zone depends on the length of that particular work zone. It can be observed from Figure 10 that the average speeds of vehicles are increasing with the increase in the lengths of the work zone up to 730 m. After that particular point, the average speed remains constant even if length of the work zone is increased.

The point beyond which the speed does not increase with the increase in the length of the work zone is termed as "Critical Length" and is found to be 730 m. Hence, for Stage-II of construction, the critical length obtained experimentally is found to be 730 m.

It can be observed from Figure 11 that the average speeds of vehicles are increasing with the increase in the lengths of the work zone up to 710 m. After that particular point, the average speed remains constant even if length of the work zone is increased. The point beyond which the speed does not increase with the increase in the length of the work zone is termed as "Critical Length" and is found to be 710 m.

The average speeds of different categories of vehicles in different components of the work zones obtained experimentally and obtained from the simulation run are compared in Table I.

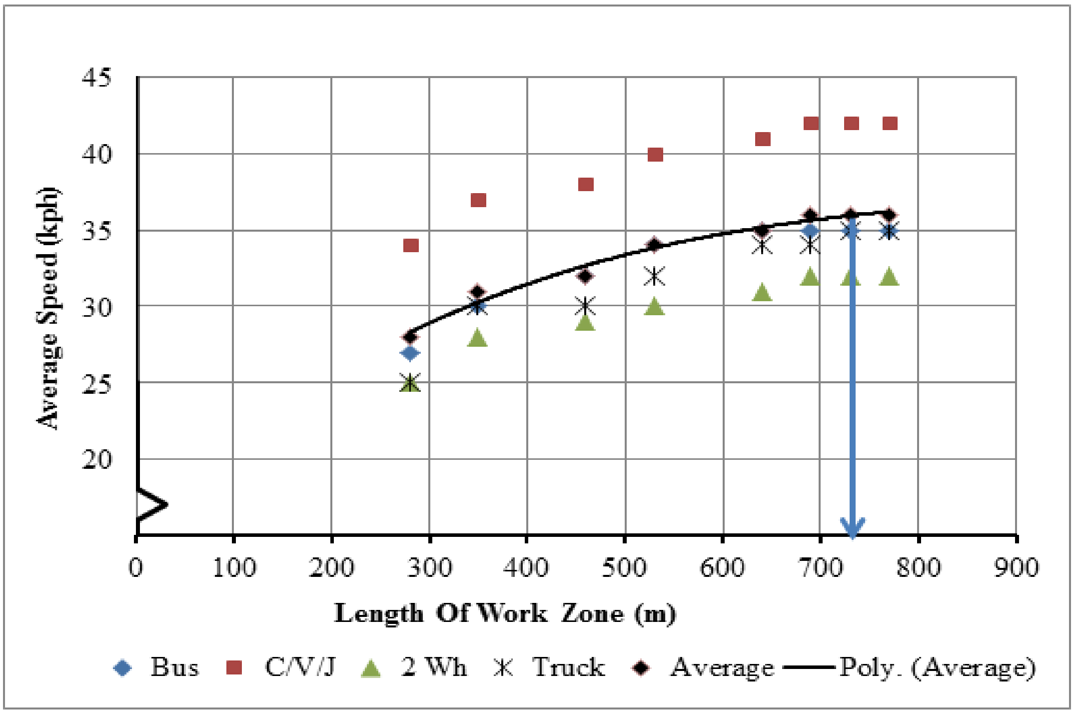

Fig. 10: *Average Speed versus Length – (Experimental Stage-II).*

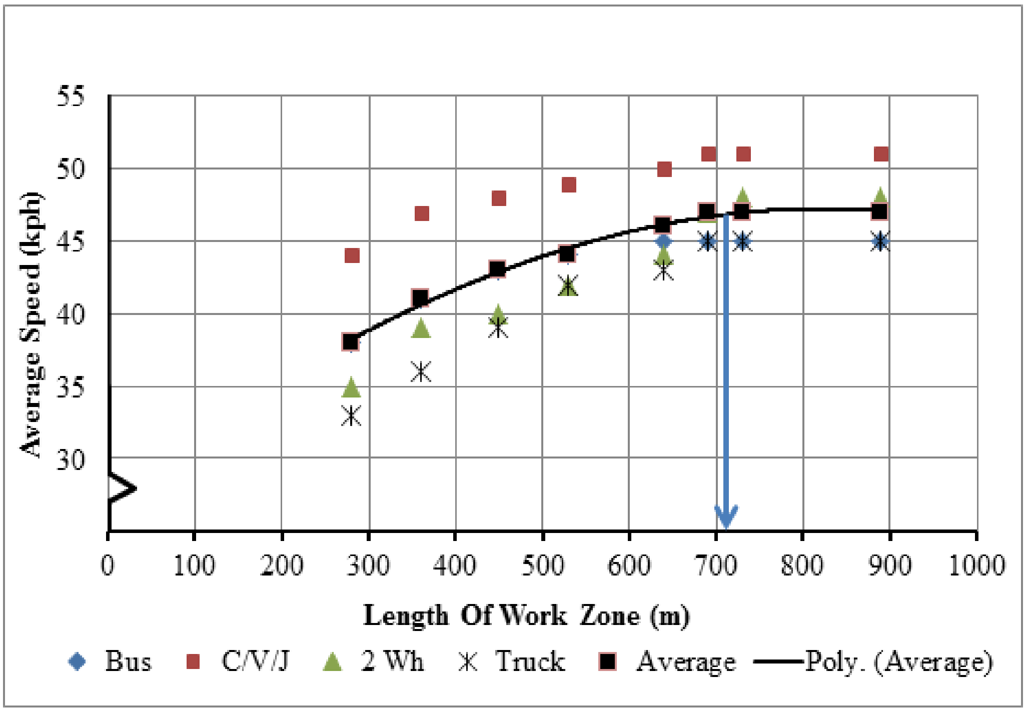

Fig. 11: *Average Speed versus Length – (Experimental Stage-III).*

Table I: *Comparison of the Average Speed (Observed and Simulated).*

Vehicle Category	Average Speed (kph)											
	Advance Warning Area			Approach Transition Area			Activity Area			Terminal Transition Area		
	Observed	Simulated	% Error	Observed	Simulated	% Error	Observed	Simulated	% Error	Observed	Simulated	% Error
Bus	44	41.5	-5.68	39	41.2	5.64	37	39.5	6.75	38	39.6	4.21
Car	51	50.2	-1.56	44	46.7	6.13	42	43.3	3.09	42	44.2	5.23
Heavy Vehicle	43	44.3	3.02	39	42.2	8.02	37	35.7	-3.51	39	41.2	5.64
Two Wheeler	41	42.3	3.17	38	41.6	9.47	36	38.1	5.83	37	39.6	7.02

Table II: *Average Speed of Vehicles versus Lengths of Work Zone in Stage-II.*

S. No.	Length (m)	Average Speed (kph)				
		Bus	Heavy Vehicle	Car	Two wheeler	All vehicles
1	500	35.5	30.1	38.4	34	34
2	550	36.4	31.5	39.2	35.1	34.8
3	600	36.9	32	39.8	35.9	35.6
4	650	37.8	32.5	40.3	36.2	36.5
5	700	38.9	32.8	40.7	36.9	37.8
6	750	39.1	33.2	40.9	37.5	38.9
7	800	39.1	33.5	41.2	37.5	39.1
8	850	39.1	33.5	41.3	37.5	39.2

Table III: *Average Speed of Vehicles versus Lengths of Work Zone in Stage-III.*

S. No.	Length (m)	Average Speed (kph)				
		Bus	Heavy Vehicle	Car	Two Wheeler	All Vehicles
1	500	40.7	35.0	44.4	39.2	39.9
2	550	41.6	36.4	45.2	40.0	40.8
3	600	41.9	37.0	45.8	41.8	41.9
4	650	42.9	37.7	46.3	42.5	42.5
5	700	43.9	37.9	47.7	42.8	43.4
6	750	44.0	38.1	47.9	43.4	43.9
7	800	44.0	38.2	47.2	43.5	44.0
8	850	44.0	38.2	47.3	43.5	44.0

Tables II and III show the variation of average speed of the vehicles with the variation in the length of the work zones in different construction stages.

It can be observed from Figure 12 that the average speeds of vehicles are increasing with the increase in the lengths of the work zone up to 790 m. After that particular point, the average speed remains constant even if length of the work zone is increased. The point beyond which the speed does not increase with the increase in the length of the work zone is termed as "Critical Length" and is found to be 790 m.

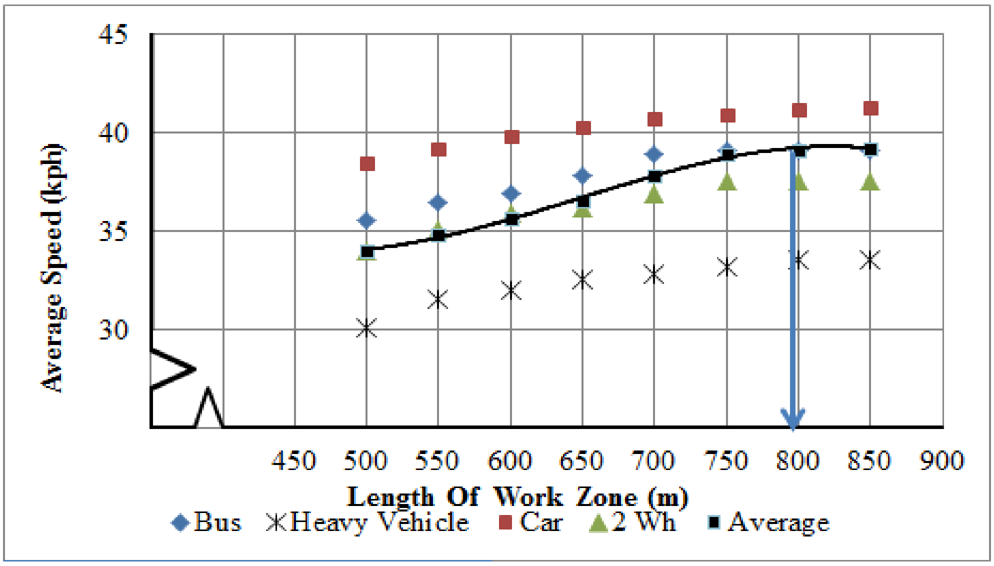

Fig. 12: Average Speed of Vehicles versus Length of Work Zone in Stage-II.

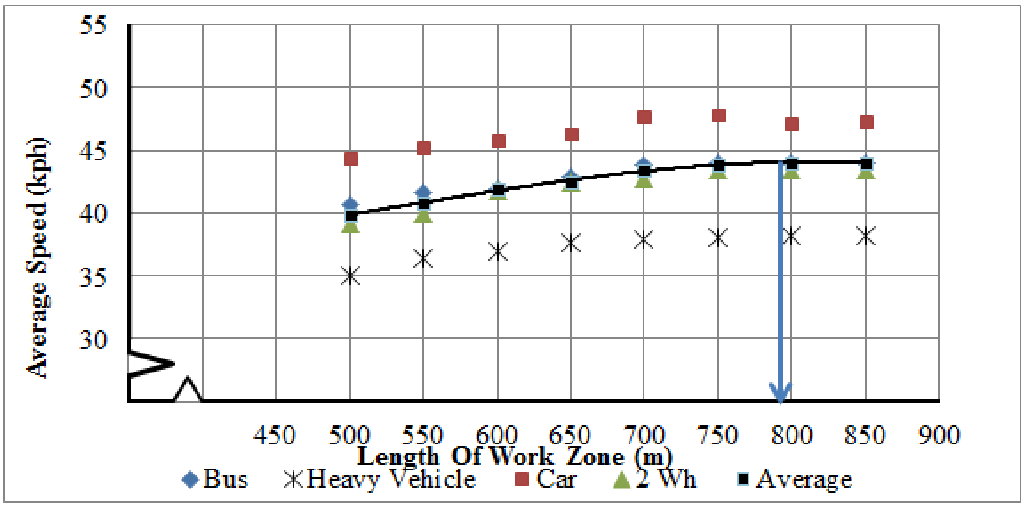

Fig. 13: Average Speed of Vehicles versus Length of Work Zone in Stage-III.

It can be observed from Figure 13 that the average speeds of vehicles are increasing with the increase in the lengths of the work zone up to 780 m. After that particular point, the average speed remains constant even if length of the work zone is increased. The point beyond which the speed does not increase with the increase in the length of the work zone is termed as "Critical Length" and is found to be 780 m. Hence for Stage-III of construction, the optimum length for the maximum speed is found to be 780 m.

6. CONCLUSIONS

The conclusions derived from the study are:

- The average speed of the vehicles at the transition zone of the construction area was reduced by 60% of the speed at the advance warning area.
- Pattern of the speed variation in different components of the construction work zone is same as that for the experimental one.
- Speed decreases from Stage-I to II due to the introduction of the restriction zone and then increases in Stage-III due to the improved riding quality in Stage-III.
- Average speeds of different categories of vehicles obtained from the VISSIM model were found comparable with that obtained experimentally in all the three stages of construction.
- With the increase in length of the work zone, speed increases and after a certain length of the work zone, the speed remains constant. This particular length of the work zone beyond which the speed remains constant is termed as "Critical Length." The critical lengths of the work zone obtained from the VISSIM model are 790 m and 780 m for Stage-II and III respectively which are more than the ones obtained experimentally (730 m and 710 m respectively).

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