QUANTIFYING USER DELAY ON HIGHWAY WORKZONE USING VISSIM

FINAL YEAR PROJECT UG 2011

By

2011-NUST-SCEE-BE-CE-20 – Bilal Shahid Khokhar

2011-NUST-SCEE-BE-CE-45 – Muazzam Ali

2011-NUST-SCEE-BE-CE-47 – Muhammad Abdullah

NUST Institute of Civil Engineering

School of Civil and Environmental Engineering

National University of Sciences and Technology, Islamabad, Pakistan

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This is to certify that the

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2011-NUST-SCEE-BE-CE-47 – Muhammad Abdullah

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Dr. Anwaar Ahmad (Advisor), Dr. Bilal Khurshid (Co. Advisor)

NUST Institute of Transportation

School of Civil and Environmental Engineering

National University of Sciences and Technology, Islamabad, Pakistan

ABSTRACT:

Value of time is a broad term which encompasses a multitude of parameters like "value of goods, services, or some utility produced within a time interval." Transportation experts are mainly concerned about the time saved and the value of each time unit saved. Transportation system in general, is continuously developing and many alterations over the years has increased the travel speed and subsequently, reduced the travel time. The savings achieved with the reduced travel time forms the major component of transportation user benefits. Highway agencies in Pakistan are committed to deliver a massive road infrastructure i.e. Motorways, and Highways, to boost economic activity and provided quality service to the passengers. However, the prevalent road network require exhaustive maintenance at regular interval. For maintenance and rehabilitation of highway infrastructure, workzones have been established by the respective highway agencies. Highway workzone reduces the capacity of that network and increases the travel time, which in turn obstructs the traffic flow. Traffic operation and proper management in work zone is of prime importance. The highway workzones required to improve infrastructure are a source of potential disruption that often impede mobility. Reduced speed limits past the work zones will cause some delays but most of all the road´s capacity significantly reduces in case of lane closures. This in turn, increases the probability of queues formation which may add to total time delay for the road users. These delays aggravate the cost incurred to the society as a whole. Additionally, queues increase fuel consumption, pollutants and risk for accidents. The proposed project aims at quantifying the user delay on highway work zone, by simulating different work zone strategies like lane closure, median crossover, using VISSIM software. In addition, analysis of different components of workzone i.e. median opening, length of work zone and bottle neck effect on the delay is carried out.

ACKNOWLEDGEMENTS

Our respects and unpretentious thanks to Almighty Allah, who granted us enough strength and desire to work and finish the task undertaken by us. We are extremely thankful to our supervisors Dr. Anwaar Ahmad and Dr. Muhammad Bilal Khurshid, without whom this project would never have transmuted into reality. We also want to thanks A/P Malik Saqib.

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

It is a matter of common knowledge that road networks deteriorate with passing time. These roads have a limited life and so many of the prevalent road networks are on the verge of going past the service life. This requires the road administrators to employ resources on large scale to facilitate the necessary rehabilitation projects. However, this will not only put strain on the road agencies' budgets but also impact the road users and the society in general.

There have been rising concerns over the increased road user costs due to extensive maintenance activities being performed to restore and extend the structural and functional capacity of the roads. To be able to perform the necessary activities, deployment of work zones is a pre-requisite. The work zone must be accompanied by speed limit reductions for the safety of road workers and users. Speed limit reductions in the work zone will result in delays for the road users. Chief of all, the work zones have a natural tendency of reducing the road capacity, particularly if lanes are closed which can potentially cause great nuisance.

In higher traffic flows, this will result in the forming of queues upstream of the work zone. The road users will consequently experience delays in queues or detours. In addition to delays, road users may be affected by an increased fuel consumption, they may be more prone to accidents and wearing of vehicles. From an economic perspective this will firstly cause increased cost for the road users. Delays for individuals may result in lost time in both professional and personal life, while commercial vehicles may miss important deliveries with consequences in downstream logistic chains. Depending on their respective valuation of time, a delay will be associated with certain costs that primarily include the escalated fuel cost and greater wear and tear of automobiles i.e. depreciation cost. From a social point of view, the adverse effects stretch far beyond the private world and includes the entire society. Having said that, there are certain indirect external costs that are qualitative in nature. For instance, increased fuel consumption results in pollutions on local, regional and global level with various environmental impacts which cannot be directly ascertained.

1.2 PROBLEM STATEMENT

After decades of rapid highway system expansion, it has reached a saturation level whereby the construction of additional capacity has diminished. Increasingly, capital program resources are being directed to the enhancement and preservation of existing facilities. However, growth in highway travel continues unabated.

Transportation agencies have the cumbersome task of managing highways continuously, thereby assuring optimal performance in the present and far into the future. To meet long-term expectations, highway infrastructure renewal and enhancement are needed.

The construction work zones required to improve infrastructure are a source of potential disruption that often impede mobility and are widely perceived as locations of elevated crash risk, if not designed properly. Enhancing the life of prevailing roads and using the available capacity plays a critical part in meeting the mobility needs of the society.

Despite of the extensive highways infrastructure, highway workzones in Pakistan are not setup according to the recommended guidelines/minimum standards. The consequences of this negligence enrolls in high user delay. A severe traffic jam appeared in that area and a lot of time wastes unknowingly, which can be used for productive work. The vehicular delay affects the society as a whole.

1.3 OBJECTIVES

In order to minimize the user delay on highway workzone, Transportation agencies have to accurately plan, design and manage the workzone. The workzone strategy should be considered, which impart minimum delay and at the same time, should provide safe environment for both the workforce and motorist. Therefore, the supreme objectives of this study is:

- To study the different highway workzone strategies on Motorways and National Highways
- To quantify user delay on Highway workzones using VISSIM
- To become proficient in the use of VISSIM

1.4 OVERVIEW OF STUDY APPROACH

To accomplish the above mentioned objectives, a detailed methodology (Figure 1.1) was worked out and the following tasks were identified;

- Literature review
- Selection of highways
- Collection of Traffic flow data on respective highways
- Identification of detailed design of highway workzone, as per recommended standards
- Traffic modelling in the software
- Results and Analysis
- Conclusion

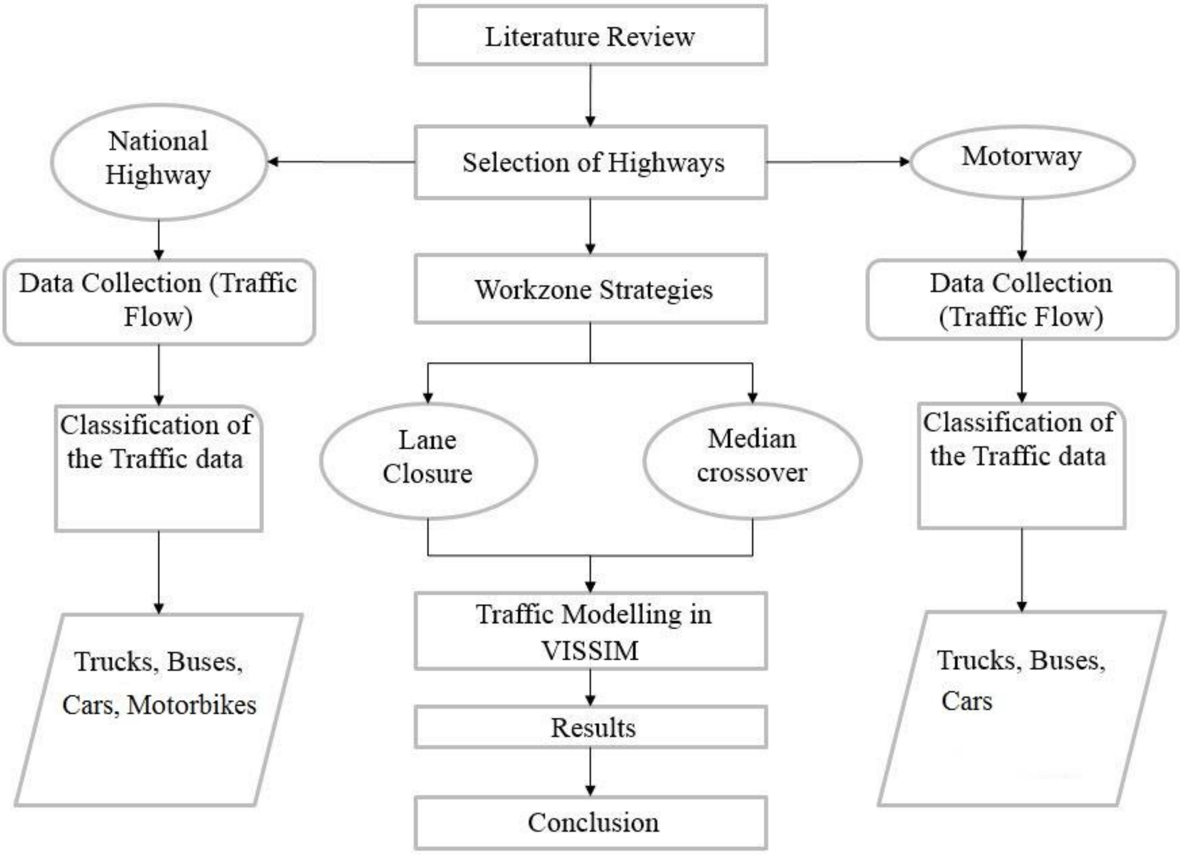

Figure 1.1: Overview of study approach

1.5 THESIS ORGANIZATION

This study is organized into five chapters. The basic introduction along with problem statement, study objectives, and overview of the project is given in chapter 1. Chapter 2 provides a literature review on highway workzones and delay incurred in it. Chapter 3 deals with the detailed explanation of the approaches used to achieve the objectives. Results and analysis are listed in chapter 4. Lastly, the conclusion is presented in chapter 5.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

According to the United States Department of Transportation (USDOT), Highway work zone means a highway segment, road, or street where the Department of Transportation, municipality, or any contractor has undertaken the task of constructing, reconstructing, and maintaining the physical structure of the roadway including its shoulders and features adjacent to the roadway. The Highway is open and motorist co-exist with the workforce in a system and work with coordination. Thus, a workzone represents spatial and temporal constraint on a roadway that effects the flow of traffic negatively. Traffic congestion, Travel times and rate of accidents increases due to the workzones and dissatisfaction arises among the traveling lot.

Drivers have to be attentive while traversing the workzone, to become aware of the dangerous and complex situations. These distinct situations comprises temporary geometrics that arise on the high-speed services, responsible for providing easy access to majority of traffic. The consequences of blunders made at high speed are usually severe.

2.2 CLASSIFICATION OF WORKZONE

Work zones are classified into five types with respect to duration. (Maint.Safety Manual)

- Long-term stationary: workzone constructed for more than three consecutive nights or days.
- Intermediate-term stationary: workzone constructed for more than one day light period up to three consecutive days, or night time work lasting more than one hour.
- Short-term stationary: Day time work that occupies a site for more than one hour within a single day light period.
- Short duration: Work for which a location is occupied for an hour.
- Mobile: Work that moves irregularly (less than 15 minute) or continuously.

2.3 COMPONENTS OF WORKZONE

Following are the components of workzone (MUTCD, Edition 2009)

Advanced warning area

It is the first component of highway workzone, which warns the road user beforehand of work in progress. First sign in that area is the construction ahead sign, which provides the information about the workzone and the distance from it. Second sign is the lane merge sign, which is used to indicate that lane is closed due to the roadwork, and communicate with drivers to keep in open traffic lane.

Transition zone

Transition area moves traffic out of its normal path. Arrow signs, delineators and chevron signs are placed here to guide the drivers about the roadwork zone. The signal arrow specifies the presence of work area and indicate the direction in which the drivers should go to avoid any hindrance or interruption.

Activity area

It is the most important and risk potential area, where the work is being carried out and is reserved for labors, machinery and material storage. Like transition zone, the activity area is also properly marked and sectioned off with delineators or rigid railing for guiding drivers.

Termination area

It is the last section, where drivers return to their normal lanes. The end construction sign is placed to resume the normal driving speed.

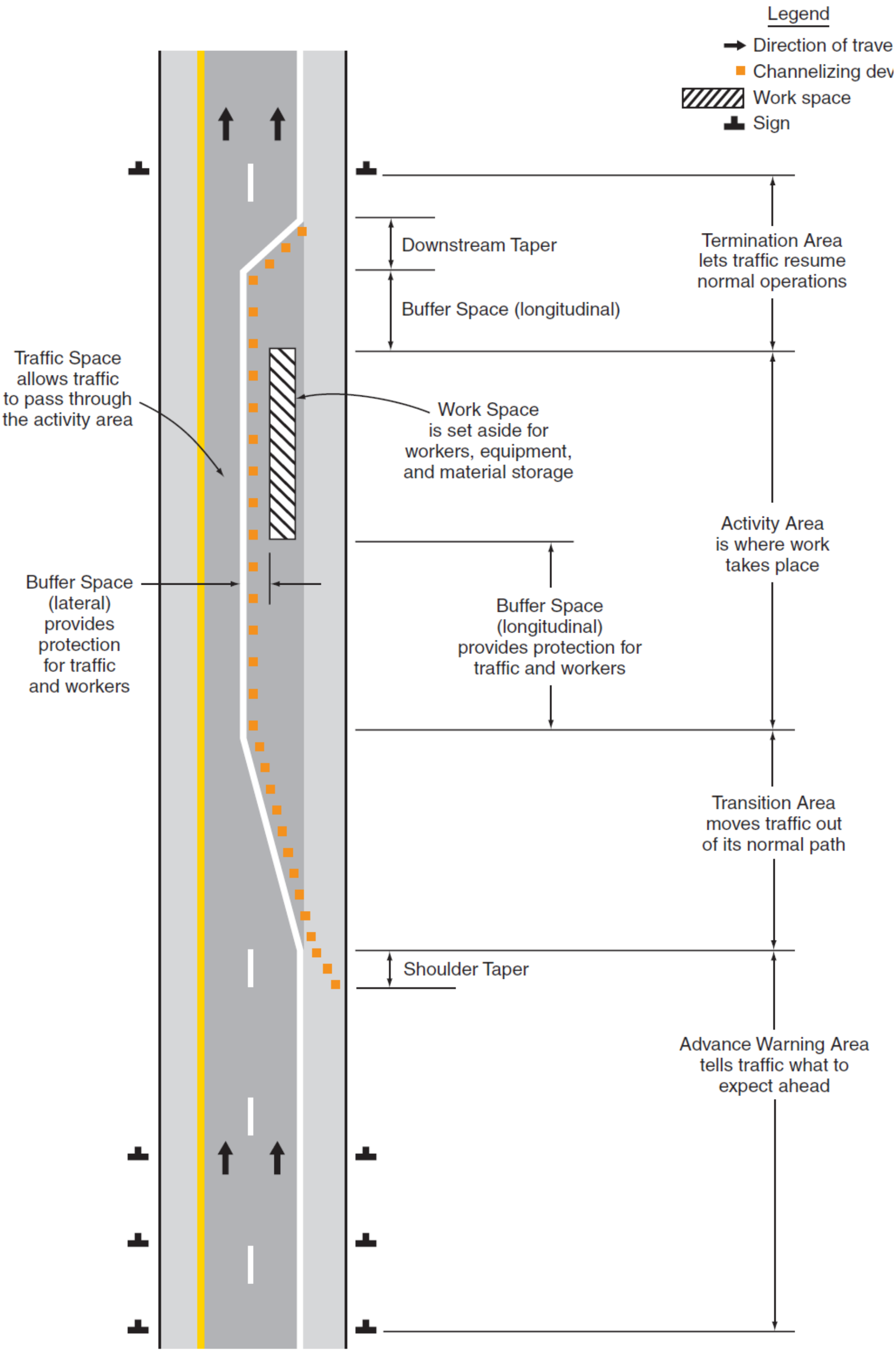

Figure 2.1: Components of workzone

2.4 TYPES OF WORKZONES

The following strategies have been extensively and successfully employed for workzones on high-speed motorways and highways:

Table 2-1: Types of Workzones (MUTCD, Edition 2009)

Strategy	Summary	Advantages	Disadvantages
Alternating one-way operation	Mitigates for full or intermittent closure of lanes. Used primarily with two-lane facilities.	Low agency cost and low non transportation impacts; flexible, several variations available.	Requires stopping of traffic; reduces capacity.
Detour	Reroutes traffic onto other existing facilities.	Flexible; cost varies depending on improvements to detour route; in some cases, only TTC needed.	Usually reduces capacity; service and infrastructure on existing roads may be degraded; may need agreement of another agency.
Diversion	Provides a temporary roadway adjacent to construction.	Separates traffic from construction; reduced impact on traffic.	Cost may be substantial, especially if temporary grade separation of hydraulic structure involved; right-of-way often required
Full road closure	Closes the facility to traffic for a specified (limited) duration.	Generally also involves expedited construction; separates traffic from construction.	Some form of mitigation is needed (detour, diversion, etc.); potentially significant traffic impacts.
Intermittent closure	Stops traffic for a short period.	Flexible and low agency cost.	Useful only for activities that can be completed in short time; requires stopping traffic.
Lane closure	Closes one or more travel lanes.	Maintains service; fairly low agency cost if temporary barriers are omitted.	Reduces capacity; may involve traffic close to active work.
Lane constriction	Reduces traveled way width.	Maximizes number of travel lanes.	Traveled way width is less than desirable; may involve traffic close to active work.
Median crossover	Maintains two-way traffic on one roadway of a normally divided highway.	Separates traffic from construction; right-of-way not required.	Reduced capacity; not consistent with approach roadway; relatively costly; interchanges need special attention
Use of shoulder	Uses shoulder as a travel lane.	Fairly low cost, depending on shoulder preparation.	Displaces traditional refuge for disabled vehicles; debilitates shoulder pavement structure; cross slopes may be problematic.

These strategies are not necessarily separate, individual choices. In fact, several of them do not provide a complete and workable solution. Use of a full road closure requires one or more additional strategies (e.g., detour or diversion). Some of the strategies are identified as mitigation strategies, meaning that they can be used to offset negative consequences (e.g., reduced capacity and access limitations) for one or more other strategies.

2.5 TRAFFIC DELAY CONDITION

Capacity and the speed are the major two parameters, which cause the delay in the workzone. There are two types of traffic delay conditions:

Congested traffic flow condition

Congested traffic flow condition occur when the traffic volume is greater than the capacity of workzone, which results in vehicle queues and delays.

Uncongested traffic flow condition

Uncongested traffic flow condition occur when the traffic volume is less than the capacity of workzone. Vehicles passes the workzone smoothly but the speed of the vehicles is less than the normal speed on that freeway. Due to which, vehicles need more time to pass the workzone as compared to the roadway of same length without a workzone. This additional time consumed at the workzone is also a traffic delay.

2.6 RISK PERCEPTION OF DRIVER IN WORKZONE

Risk perception can be define as, “the subjective judgment that people make about the characteristics and severity of a risk”**.**

There are so many happenings in the work zone that contains high risk potential for drivers, workers, equipment and costly material placed within the work zone, that’s why the work zone is highly threat potential area. The driver must have to negotiate the required safety manure while passing through workzone area. While passing within the workzone, the driver behavior largely depends upon traffic conditions and level of risk perception of the driver. Risk perception alone is varied from driver to driver. (Hasnain, 2014)

Factors affecting Risk Perception

The driving behavior and actions are varied from driver to driver in a risk situation that depends upon so many factors such as:

- Education
- Social norms
- Customs
- Culture
- Risk perception level

The variables which causes uncertainty in driving behavior are:

- Age
- Gender
- Level of comfort while passing from work zone
- Drivers are unwilling to use work zone
- Speed of vehicle
- Law enforcement within work zone
- Experience of driver
- Education
- Visual acuity of driver
- Reduction in speed limit while observing work zone

By investigating the behavior of the drivers, it is revealed that female have 40 % high level of risk perception. Many studies shows that accident rates are much higher in work zone area. Studies also revealed that accident rates are associated with weather conditions and seasons. Work zone length, average daily traffic and the duration of workzone increase the occurrence of both injury and non-injury crashes. Some studies have shown that most injurious and harmful work zone crashes involve truck collision in median cross over strategy.

Highway work zone especially on high speed facility or freeway demand special attention and adequate traffic management to minimize the effect of altered geometry. To convince the driver with altered geometry a proper and efficient communication system is needed which guide the drivers to complete their maneuver safely and efficiently. Therefore there is need to design a work zone according to regulations is very important in order to ensure the safety of drivers, workers, equipment and travelers. Delay in the system and risk potential are the least desirable effects of work zone but they are associated with it. To minimize the risk and hazards an efficient traffic control plan and traffic management plan can be made and implement. To minimize the delay different traffic diversion and geometric diversion strategies can made. For the accuracy and efficiency different software can be used to generate results and simulations for better understanding and implementation.

2.7 INTRODUCTION OF SOFTWARE (VISSIM)

PTV Vissim is a microscopic multi-modal traffic flow simulation software. Microscopic simulation, sometimes called micro simulation, means that each item (car, train, and person) of real world that is to be simulated is simulated individually. Multi-modal simulation describes the ability of PTV Vissim to simulate more than one type of traffic. All these types can interrelate mutually. (Wikipedia)

Following types of traffic can be simulated individually in VISSIM:

- Vehicles (cars, buses, and trucks)
- Pedestrians
- Cycles (bicycles, motorcycles)
- Rickshaws
- Public transport (trams, buses)

CHAPTER III

METHODOLOGY

The subject matter of this chapter pertains to the very policies used for determining the user delay on workzone and consequently, determining that which workzone strategy will cause minimum vehicular delay. The detail of each step is listed below:

3.1 SELECTION OF HIGHWAYS

For analyzing the Highway work zones and calculating the delay being occurred in the work zones, two different type of roadways were chosen i.e. Motorway and National Highway. Both road ways have different cross sections; Motorway being a 6 lane divided highway and National Highway having a 4 lane divided Highway. Delays occurring on each road is unique and is mainly dependent on the traffic flow of that road and the workzone type used for that specific road.

3.2 DATA COLLECTION

In order to ascertain the general traffic flow and vehicular composition on the respective roads, a traffic survey was conducted. Traffic data was classified into Trucks, Buses, Cars and motorbike. For Motorway, Data was collected near Thallian on motorway M-2, and for National Highway, Data was collected near Rawat. The survey lasted for 4 hours based on which a peak hourly volume was determined. The graph of the collected data on each road is below. Separate graphs were plotted for each direction.

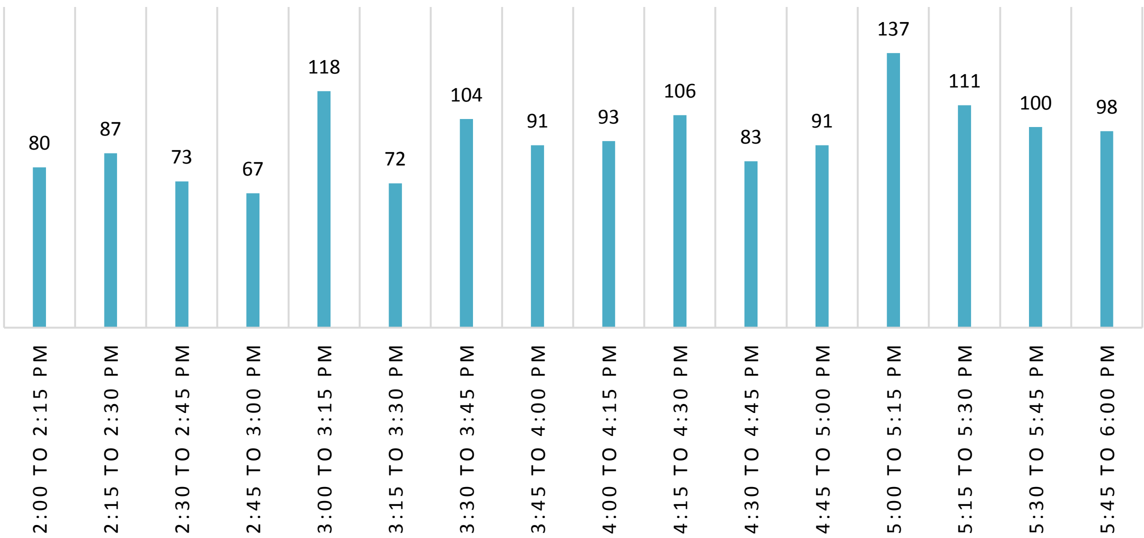

Figure 3.1: Graph: Traffic count on North Bound leg, Motorway

Peak hour is from 5 pm to 6 pm and 446 vehicles passes in that time.

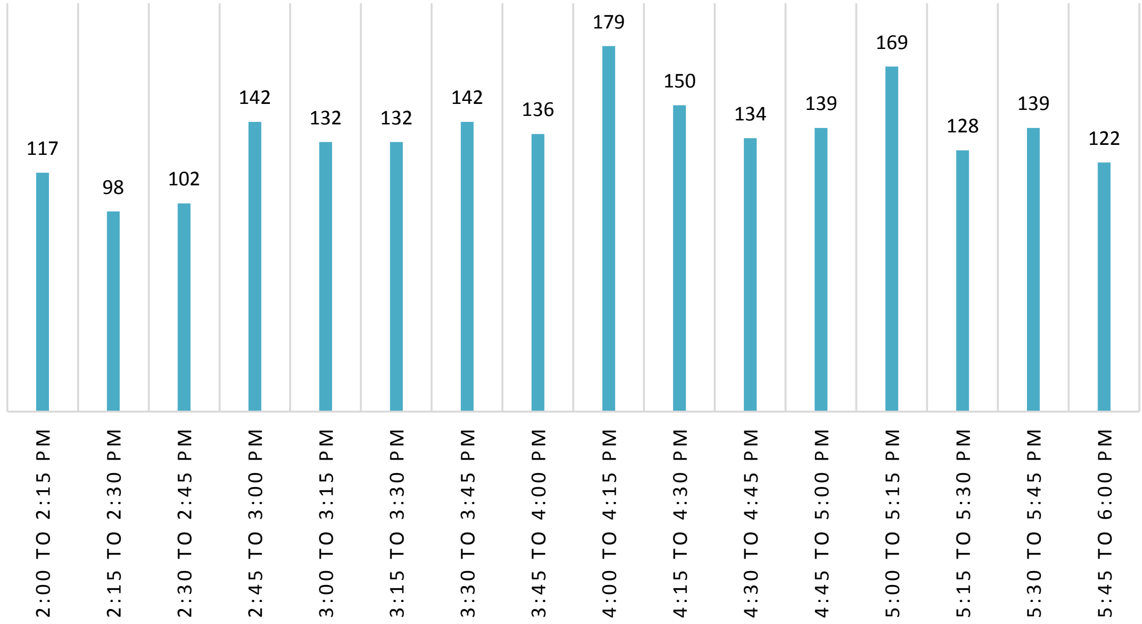

Figure 3.2: Graph: Traffic count on south bound leg, Motorway

Peak hour is from 3:30 pm to 4:30 pm and a total of 607 vehicles passes in that time. The percentage of each vehicle type on motorway is represented by the graph below.

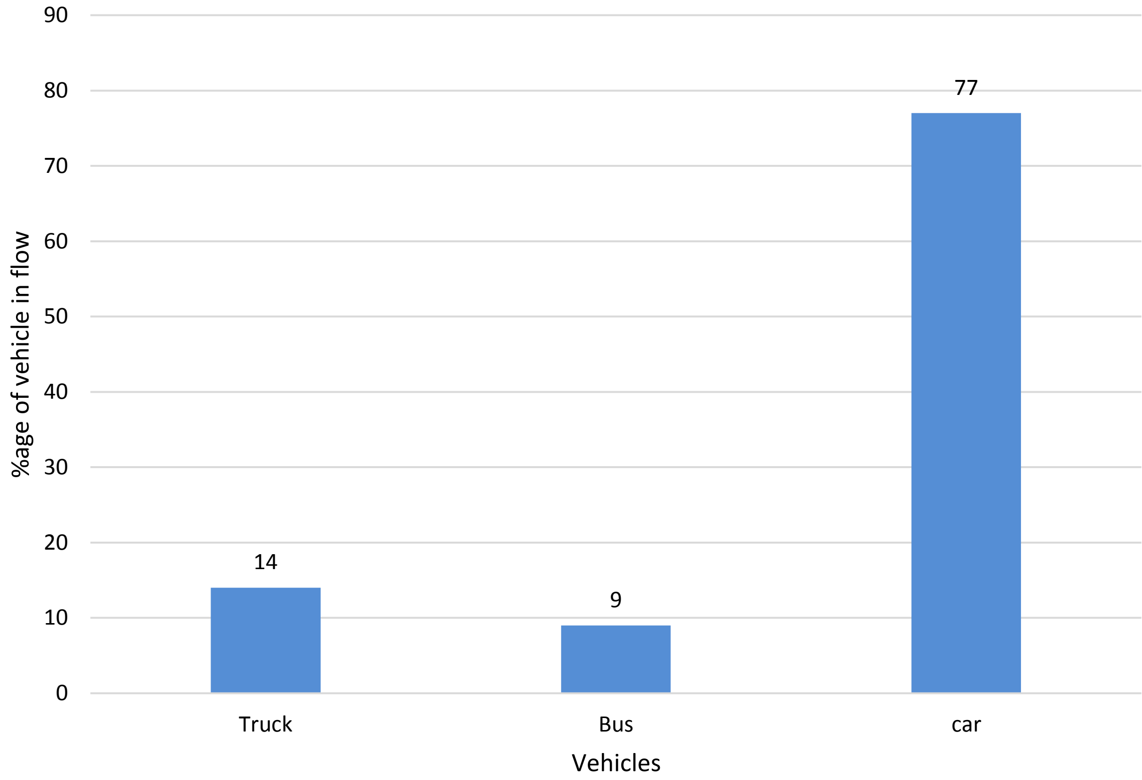

Figure 3.3: Graph: Vehicle composition by percentage, Motorway

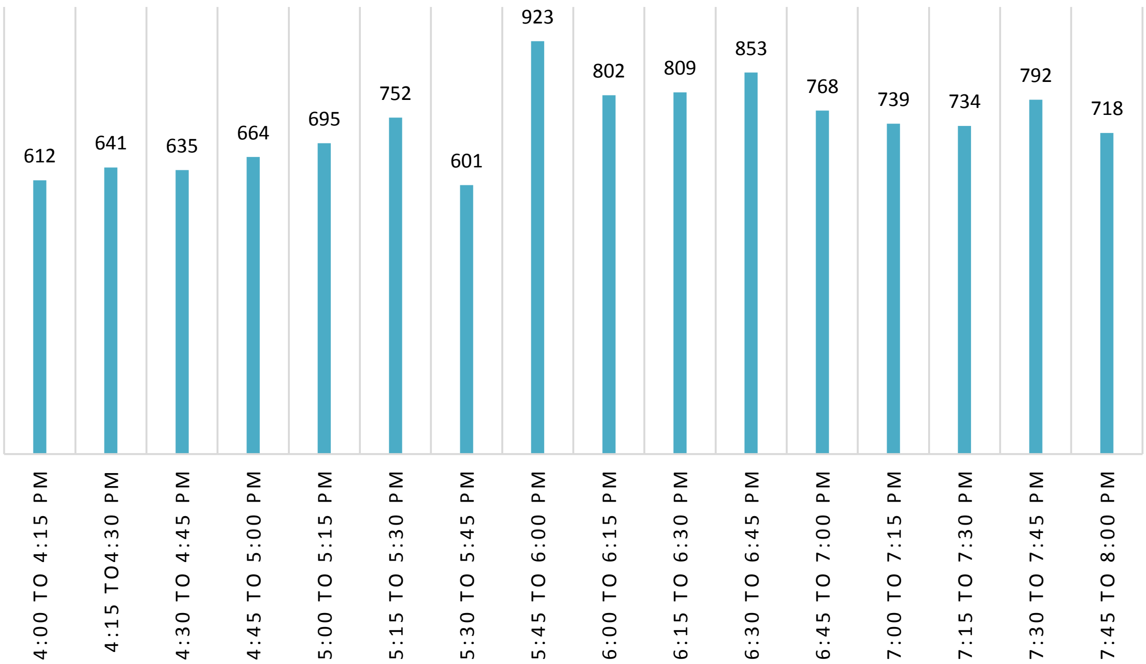

Figure 3.4: Graph: Traffic count on North bound leg, National Highway

Peak hour is from 5:45 pm to 6:45 pm and a total of 3387 vehicles passes in that time.

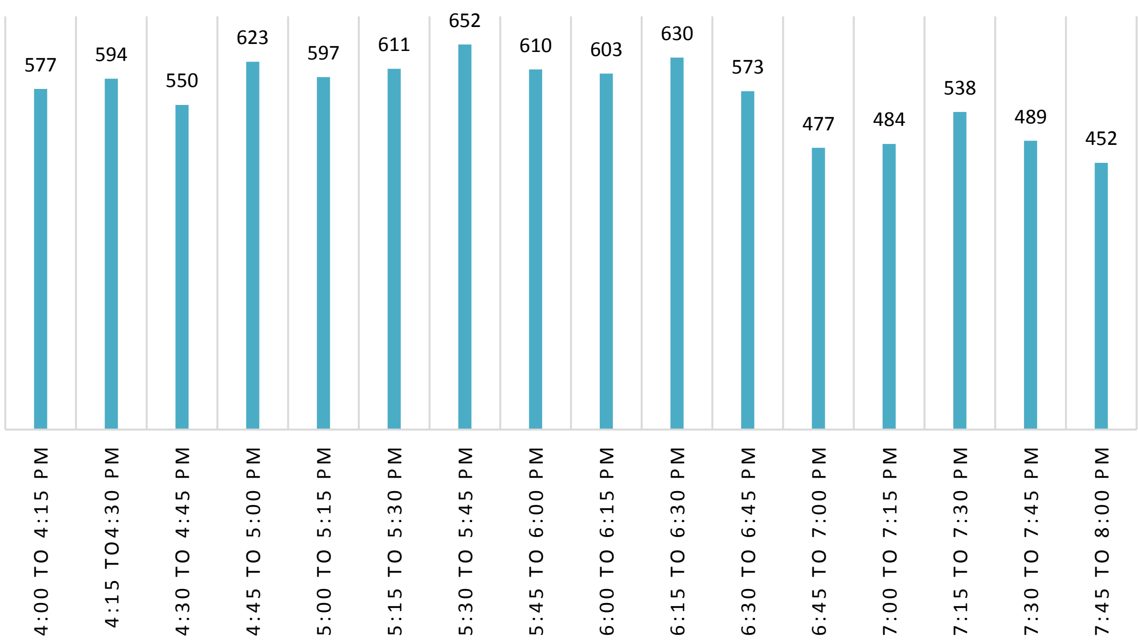

Figure 3.5: Graph: Traffic count on South bound leg, National Highway

Peak hour is from 5:30 pm to 6:30 pm and a total of 2495 vehicles passes in that time. The percentage of each vehicle type on N-5 is presented in a graph below.

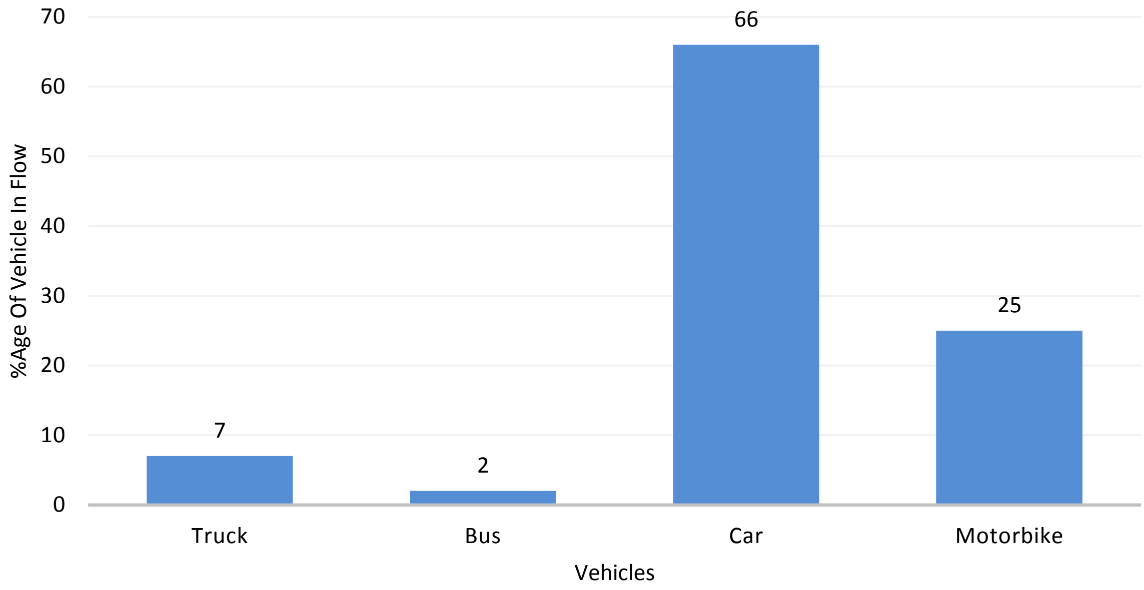

Figure 3.6: Graph: Vehicle composition by percentage, National Highway

3.3 WORKZONE STRATEGIES

As described in chapter 2, different types of work zone strategies were developed. Median crossover and lane closure models were incorporated to meet the demands of this project. MUTCD was used as a standard for designing the work zones. The plans of the designed workzones are shown below.

3.3.1 MOTORWAY (6 LANE DIVIDED HIGHWAY):

A divided highway with complete access control having two or more lanes for exclusive use of traffic in each direction is called a freeway. The traffic on motorways cannot be diverted due to the limited access and hence, justifies why detouring and diversion strategies cannot be incorporated in the process. Therefore, engineers have the liberty of only altering the existing geometry to develop a proper layout to manage the traffic efficiently. This can help achieve the objective of reducing the total delay and risk potential while passing through work zone.

The proposed strategies were designed on 70km/hr. Heavy vehicles are allowed to pass at 60 km/hr. Following strategies were applied on motorways.

- Lane closure
- Median crossover

Lane Closure

This strategy is further classified into three different modals

- Slow lane closure
- Middle lane closure
- Double lane closure

Slow Lane Closure

Left shoulder and lane adjacent to it is closed. Middle and fast lanes are open for through traffic movement.

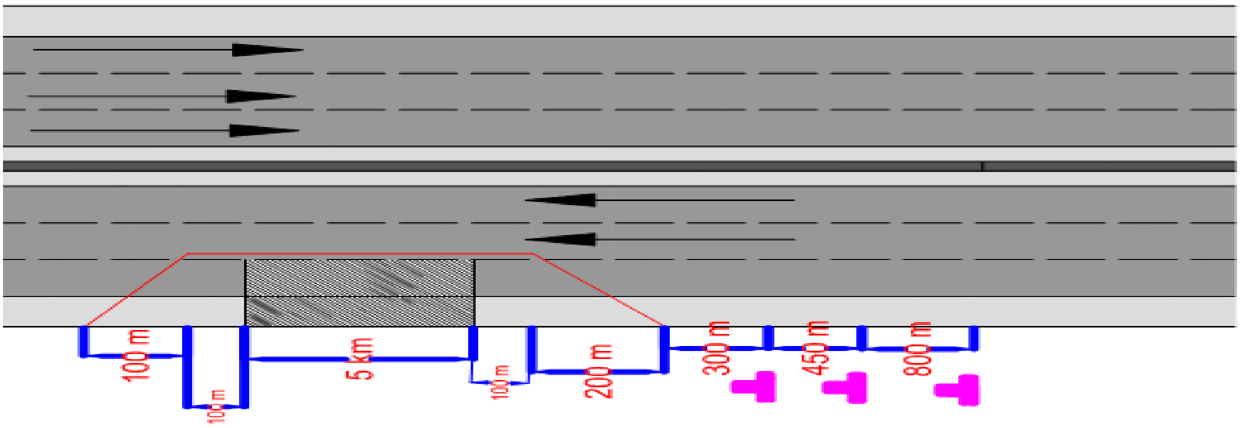

Figure 3.7: Slow lane closure, Motorway

Middle Lane Closure

Only middle lane is closed for rehabilitation work. Both fast and slow lanes are open for through traffic.

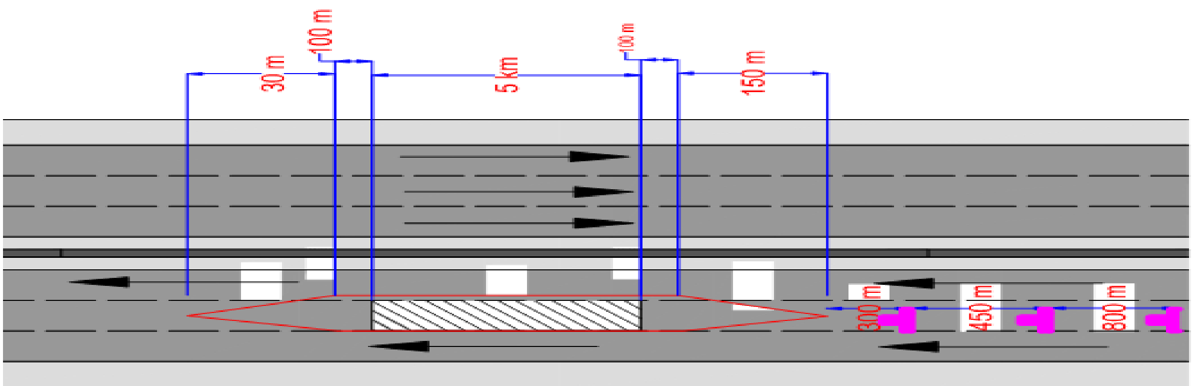

Figure 3.8: Middle lane closure, Motorway

Double Lane Closure

In this phase left shoulder, slow lane and middle lane are closed for rehabilitation work and the traffic is allowed to pass through the workzone using fast lane only.

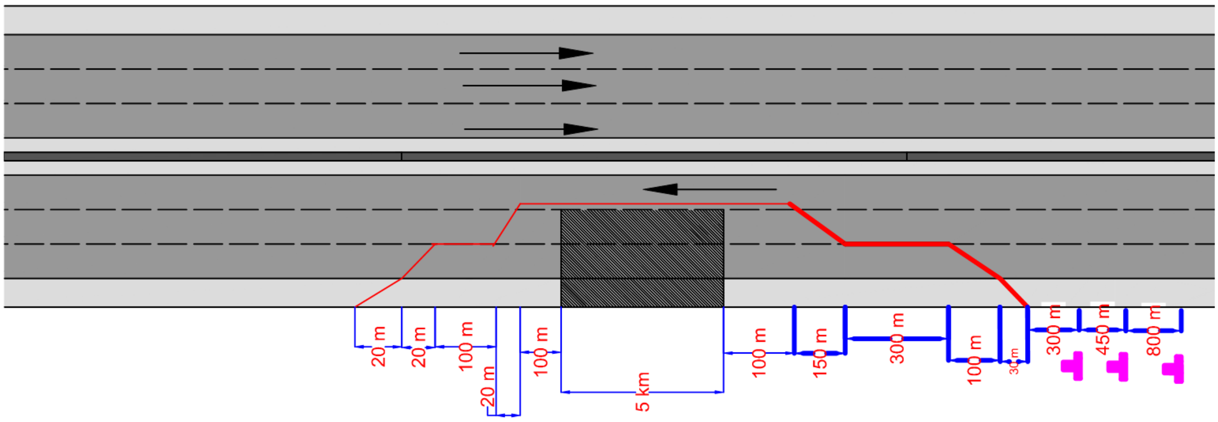

Figure 3.9: Double lane closure, Motorway

Median Crossover

One side of the road is completely closed and vehicles are diverted on the opposite road which will operate under two way traffic operation. Rehabilitation will be done on the closed roadway. The main advantage of this strategy is that it provides an extended work area to the contractor.

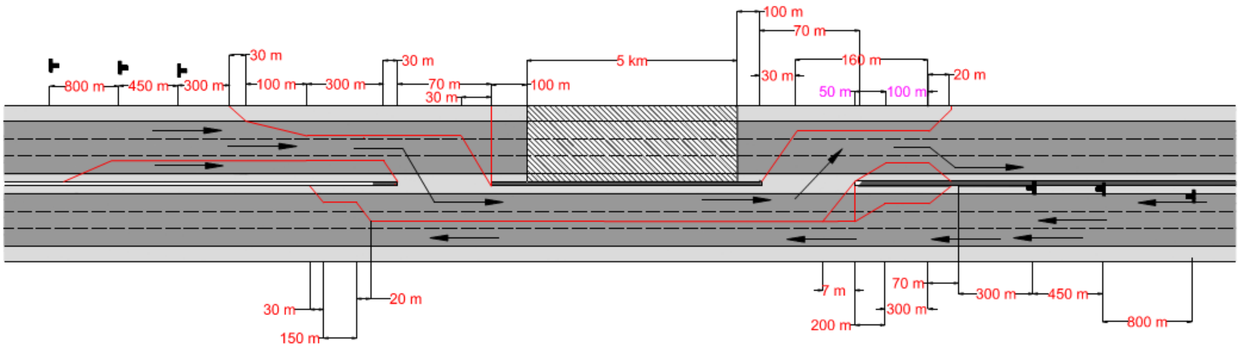

Figure 3.10: Median crossover, Motorway

3.3.2 NATIONAL HIGHWAY (4 LANE DIVIDED HIGHWAY):

The National Highways of Pakistan consists of all public highways maintained by National Highways Authority under the Ministry of Transport. This encompasses over 12,000 kilometers (7,500 mi) of roadways divided into various forms which crisscross the country and provide access to major population centers. Following workzone strategies were adopted on that road. The designed speed of the workzones is 50 km/hr.

- Lane Closure
- Median crossover

Lane Closure

In this case, slow lane is closed and fast lane is opened for through traffic

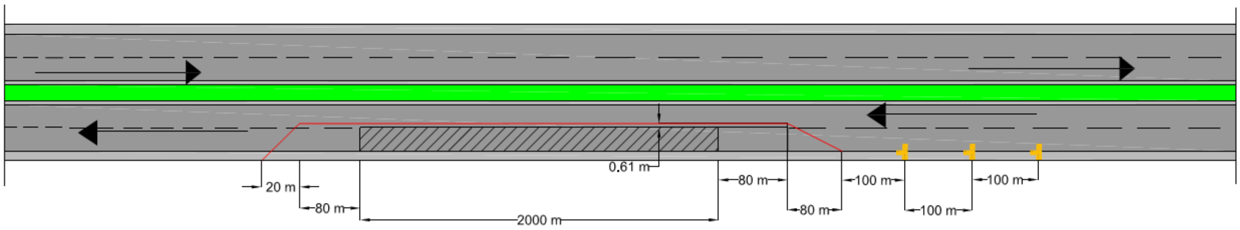

Figure 3.11: Lane closure, National Highway

Median Crossover

As discussed in the case of motorway, one side is completely closed and vehicles are diverted on the opposite road which will operate under two way traffic operation. Rehabilitation will be done on the closed roadway. This strategy is given preference as that it provides more work area to the contractor.

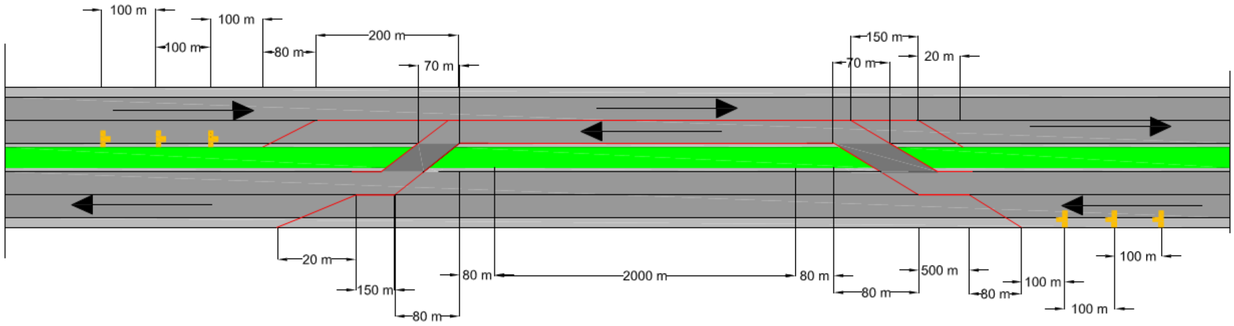

Figure 3.12: Median crossover, National Highway

3.4 TRAFFIC MODELLING

In this step, the workzone models were designed in VISSIM. Different 3d models were imported in the software for example, cars, buses, motorbikes and construction machines. Sketch up and V3dm software's were used to import 3d models in VISSIM. 3d models were taken from SketchUp 3d warehouse. Vehicle dimensions imported in the software were adjusted accordingly, as prevalent in Pakistan. Traffic flow data was entered in the software. This software is based upon weidemann's car following modal. For this project, the weidemann's constants were re calibrated and incorporated in the software. Pruthvi et al., carried out a case study to calibrate the different parameters of VISSIM. The recalculated parameters proposed by them were as under:

Table 3-1: Calibrated car following Parameters (Pruthvi Manjunatha et al, 2012)

Parameter	Default	2W	3W	Car/LCV	Bus/HCV
CCO (Standstill distance)	1.50	0.47	1.00	1.20	2.00
CC1 (Headway Time)	0.90	0.43	1.2	0.81	0.94
CC2 (Following Variation)	4.00	4.42	4.42	6.84	6.84
CC3 (Threshold for entering following)*	-8.00	-8.00	-8.00	-8.00	-8.00
CC4 (Negative following threshold)*	0.35	0.35	0.35	0.35	0.35
CC5 (Positive following threshold)*	-0.35	-0.35	-0.35	-0.35	-0.35
CC6 (Speed dependency of Oscillation)*	-11.44	-11.44	-11.44	-11.44	-11.44
CC7(Oscillation acceleration)	0.25	0.20	0.20	0.77	0.77
CC8 (Standstill acceleration)	3.50	2.30	2.30	2.30	2.30
CC9 (Acceleration at 80km/h)*	1.50	1.50	1.50	1.50	1.50

These parameters were used to analyze delay on N-5, whereas on Motorways, these parameters have no significant effect on delays. So, the default parameters were used in case of motorway. Headway time is only changed for M-2. The average headway on motorway is 3 sec. The calibrated lateral distance parameters were also incorporated in the simulations. The refine parameters are as under:

Table 3-2: Calibrated lateral distance parameters (Pruthvi Manjunatha et al, 2012)

Vehicle Type	Minimum lateral distance (m)	
	0 km/hr	50 km/hr
Two wheeler	0.3	0.7
Three wheeler	0.4	0.8
Car	0.5	0.9
LCV	0.5	0.9
HCV	0.6	1.0

For two wheeler, minimum lateral distance was taken as 0.1 m instead of 0.3 for 0 km/hr and 0.3 m instead of 0.7 for 50 km/hr. The changed values for two wheelers were calculated on trial and error basis.

Advance warning signs and the Speed reductions signs were inserted. Barriers and cones were introduced to discriminate workzone area from the travelled way. Data Collection points were installed to calculate the required variables. Reduced speed areas were introduced in median crossover strategies, where the median opening is less than the designed value.

3.5 CALCULATING USER DELAY

First, all the parameters were kept constant and flow was varied to calculate the delay and determine the flow against which the delay exceed exponentially. Then length was altered keeping all other parameters constant to evaluate the effect of work-zone length on the delay. Activity area was changed from 1 km to 5 km to analyze the effect of length on delay. Then, flow and length of workzone were kept constant while median opening was varied to establish a relation between median opening and delay in case of median crossover strategy.

3.6 GENERATING VIDEOS

To display the end product, videos were generated. Camera position of the videos can be changed to have a glimpse of the entire workzone section. The length of the videos can be reduced by using compression factor. This video elaborates upon the whole scenario which will be going on at that workzone.

CHAPTER IV

RESULTS AND ANALYSIS

The basic purpose of this study is to analyze the different Highway workzone strategies and to investigate the effect of different parameters of workzones on vehicular delay and to determine that which workzone strategy will cause minimum vehicular delay. The graphical representation of result are explained below.

4.1 CAPACITY OF WORKZONE

Capacity is defined as, 'the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point or uniform segment of a lane or roadway during a given time period under existing roadway, traffic, and control conditions". When a road segment reached its capacity, the volume to capacity ratio (v/c) becomes equal to 1. After that, if volume increases further, v/c becomes greater than 1 theoretically but practically it's not possible. The same concept applies on highway workzones, when traffic volume keep on increasing, work zone will ultimately reach its capacity and with further increase in traffic volume, the vehicles will start making queue at the upstream side of workzone.

Motorway

In case of motorway, median crossover has the least capacity, whereas slow lane closure has the maximum capacity. That's why by increasing the volume of traffic, outflow from workzone becomes constant early in median crossover strategy as compared to other workzone strategies.

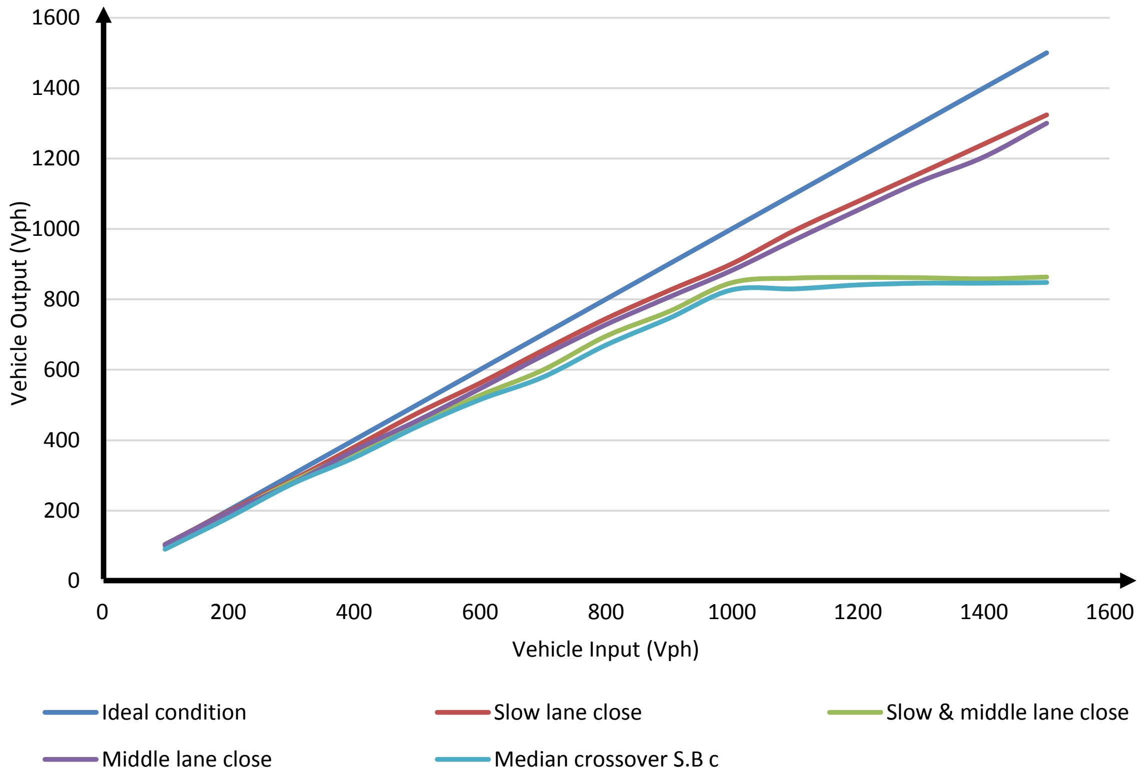

Figure 4.1: Graph: Capacity of work zones, Motorway

National Highway

In case of national highway, median crossover strategy has less capacity than lane closure. The trend is shown in the graph below.

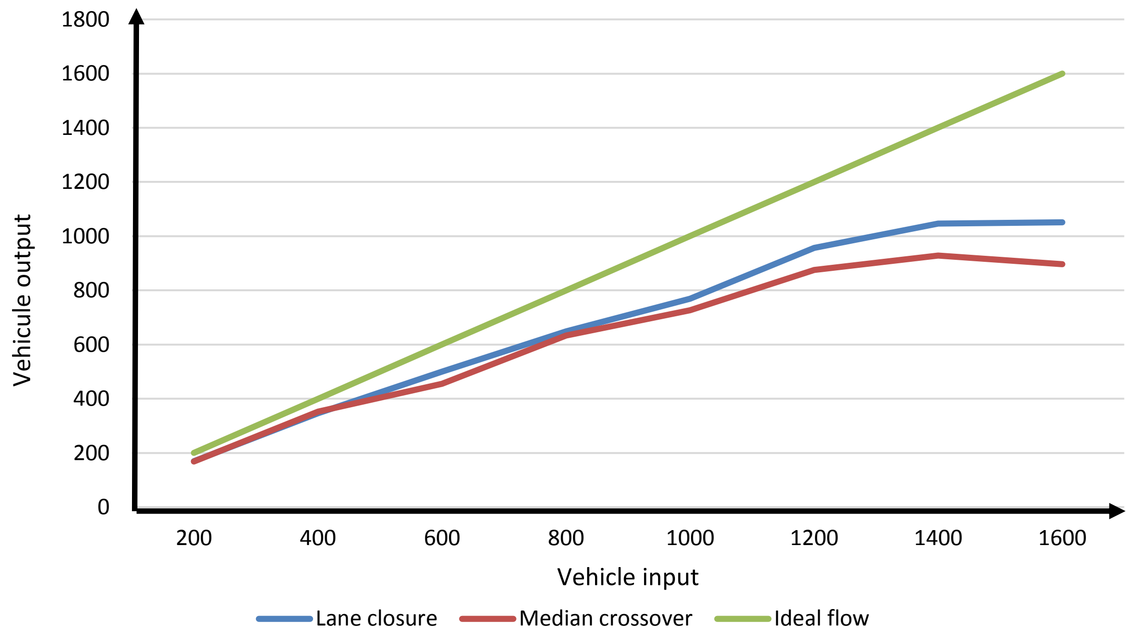

Figure 4.2: Graph: Capacity of workzones, National Highway

4.2 EFFECT OF WORK ZONE LENGTH ON USER DELAY

Delay is directly proportional to the workzone length. Therefore, more the workzone length, more the delay will be. Also, vehicular delay is directly proportional to the traffic volume. Less hindrance and delay is experienced by the vehicles at low traffic volume but when the traffic volume increases, vehicles start interacting each other. Due to this increased in interaction between different vehicles, some of the vehicles might stuck behind slow moving vehicles i-e trucks, which increase the travel time and so the delay increases. By keeping all other factors same, as the traffic volume increase, travel time and delay also increase (Madhav et al., 2007). The graph below describes the effect of work zone length and flow on delay. The length of workzone varies from 1km to 5km and the flow is varied from 100 veh/hr to 1500 veh/hr. The graph is plotted between volumes (veh/hr) versus average vehicular delay (sec/veh). Volume is taken on horizontal axis and Average delay is on vertical axis.

Motorway

Slow Lane Closure

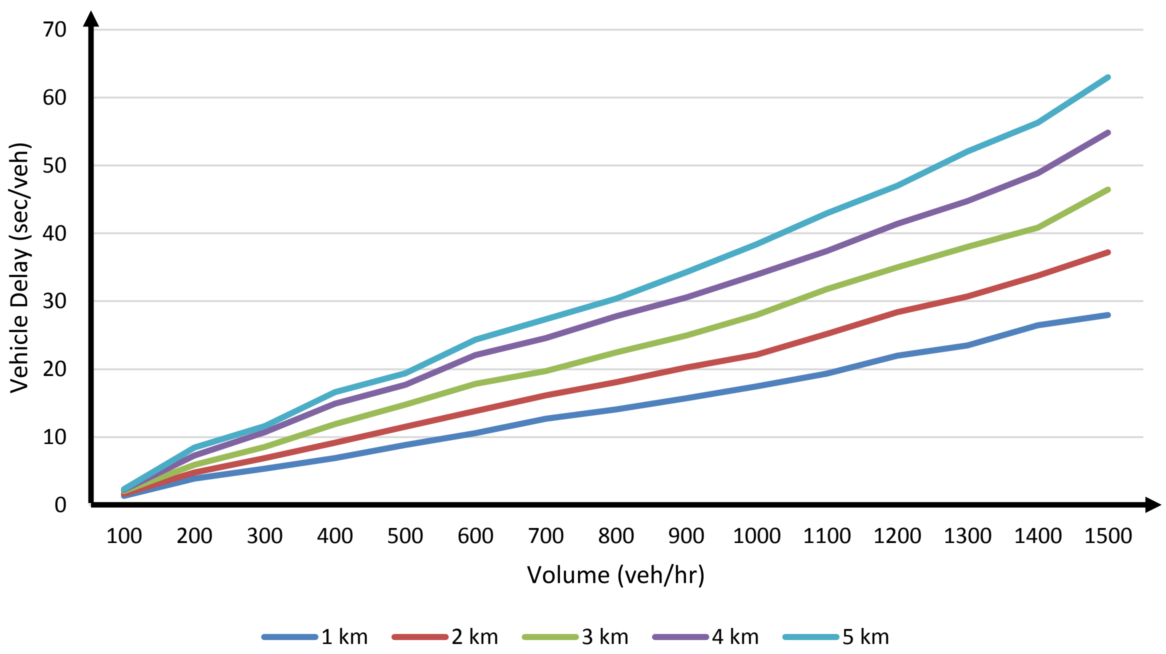

Figure 4.3: Graph: Effect of workzone (Slow lane closure) length on delay, Motorway

The graph explains that when the length of work zone increases, delay also increases because vehicles have to traverse longer distances at the reduced speed. The linear increase in delay shows that vehicles are moving under uncongested traffic flow condition. Also the graph explains that by increasing the volume of traffic, delay increased.

Middle Lane Closure

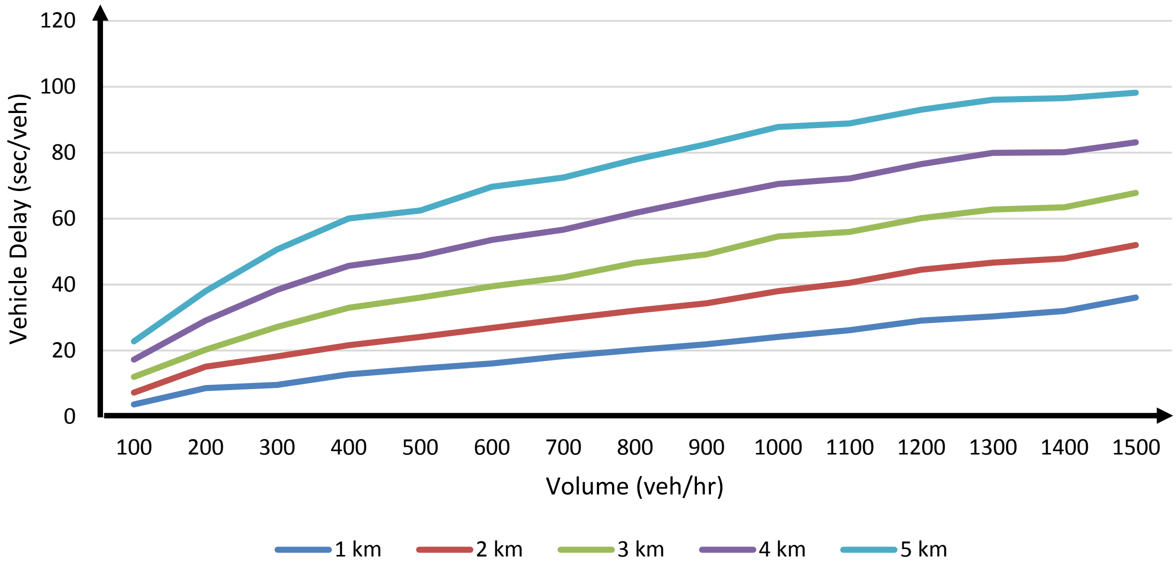

Figure 4.4: Graph: Effect of workzone (middle lane closure) length on delay, Motorway

The graph explains that as the length of workzone increases, the vehicle travel time and delay increases.

Two Lane Closure

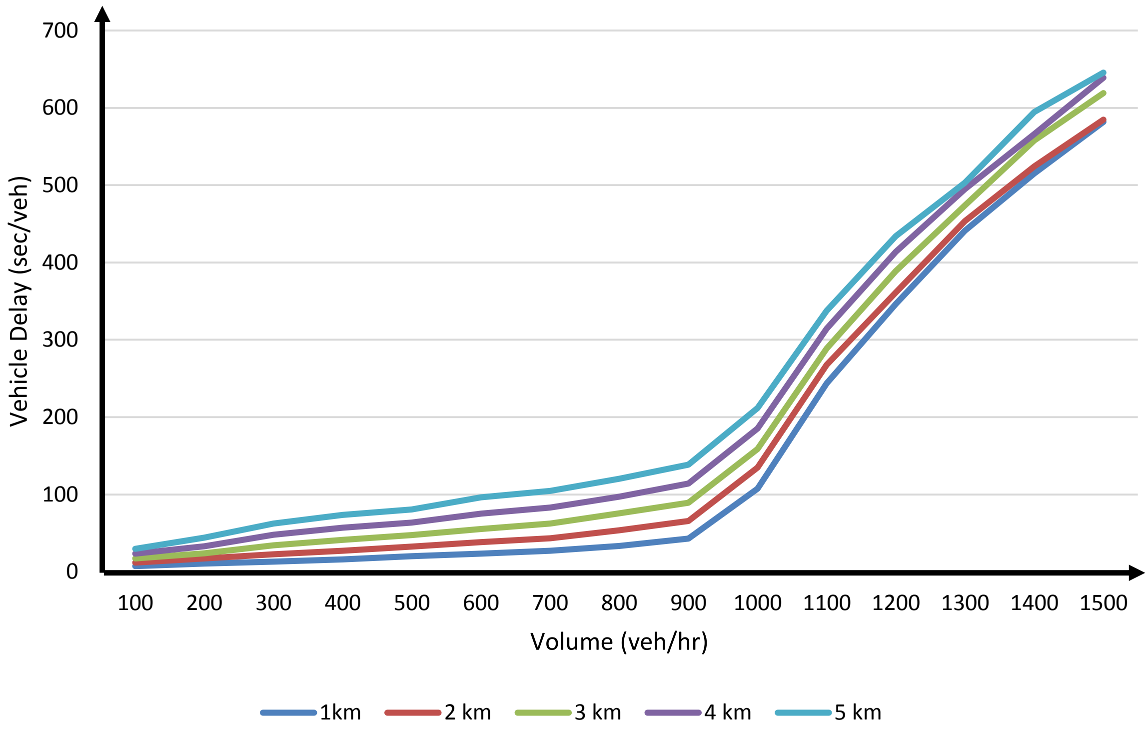

Figure 4.5: Graph: Effect of workzone (Two lane closure) length on delay, Motorway

In case of two lane closure, the graph shows that upto 900 veh/hr, vehicular delay increased linearly, but after that volume, the delay increases exponentially. This is because the workzone reached its capacity and the further increase in the volume will only cause the increase in the queue length at the upstream side of workzone. After that particular volume, the flow through the workzone will remains the same even if volume is increased. This phenomenon can be shown with the help of a graph shown below. From 1000 veh/hr, the output of the vehicles become constant even if volume is increased.

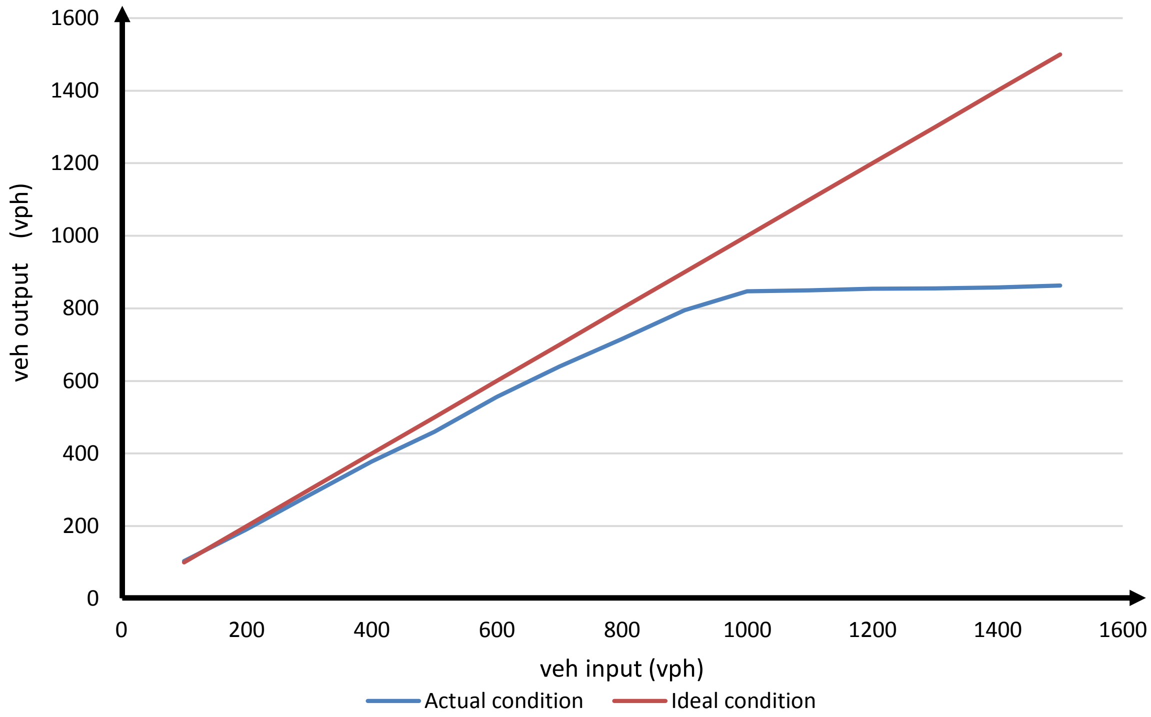

Figure 4.6: Graph: Capacity of workzone (Two lane closure), Motorway

Median Crossover

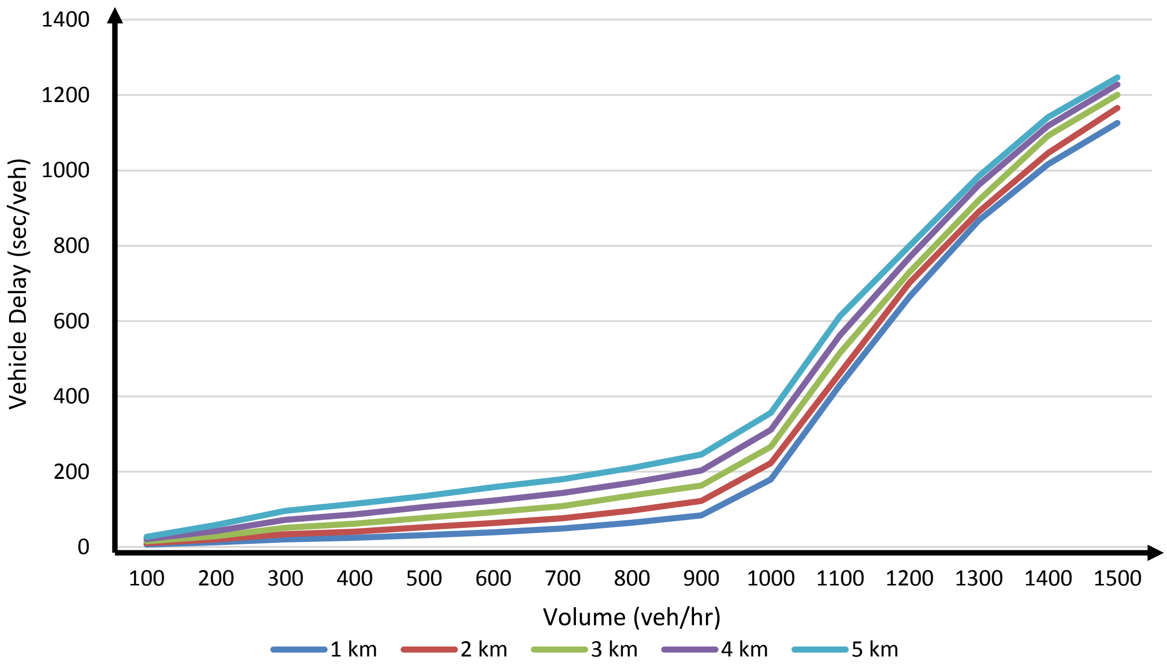

Figure 4.7: Graph: Effect of workzone (Median crossover) length on delay, Motorway

The trend is same as that of two lane closure. After 900 veh/hr, the delay increased exponentially because workzone reached its capacity after which, number of vehicles leaving the workzone becomes constant even if flow is increased.

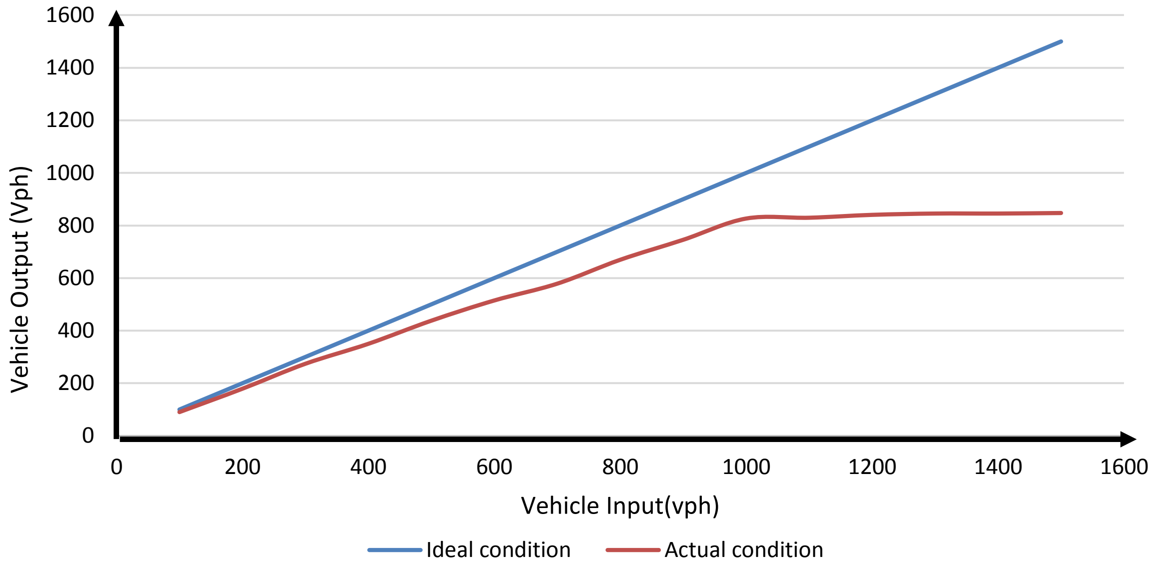

Figure 4.8: Graph: Capacity of workzone (Median crossover), Motorway

National Highway

Lane Closure

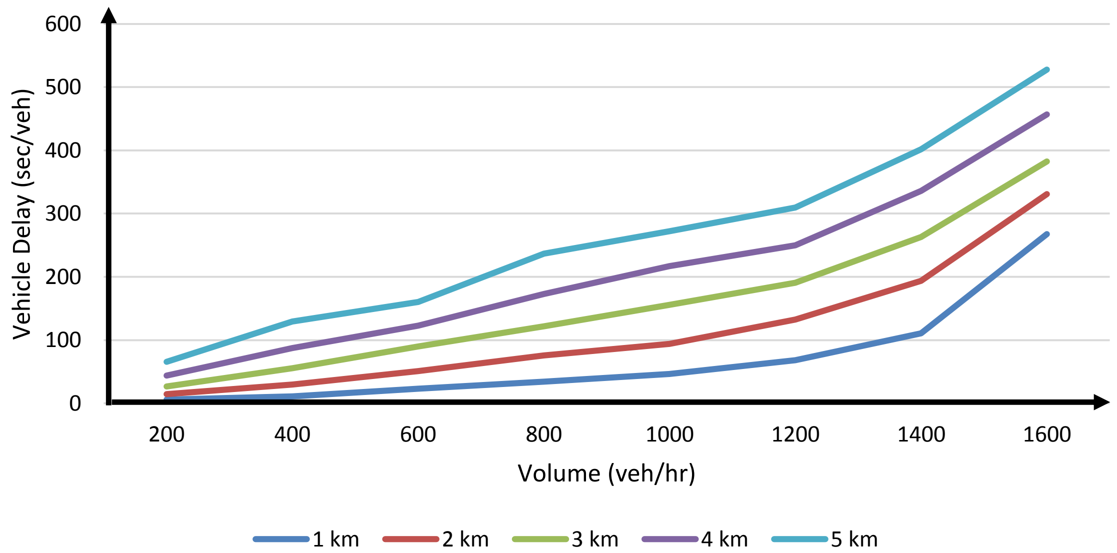

Figure 4.9: Graph: Effect of workzone (Lane closure) length on delay, National Highway

Workzone length and flow have direct relation with vehicular delay. After 1400 veh/hr, delay increases exponentially because volume of vehicles increased from the capacity of workzone. Any further increase in the volume will only increase the length of the queue at the upstream side of the workzone. The flow through the workzone will remain constant after workzone reaches its capacity and can be explained with the help of graph below.

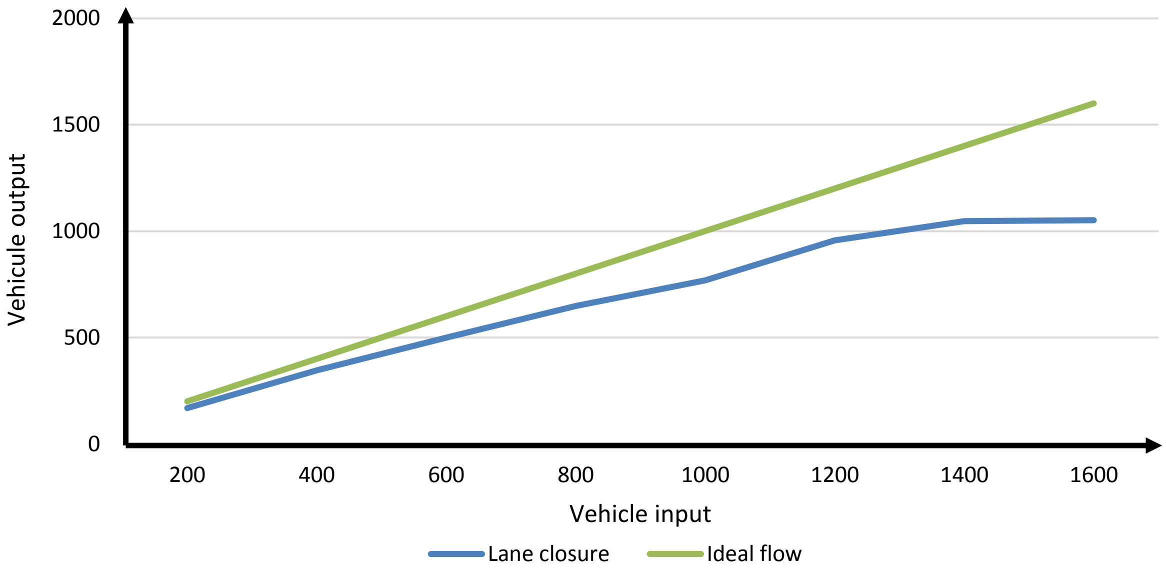

Figure 4.10: Graph: Capacity of workzone (lane closure), National Highway

Median Crossover

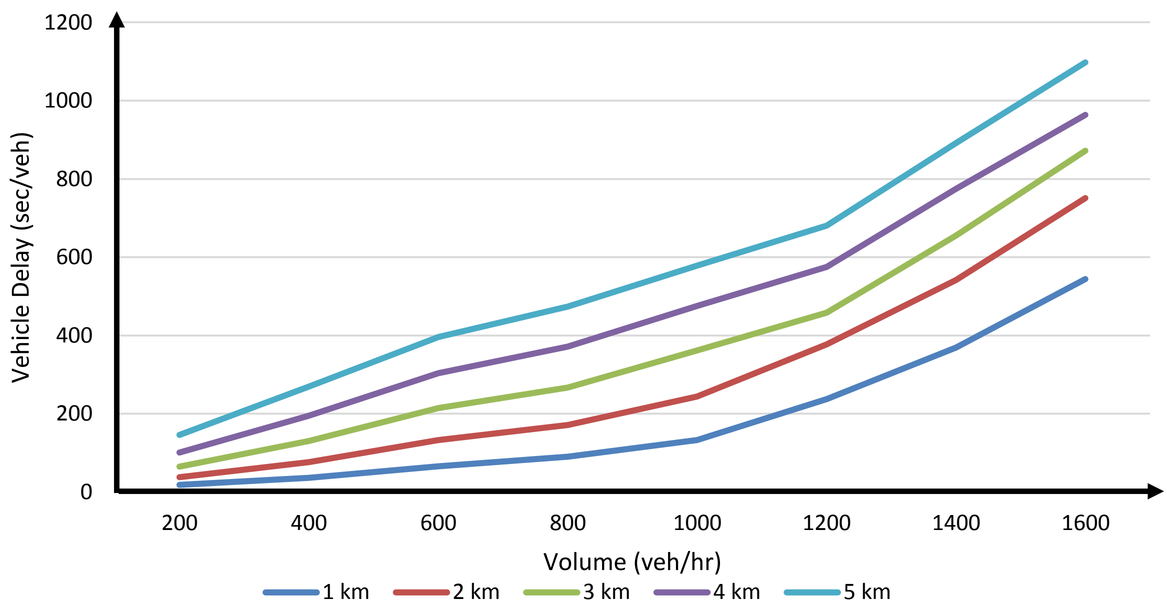

Figure 4.11: Graph: Effect of workzone (Median crossover) length on delay, National Highway

The graph depicts that delay and travel time are directly proportional to the length of the travel section. The capacity of median crossover is 1200 veh/hr. After that, vehicular delay increases rapidly. The graph below shows that after 1200 veh/hr, flow through the workzone remains constant.

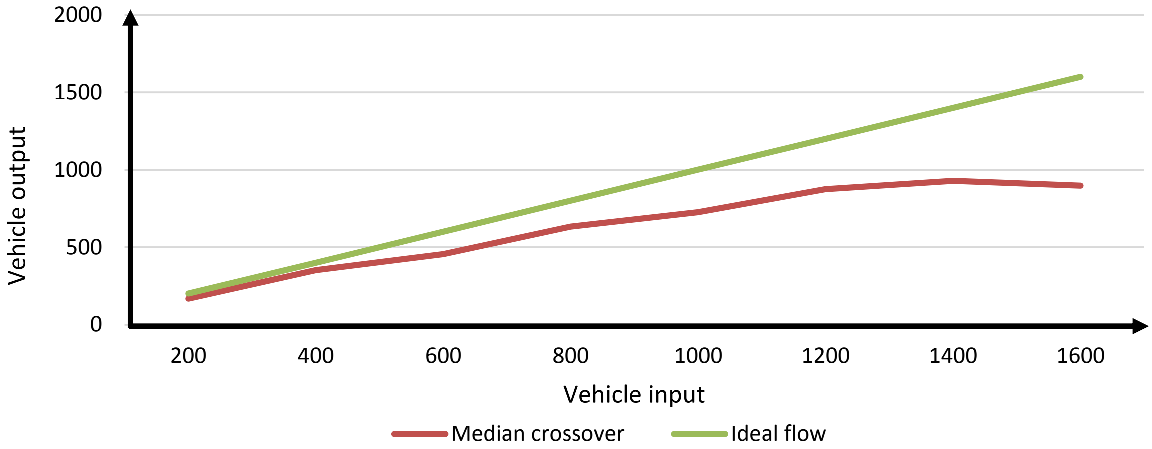

Figure 4.12: Graph: Capacity of workzone (Median crossover), National Highway

4.3 COMPARISON OF STRATEGIES:

Motorway

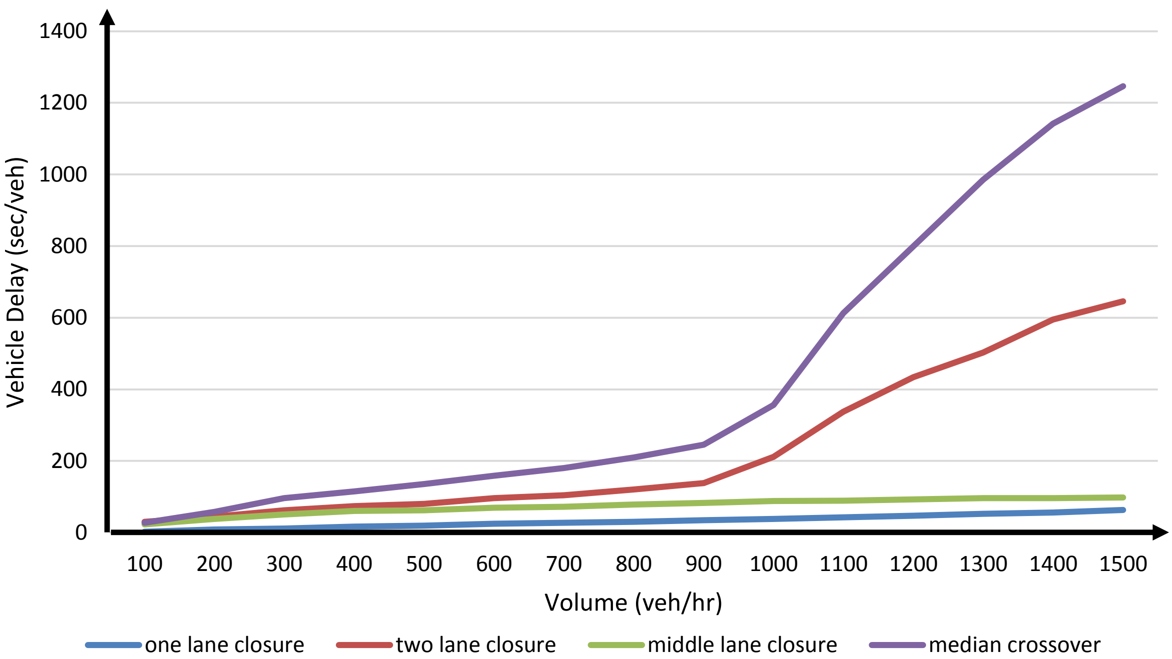

Figure 4.13: Graph: Comparison of Workzone Strategies, Motorway

The graph shows that vehicular delay in case of slow lane closure is less than middle lane closure. In case of middle lane closure, drivers are provided with options to use slow lane or fast lane, which creates confusion among the drivers, and require high perception reaction time which results in serious accidents.

The vehicular delay in case of middle lane closure is less than two lane closure, because in case of two lane closure, only single lane is used by the through traffic and the capacity is almost half of the slow or middle lane closure. The number of lanes available to the drivers determines the accessibility to pass the slow moving vehicles. Consider a work zone with one lane open as in case of two lane closure and median crossover. In this scenario, vehicles do not have any opportunity to pass the slow moving vehicles and therefore once they are queued behind them, then they have to travel at that low speed till they exit the workzone. When there are more than one lane available to the driver in the work zone as in case of slow lane or middle lane closure, vehicles have more chances to pass slow moving vehicles and therefore extra delay due to slow-moving vehicles would be minimal.

Maximum delay occurred in case of median crossover strategy, because one side is completely closed and the traffic is diverted on the opposite side. This will decrease the number of lanes available for the traffic of both sides, which eventually decrease the capacity of the workzone.

National Highway

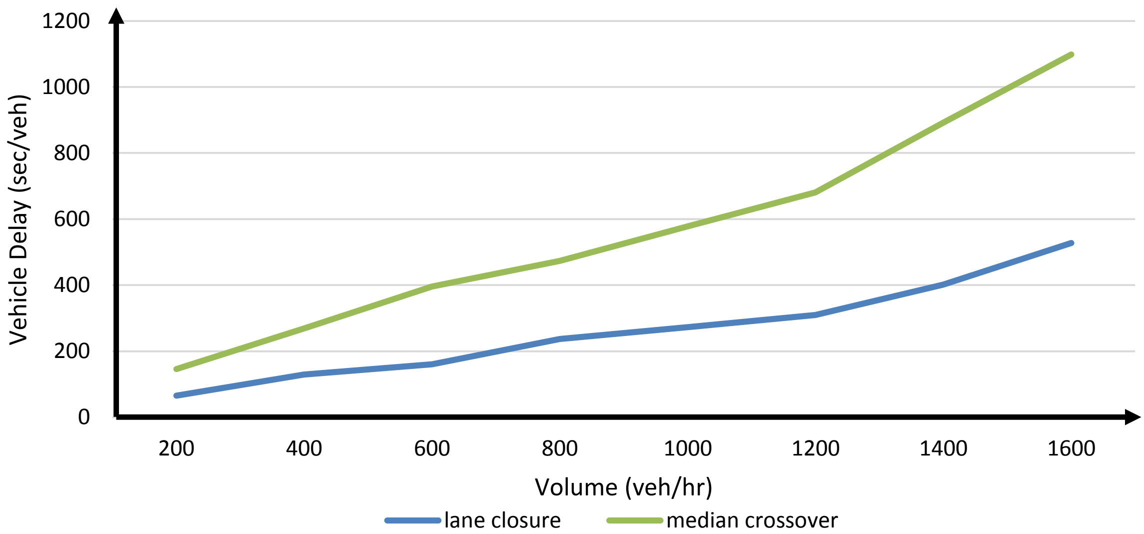

Figure 4.14: Graph: Comparison of workzone strategies, National Highway

The graph shows that in case of median crossover, vehicular delay is more as compared to lane closure strategy and the capacity of median crossover (1200veh/hr) is less than lane closure strategy (1400 veh/hr).

4.4 EFFECT OF MEDIAN OPENING ON DELAY:

In case of median crossover strategy, median opening is the major issue. The smaller median opening causes the threats to the drivers safety and increase the risk, whereas, large median opening, however decrease the potential of risk but at the same time, the cost of dismantling and reconstructing the median increased. Also in small median opening, drivers reduce their speed while crossing the median which ultimately results in increased vehicular delay. In reality, larger median openings are avoided because it unnecessarily increase the cost of the project. To understand the relationship between median opening and delay, workzone models were made with varying length of median opening. The designed speed for workzone is 70 km/hr. The speed of the vehicles were reduced by providing reduced speed areas along the median opening. The reduced speed of vehicles were shown below

Table 4-1: Reduced speed of vehicles at median opening

Median opening (m)	Speed (km/hr)		
	Truck	Bus	Car
10	10	10	20
20	30	30	40
30	40	40	50
40	50	50	60
50	60	60	70
60	60	60	70
70	60	60	70
80	60	60	70
90	60	60	70
100	60	60	70

Simulations were run and by arranging the results, graph was plotted between median opening and delay.

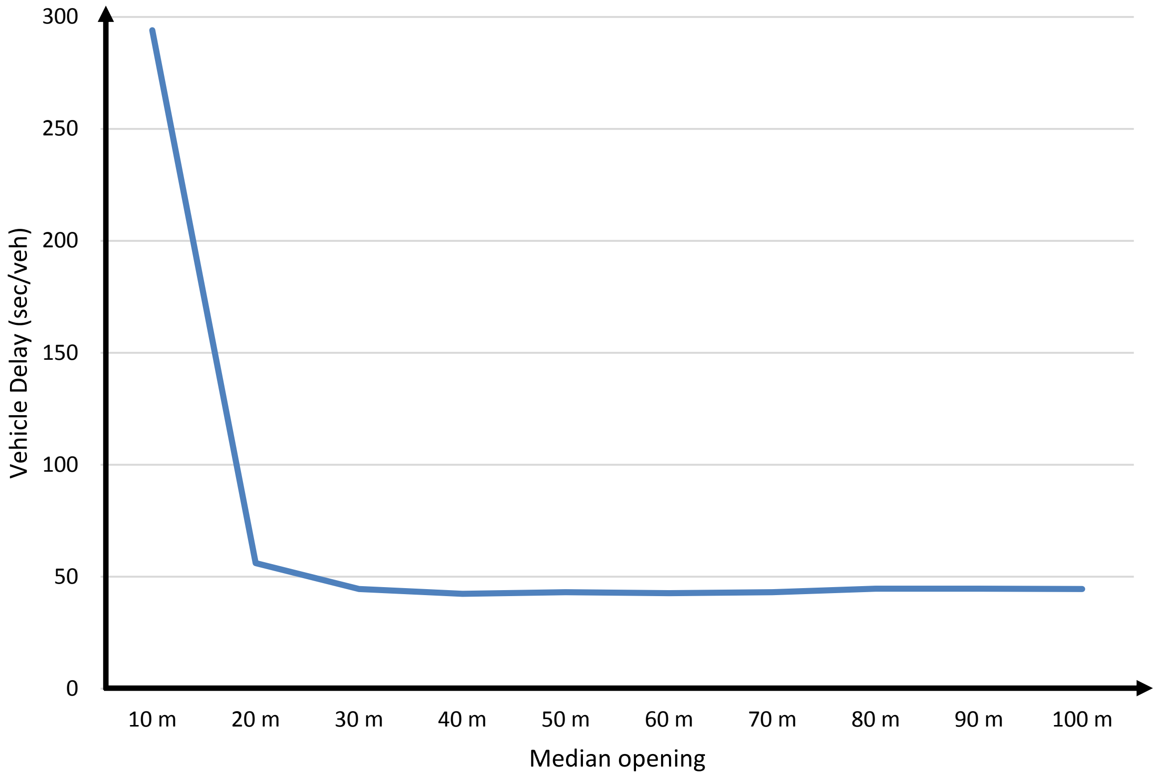

Figure 4.15: Graph: Effect of median opening on delay

The graph illustrates that the vehicular delay decreases upto 30 m of median opening. After 30 m, the vehicular delay remains constant, even if length of median opening is increased.

CHAPTER V

CONCLUSION

5.1 SYNOPSIS OF THE STUDY

This research study addressed the effect of different workzone strategies on delay. The study began with an extensive review of the literature. The detailed review helps in understanding the workzone and its importance. The international literature exploration provided an understanding about the subject as it is dealt with around the world. It also provided a view of current practices followed in different countries along with latest enhancements being introduced. The MUTCD provides an easy to follow and well established designs for highway workzones. Such design ensures safe and efficient flow of traffic through workzone. Some of the parameters like median opening in case of median crossover strategy was varied and the results were determined. The main focus of this study is on lane closure and median crossover strategies for the selected roadways. Detailed literature search helped in clear identification of study objectives and kept the study effort focused. Based on the proposed objectives, detailed study methodology was worked out. It covered all the required steps with a reasonable and realistic work schedule.

This study examined the effect of following different factors on vehicular delay in workzones. The factors are; length of workzone, Flow through the workzone and length of median opening. VISSIM was used to obtain the delay for different combinations of the above-mentioned factors.

5.2 STUDY FINDINGS

The results obtained from the analysis of highway workzone modals dictate that as the length of the workzone increases, vehicular delay increases. Flow through the workzone has direct relation with delay i-e more flow, more will be the delay. In case of median crossover strategy, the delay will be maximum as compared to the rest of the workzone strategies. The average vehicular delay decreases upto 30 m of median opening. After this, delay become constant, even if length of median opening is increased.

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