SIMULATION OF TRAFFIC ON SWAT MOTORWAY (65±00 – 70±00)

Project submitted in partial fulfillment of the requirements for the degree of BE Civil Engineering

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Abbreviations

LOS: Level of Service

DD&C: Detail Design and Construction

FWO: Federal Works Organization

OD Matrix: Origin Destination Matrix

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Abstract

Deficient relief and varying slope lead to cost in-effectiveness and vehicular hazards. Swat MW (65±00 – 70 ±00) that ends at the opening of a tunnel. This 5 kilometer strip has been problematic due to elevation difference. Elevation differences have resulted into constant slopes that affect the critical length for particular speed and slope. To alleviate the elevation difference, three geometric designs of 5KM segment were accomplished using AutoCAD software and then simulated on PTV VISSIM 9 and traffic data was collected by traffic reports, comparison of the simulation results of various designs was required to find the best design. An evaluation of traffic conditions is suggested undertaking highway performance measures for improvements in traffic conditions that include capacity enhancement i.e. channelizing or increasing the number of lanes to maximize traffic progression. The suggested model is envisioned to improve the overall traffic conditions and transforming the existing facility into an uninterrupted traffic flow with an acceptable level of service.

Chapter 1

INTRODUCTION

1.1 BACKGROUND

Design of freeways in mountainous regions is always challenging due to natural terrain limitations. A poor geometric design in such a terrain results in long and steep roads which are often traffic accidents black spots. Especially the problem is aggravated when trucks volumes account for a substantial proportion of freeway traffic flow. Freeway upgrade section has significant effect on traffic safety, especially on longitudinal slopes, as it become traffic bottleneck for decelerating trucks thus impeding the traffic flow, which greatly affect road capacity as well as level of service. The answer to this challenge is optimization of longitudinal grade, grade length and suitable relief on the mountainous segments of these freeways. There is no definite solution for selection of adequate slope and the provision of relief and will vary with location and therefore has to dealt as unique solution for every situation.

1.2 SWAT MOTORWAY

Swat motorway connects Noweshera to Chakdara and it goes through Swabi, Malakand, Mardan and Swat districts. The project was initiated in August 2016 while it has been partially opened to traffic since 3 June, 2019. This motorway will reduce the travelling time from Nowshera to Chakdara by about two hours. Swat Motorway has a total length of 81 kilometers. During the project design phase, a mountainous segment of 5 kilometers negotiating Malakand Range (65±00 km - 70±00 km) posed design challenge due to the elevation involved in this segment.

1.2.1 5 Kilometer Malakand Range Segment (65±00 km - 70±00 km)

The 5 kilometer segment of the freeway basically negotiate the elevations of Malakand Range. The primary importance given in any geometric design is the safety and comfort of the user. The next consideration is the total cost of the project that should also be kept in mind. A simple solution in any such project is the directness of the route which may entail the construction of numerous structures which mostly is not a viable option. Thus keeping all the relevant factors in mind three designs were prepared for this 5 kilometer segment.

1.2.2 Designs for the 5 Kilometer Strip (65±00 km - 70±00 km)

Out of the three design suggestions for this 5 kilometer segment, two of the designs were provided by Military College of Engineering, NUST, Risalpur (MCE) through the DD&C platform while one design was prepared by Frontier Works Organization (FWO). The aim of this Final Year Project is to evaluate the four designs in the light of Level of service (LOS) offered by three alternatives basing on recommended MOE (Measure of Effectiveness) like density, speed and travel time etc. The design offering the best LOS comparatively will be adjudged the preferred one. In this project, the designs will be referred to as Option 1, Option 2, Option 3 and Option 4, detail of these options are given in succeeding paragraphs.

1.2.2.1 Option 1

The initial design submitted by DD&C.

1.2.2.2 Option 2

The revised design submitted by DD&C

1.2.2.3 Option 3

FWO design which is being implemented on ground.

1.2.2.4 Option 4

The shoulders provided in Option 2 were converted into a lane making Option 4 a three-lane freeway.

1.3 PROBLEM STATEMENT

A 5 kilometer strip on Swat Motorway (65±00 km, 70 ±00 km) terminates at the south portal of a tunnel. This 5 kilometer strip has proven to be challenging to design due to substantial difference in elevation of starting point and end point of this upgrade section as it is actually negotiating the Malakand Ranges in a span of this 5 kilometers distance. In order to negotiate this elevation difference, designer has to intelligently plan the freeway with suitable grades appropriate grade lengths and moreover the suitable relief in order to cause minimum disruption to traffic flow on this section resulting in maintaining an acceptable level of service (LOS). In the absence of any real data on freeway which is yet to be built, the only option left is to simulate the traffic and analyze the traffic operations in the light of some well-established measure of effectiveness (MOE). Level of Service (LOS) criteria is used to assess the traffic operations through simulations of PTV VISSIM software. Hence, comparison of the simulation results of three alternatives can provide a sound basis for checking their efficacy. Traffic data and geometric design will be the basic input for the simulations carried out on PTV VISSIM.

1.4 PTV VISSIM

PTV VISSIM is a microscopic multi-modal traffic flow simulation software package developed by PTV Planung Transport Verkehr AG in Karlsruhe, Germany. It is the ideal tool for state-of-the-art transportation planning and traffic operations analysis. The software is designed to assist you in realistically simulating and balancing roadway capacity as well as traffic and transport demand. With PTV VISSIM different modal as well as multimodal scenarios can be modelled realistically and assessed with regard to the effect they have on traffic flow – whether for motorized traffic such as cars, trucks and buses, rail-based transport such as trams and trains, or non-motorized traffic such as pedestrians and cyclists. It achieves realistic results at the aggregated level by means of detailed geometry and microscopic behavior models like Driving behavior at operational level and lane selection and cooperative behavior at tactical level.

VISSIM is a microscopic simulation tool and based on time interval and vehicle driving behavior. It can be used to simulate and analyze the traffic operation state of various road traffic conditions, and is an effective tool to evaluate road traffic engineering design.

1.5 Measure of Effectiveness (MOE)

The classification of transportation facilities from the engineering viewpoint is based on the flow continuity, and generally classified as uninterrupted flow and interrupted flow facilities. Uninterrupted flow is the one in which there is no blockade to the movement of vehicles along the road. Freeway is one example for this type of facility. When a vehicle enters a freeway, there is no need for the vehicle to stop anywhere till it leaves the freeway. For uninterrupted flow of traffic, measure of effectiveness (MOE) is density in freeways. Speed also becomes important in two-lane highways and multilane highways. HCM defines the levels of service of freeway sections based on density.

A term closely related to capacity and often confused with it is service volume. While capacity gives a quantitative measure of traffic, level of service or LOS defines the qualitative measure. A service volume is the maximum number of vehicles, passengers, or the like, which can be accommodated by a given facility or system under given conditions at a given level of service. The intention of LOS is to relate the traffic service quality to a given flow rate of traffic. It is a term that designates a range of operating conditions on a particular type of facility. Highway capacity manual (HCM) developed by the transportation research board of USA provides some procedure to determine level of service. It divides the quality of traffic into six levels ranging from level A to level F.

Level A represents the best quality of traffic where the driver has the liberty to drive with free flow speed while level F represents the poorest quality of traffic. Level of service is defined based on the measure of effectiveness or (MOE). Traditionally, there are three parameters which are used and they are speed and travel time, density, and delay. An important measures of service quality is the amount of time spent in travel. Therefore, speed and travel time are considered to be more effective in defining LOS of a facility. Density gives the proximity of other vehicles in the stream. Since it affects the ability of drivers to maneuver in the traffic stream, it is also used to describe LOS. Delay is a term that describes excess or unexpected time spent in travel. Many specific delay measures are defined and used as MOE's in the highway capacity manual.

LOS	Density (Veh/km/lane)	FFS (Km/hr)	V/C (volume/Capacity)
A	0-7	120	0.35
B	7-11	120	0.55
C	11-16	114	0.77
D	16-22	99	0.92
E	22-28	85	1.0
F	>28	<85	>1.0

Table: LOS for a Basic Freeway Segment

1.6 AIMS AND OBJECTIVES

The aim of this project is to evaluate the four designs alternatives (Initial DD&C option, FWO option, Revised DD&C option and Revised DD&C option with three lanes) by running simulations on VISSIM with different inputs. The inputs vary in terms of traffic volume and design speed. The simulations will generate report defining LOS (level of service), average speed etc. which will dictate the suitability of the designs.

Chapter 2

LITERATURE REVIEW

2.1 FREEWAYS

They are highways where access to roads is limited and fully controlled. They provide safety and efficiency to large volume of traffic flow. It is free from signals, intersections crossing of pedestrians or other roads or rails etc. (A policy on geometric design of highways and streets - 2001, 2001, p. 507).

2.2 FREEWAYS IN MOUNTANIOUS TERRAIN

In mountain areas, because of the geological conditions, longer upgrades must be used at which the speed of light traffic vehicle does not reduce, but the effect on heavy traffic vehicles is great. light traffic vehicles and heavy traffic vehicles speed difference will cause problems to traffic. ("Study on the Mountainous Freeway Vertical Alignment Safety Based on Typical Truck Climbing Characteristics in China", 2011, p. 1634)

2.2.1 Rural Freeways

Rural freeways are like urban freeways, however the alignment and cross-sectional parts are more generous once it involves the design, that is equal with the higher design speed and usually with greater availableness of right-of-way wherever terrain permits, a design speed of one hundred ten km/h will be optimal and safer than the one for lower speed. Freeways are supposed to include foreseen traffic for concerning two decades and remain in function for a greater period. Any construction done for lower design speed may be cheaper initially but will be outweighed by the high costs that accompany the reconstruction of major facilities. (A policy on geometric design of highways and streets - 2001, 2001, p. 512).

2.3 CRITICAL LENGTH

The term "critical length of grade" is used to point the utmost length of a grade where a truck fully loaded will operate without unreasonable decrease in speed. If needed freedom of operation is required to be maintained on grades having additional length than the crucial length, changes like changes in location for the reduction of the grade or addition of additional lanes ought to be done. (A policy on geometric design of highways and streets - 2001, 2001, p. 242).

2.3.1 Grade

Freeway grades are shown in table 2.1 as a function of type of terrain and speed. Grades on urban freeways and rural freeways of the same design speed are comparable.

Type of Terrain	Metric						US Customary						
	Design Speeds (km/h)						Design Speeds (mph)						
	80	90	100	110	120	130	50	55	60	65	70	75	80
	Grades (%)[a]						Grades (%)[a]						
Level	4	4	3	3	3	3	4	4	3	3	3	3	3
Rolling	5	5	4	4	4	4	5	5	4	4	4	4	4
Mountainous	6	6	6	5	–		6	6	6	5	5	–	–

[a] Grades 1% steeper than the value shown may be used for extreme cases in urban areas where development precludes the use of flatter grades and for one-way downgrades except in mountainous terrain.

Table 2.1

Rural/Urban Freeway grades (A policy on geometric design of highways and streets - 2001, 2001, p. 510).

2.4 DESIGN OF HORIZONTAL AND VERTICAL ALIGNMENT

2.4.1 Horizontal Alignment

Factors to be considered for the design are design speed, horizontal curve, super elevation, width of pavement on curves and set back distance. (*Geometric Design of Highway*, 2017)

2.4.2 Design Speed

It depends on upon:

- Class of the road
- Type of terrain

Classification of Terrain

Terrain Classification	Cross Slope Of Country in %
Plain	0-10
Rolling	10-25
Mountainous	25-60
Steep	Greater than 60

Table 2.2

(*Geometric Design of Highway*, 2017)

2.4.3 Horizontal Curve

It is used to change the direction of path, vehicle going through it faces centrifugal force which is given by:

$$P = \frac{Wv^2}{gR}$$

where, P is centrifugal force (kg), W is Weight of the vehicle (kg), R is radius of the curve (m), v is speed of the vehicle (m/s) and g is acceleration due to gravity (9.8 m/s2) (*Geometric Design of Highway*, 2017)

2.4.4 Super Elevation

To oppose the centrifugal force and to avoid overturning and skidding of a vehicle, the outside of the road is raised as compared to the inside, therefore, providing a slope throughout the curve length. This inclination to the road is known as Super elevation. (*Geometric Design of Highway*, 2017)

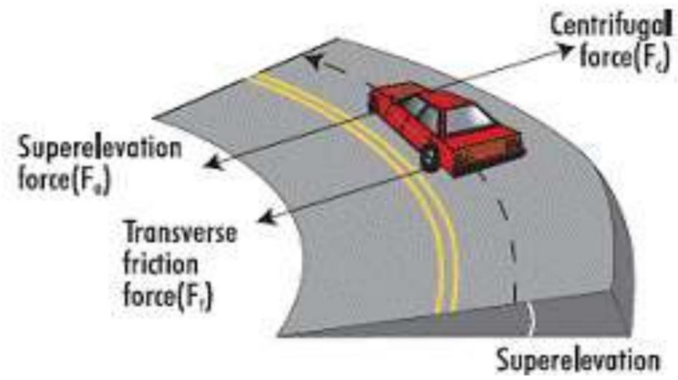


Figure 2.1

2.4.5 Widening of pavement on horizontal curve

It is required for the reasons below:

- An automobile contains a rigid wheelbase and wheels on the front are accustomed to take a turn, when a vehicle takes a turn, the rear wheel do not follow the front wheels. This development is termed off trailing
- When two vehicles overtake at horizontal curve there is a tendency to maintain a bigger clearance between the vehicles for safety.

- For better vision at curve, the person driving the vehicle uses the outer edge of the road.
- At higher speed it gets difficult to counteract centrifugal force and it can cause skidding. (*Geometric Design of Highway*, 2017)

2.4.6 Setback Distance

It is the length between obstruction on inside lane and center of horizontal curve. These obstructions can be a presence of a tree, a building etc. on inside lane of a curve.

- It's needed for provision of necessary sight distance on a curve.
- On thinner road, the center line of road is used as a sight distance measurement
- On thicker road, the center line of inside lane is used as a sight distance measurement. (*Geometric Design of Highway*, 2017)

2.4.7 Vertical Alignment

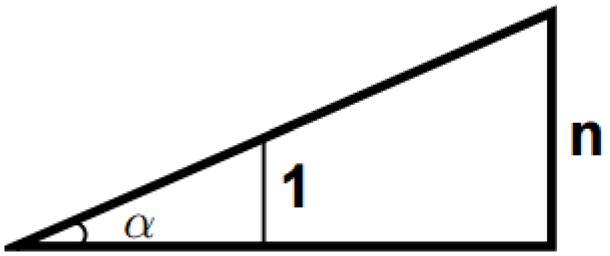
It is the elevation of the center line of the road, consisting of grades and vertical curves. The vertical alignment of a highway affects vehicle speed, acceleration, sight distance, cost of vehicle operation, comfort at high speeds.

Components of vertical alignment are:

i. Gradients
ii. Grade compensation
iii. Vertical curves ("The Constructor - Civil Engineering Home for Civil Engineers", 2020)

2.4.8 Gradient

Gradient is the of increase or decrease of slope with respect to the horizontal. It is given as a percentage (n%) or as a ratio of 1 in n.



("The Constructor - Civil Engineering Home for Civil Engineers", 2020)

There are four types of gradients which are ruling gradient, limiting gradient, exceptional gradient and minimum gradient. These gradients are explained below.

2.4.8.1 Ruling Gradient

Also known as design gradient. It is the max gradient at which the vertical profile of a roadway is designed. Depends on terrain type, grade length, speed, vehicle pulling power etc. for its design. (*Geometric Design of Highway*, 2017)

2.4.8.2 Limiting Gradient

Limiting gradient is steeper compared to ruling gradient. For mountainous terrain, sometimes limiting gradient is taken instead of ruling gradient, it depends on

- Topography
- Cost in constructing the road. (*Geometric Design of Highway*, 2017)

2.4.8.3 Exceptional Gradient

They are steep gradients provided at situations that are unavoidable. They should be less than 100 meters at a stretch.

Type of terrain	Ruling gradient	Limiting gradient	Exceptional gradient
Plain and rolling	3.3 % 1 in 30	5% 1 in20	6.7 % 1 in 15
Mountainous and steep having elevation more than 3000 m above MSL	5% 1 in20	6 % 1 in 16.7	7 % 1 in 14.3
Mountainous and steep having elevation more than 3000 m above MSL	6 % 1 in 16.7	7 % 1 in 14.3	8 % 1 in 12.5

Table 2.3

(*Geometric Design of Highway*, 2017)

2.4.8.4 Minimum Gradient

This is for locations where surface drainage is essential. The longitudinal drainage along the side drains require some slope for smooth flow of water. (*Geometric Design of Highway*, 2017)

2.4.9 Grade Compensation

When a horizontal circular curve lies in vertical curve there'll be curve resistance with the element of gravity. For grades less than 4 percent, grade compensation might not be required because of negligible loss of frictional force. ("The Constructor - Civil Engineering Home for Civil Engineers", 2020)

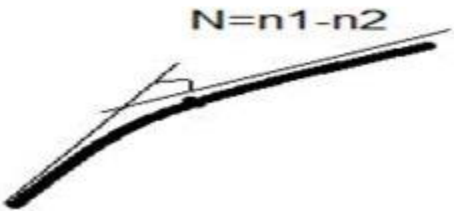
2.4.10 Vertical Curves

2.4.10.1 Summit Curve

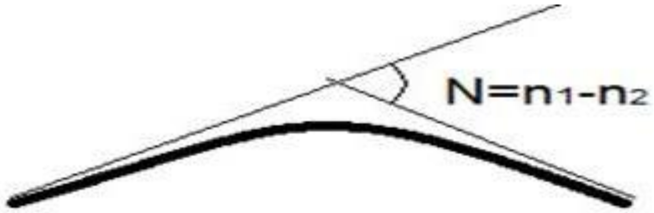
It is a vertical curve provided when the slope is moving upwards. In this curves case best shape is a simple parabola. It has following cases:

When upward slope joins a flatter slope.

When upward slope joins another slope moving upside



When upward and downward slope joins



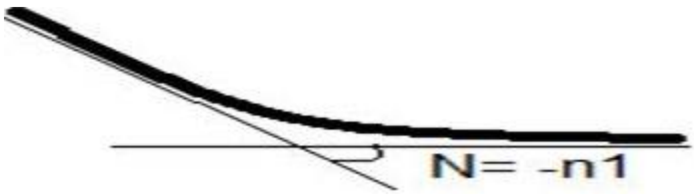
When downward slope joins another downward slope

("The Constructor - Civil Engineering Home for Civil Engineers", 2020)

2.4.10.2 Valley Curve

It is a vertical curve provided when the slope is moving downwards. when the vehicle meets downward slope, it causes an increase in the acceleration and discomfort. So, in its design comfort and sight distance both are considered. It also has four cases but two of them are same as summit curve and the other two are:

When downward slope joins flatter slope



When downward slope joins upward slope

("The Constructor - Civil Engineering Home for Civil Engineers", 2020)

2.5 RELATIONSHIP BETWEEN SPEED, DENSITY AND FLOW

Macroscopic stream models show how a change in one parameter of traffic affects other. Greenshields took a linear speed-density relation as given in figure 2.2 for the model derivation.

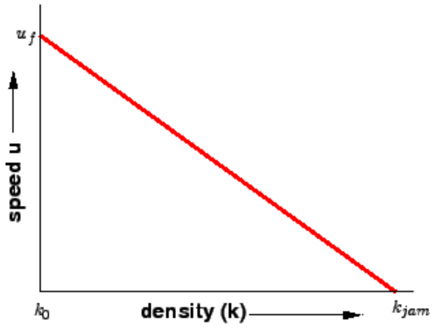


Figure 2.2

(Speed-density)

The equation for this is:

$$v = v_f - \left[\frac{v_f}{k_j}\right].k$$

where v is the mean speed at k density.

v_f (free speed) k_j (jam density), This equation as the Greenshields' model. According to which at zero density we get ffs (free flow speed).

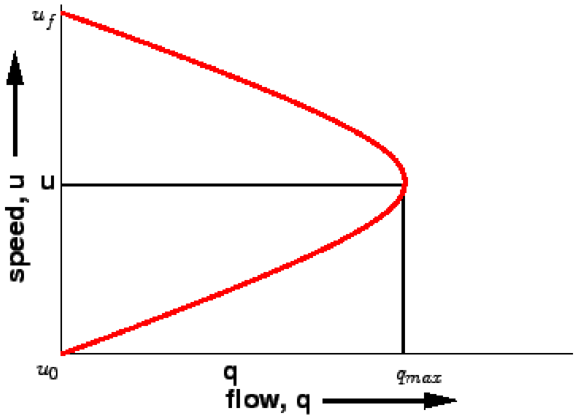


Figure 2.3

(Speed-flow)

After obtaining the relation between speed and flow, the relation with flow can be derived. This relation between flow and density is parabolic in shape as shown in figure 2.4. as we know

$$q = k.v$$

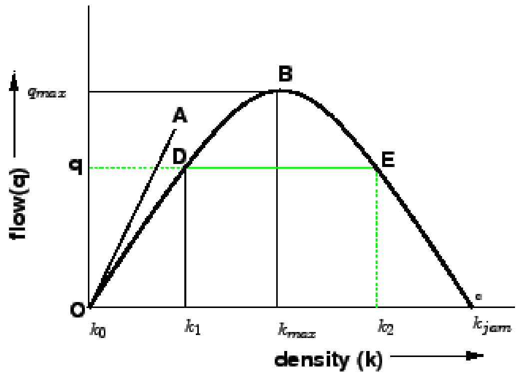


Figure 2.4

(Flow-density)

Now substituting previous two equations, we get

$$q = v_f.k - \left[\frac{v_f}{k_j}\right] k^2$$

In the same way, the relation between speed and flow can be derived. For this, put $k = \frac{q}{v}$ in speed/density equation and by solving, we get

$$q = k_j.v - \left[\frac{k_j}{v_f}\right] v^2$$

For maximum flow density, differentiate equation $q = k_j.v - \left[\frac{k_j}{v_f}\right] v^2$ with respect to k and equate it to zero. i.e.,

$$\begin{aligned} \frac{dq}{dk} &= 0 \\ v_f - \frac{v_f}{k_j}.2k &= 0 \\ k &= \frac{k_j}{2} \end{aligned}$$

Density with respect to max flow,

$$k_0 = \frac{k_j}{2}$$

Therefore, density corresponding to maximum flow is half the jam density Once we get k_0, we can derive for maximum flow, q_{max}.

Substituting equation $k_0 = \frac{k_j}{2}$ in equation $q = k_j.v - \left[\frac{k_j}{v_f}\right] v^2$

$$
\begin{aligned}
q_{max} &= v_f.\frac{k_j}{2} - \frac{v_f}{k_j}.\left[\frac{k_j}{2}\right]^2 \\
&= v_f.\frac{k_j}{2} - v_f.\frac{k_j}{4} \\
&= \frac{v_f.k_j}{4}
\end{aligned}
$$

To get the speed at maximum flow, v_o, substitute equation $k_0 = \frac{k_j}{2}$ in equation $v = v_f - \left[\frac{v_f}{k_j}\right].k$ and solving we get,

$$v_0 = v_f - \frac{v_f}{k_j}.\frac{k_j}{2}$$

$$v_0 = \frac{v_f}{2}$$

Therefore, maximum flow speed is half of the free speed. (Region, 2010)

2.6 LEVEL OF SERVICE

The level of service gives us the freedom of traffic operation with respect to speed and time to travel. The LOS ranges from A to Where A being least congested to F being most congested. (A policy on geometric design of highways and streets - 2001, 2001, p. 84).

Level of service	General operating conditions
A	Free flow
B	Reasonably free flow
C	Stable flow
D	Approaching unstable flow
E	Unstable flow
F	Forced or breakdown flow

Table 2.4

(A policy on geometric design of highways and streets - 2001, 2001, p. 84).

2.6.1 Factor Affecting Level of Service

The factors that can affect LOS are speed and time to travel, interruptions in the traffic, ease to travel with desired speed, comfort and convenience of the driver, cost of operation. ("CDEEP-IIT Bombay", n.d.)

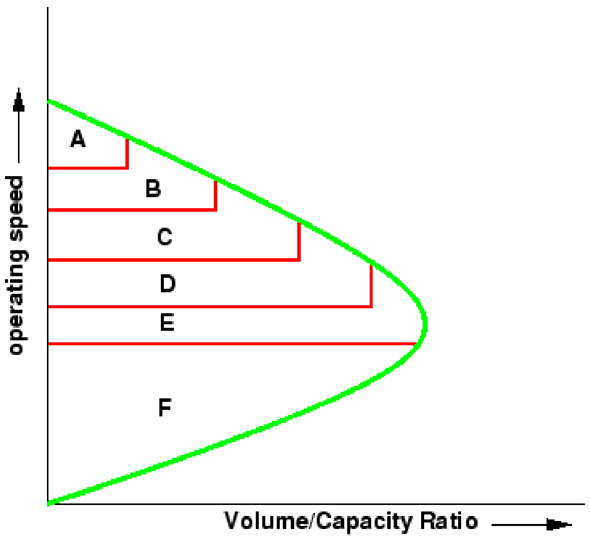


Figure 2.5

("CDEEP-IIT Bombay", n.d.)

Level of service A (zone of free flow). Less traffic volume and freedom to settle on speed. Average space between vehicles is 167 m. simple to alter lanes.

Level of service B (zone of fairly free flow). Free flow speeds may be maintained at this LOS. Slight restriction within the want to decide on speed. Average space between vehicles is concerning 100 m. At level of service C, the presence of different vehicles begins to limit the flow of traffic. Average speeds stay close to the free flow speed, but active driving is required. Space between the vehicles is of 67 m. there can be formation of the queues because of blockage. At level of service D, density and restrictions increase with the decrease in the speed of the vehicle. Average space between the vehicles is 50 m, queuing of the cars due to even a minor incident. At level of service E the stream reaches its max density limit. Maneuvering within the traffic stream becomes extraordinarily tough. Level of service F gives jam density because of a disruption queues are formed. Level of service F has the region of forced flow, very slow speed, and system breakdown. ("CDEEP-IIT Bombay", n.d.)

Chapter 3

METHODOLOGY

3.1 PROJECT METHODOLOGY

This chapter will cover the methods, strategies, and procedures adopted for various activities like data collection, software usage, and analysis carried out in the project. It also includes the demonstration and description of these procedures adopted to reach to the desired objectives and solutions. The following flowchart describes the complete scheme, sequence and working of the project activities, procedures, and plan. All the following steps are discussed in detail in this chapter.

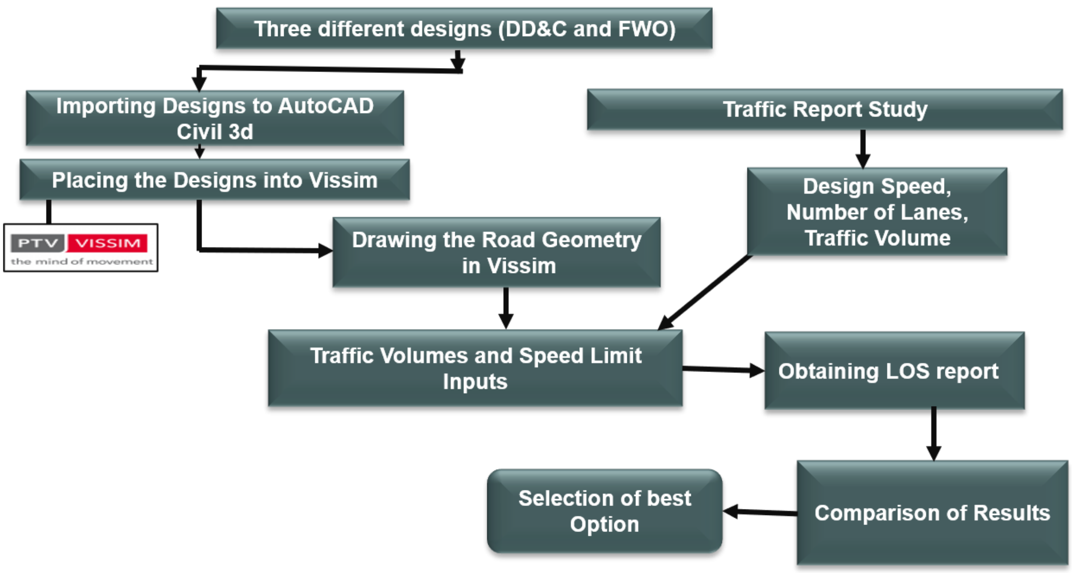


FIG 3.1: Project Methodology

3.1.1 AutoCAD Civil 3d

Using the survey reports and slope variations of the options, the whole design was drawn into AutoCAD Civil 3d. The survey data was used to plot the freeway by providing lanes and shoulders on both sides. After designing all the options, three options with 2 lanes and one option with 3 lanes, they were imported to PTV Vissim in order to trace the road.

V9

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	X	Y	Z	Disc	Points	Formation	Command	[E,N]	Rotattion	Text	Command	[E,N]	Rotation	Text
2	3825728.514	227305.47	599.8469849	R5	PO	3825728.514,227305.47	-TEXT	3825729.014,227304.87	0	R5	-TEXT	3825729.014,227303.97	0	599.8
3	3825721.283	227312.6669	597.973999	R5	PO	3825721.283,227312.6669	-TEXT	3825721.783,227312.0669	0	R5	-TEXT	3825721.783,227311.1669	0	597.9
4	3825721.276	227312.7065	597.9849854	R5	PO	3825721.276,227312.7065	-TEXT	3825721.776,227312.1065	0	R5	-TEXT	3825721.776,227311.2065	0	597.9
5	3825713.875	227319.0293	597.4589844	R5	PO	3825713.875,227319.0293	-TEXT	3825714.375,227318.4293	0	R5	-TEXT	3825714.375,227317.5293	0	597.4
6	3825705.798	227326.1163	595.6660156	R5	PO	3825705.798,227326.1163	-TEXT	3825706.298,227325.5163	0	R5	-TEXT	3825706.298,227324.6163	0	595.6
7	3825698.147	227332.0158	597.9450073	R5	PO	3825698.147,227332.0158	-TEXT	3825698.647,227331.4158	0	R5	-TEXT	3825698.647,227330.5158	0	597.9
8	3825692.2	227339.4511	596.6129761	R5	PO	3825692.2,227339.4511	-TEXT	3825692.7,227338.8511	0	R5	-TEXT	3825692.7,227337.9511	0	596.6
9	3825748.808	227326.8651	600.0250244	R35	PO	3825748.808,227326.8651	-TEXT	3825749.308,227326.2651	0	R35	-TEXT	3825749.308,227325.3651	0	600.0
10	3825742.195	227334.3909	596.8920288	R35	PO	3825742.195,227334.3909	-TEXT	3825742.695,227333.7909	0	R35	-TEXT	3825742.695,227332.8909	0	596.8
11	3825734.315	227340.5128	594.2319946	R35	PO	3825734.315,227340.5128	-TEXT	3825734.815,227339.9128	0	R35	-TEXT	3825734.815,227339.0128	0	594.2
12	3825712.482	227361.3012	591.6669922	R35	PO	3825712.482,227361.3012	-TEXT	3825712.982,227360.7012	0	R35	-TEXT	3825712.982,227359.8012	0	591.6
13	3825709.196	227364.7757	591.9190063	R35	PO	3825709.196,227364.7757	-TEXT	3825709.696,227364.1757	0	R35	-TEXT	3825709.696,227363.2757	0	591.9
14	3825745.259	227323.9555	599.9860229	R30	PO	3825745.259,227323.9555	-TEXT	3825745.759,227323.3555	0	R30	-TEXT	3825745.759,227322.4555	0	599.9
15	3825738.119	227330.2203	596.9810181	R30	PO	3825738.119,227330.2203	-TEXT	3825738.619,227329.6203	0	R30	-TEXT	3825738.619,227328.7203	0	596.9
16	3825731.051	227337.4928	594.3209839	R30	PO	3825731.051,227337.4928	-TEXT	3825731.551,227336.8928	0	R30	-TEXT	3825731.551,227335.9928	0	594.3
17	3825709.296	227358.2196	591.9279785	R30	PO	3825709.296,227358.2196	-TEXT	3825709.796,227357.6196	0	R30	-TEXT	3825709.796,227356.7196	0	591.9
18	3825741.74	227319.8126	600.5949707	R25	PO	3825741.74,227319.8126	-TEXT	3825742.24,227319.2126	0	R25	-TEXT	3825742.24,227318.3126	0	600.5
19	3825735.219	227327.167	597.4190063	R25	PO	3825735.219,227327.167	-TEXT	3825735.719,227326.567	0	R25	-TEXT	3825735.719,227325.667	0	597.4
20	3825727.436	227333.5391	594.5269775	R25	PO	3825727.436,227333.5391	-TEXT	3825727.936,227332.9391	0	R25	-TEXT	3825727.936,227332.0391	0	594.5
21	3825713.035	227347.5945	593.3549805	R25	PO	3825713.035,227347.5945	-TEXT	3825713.535,227346.9945	0	R25	-TEXT	3825713.535,227346.0945	0	593.3
22	3825705.306	227353.6133	594.7299805	R25	PO	3825705.306,227353.6133	-TEXT	3825705.806,227353.0133	0	R25	-TEXT	3825705.806,227352.1133	0	594.7
23	3825667.804	227388.7531	604.6660156	R25	PO	3825667.804,227388.7531	-TEXT	3825668.304,227388.1531	0	R25	-TEXT	3825668.304,227387.2531	0	604.6
24	3825738.378	227316.3076	598.598999	R20	PO	3825738.378,227316.3076	-TEXT	3825738.878,227315.7076	0	R20	-TEXT	3825738.878,227314.8076	0	598.
25	3825731.357	227323.1872	597.5650024	R20	PO	3825731.357,227323.1872	-TEXT	3825731.857,227322.5872	0	R20	-TEXT	3825731.857,227321.6872	0	597.5
26	3825724.068	227330.0748	594.8649902	R20	PO	3825724.068,227330.0748	-TEXT	3825724.568,227329.4748	0	R20	-TEXT	3825724.568,227328.5748	0	594.8
27	3825709.512	227344.2961	594.3640137	R20	PO	3825709.512,227344.2961	-TEXT	3825710.012,227343.6961	0	R20	-TEXT	3825710.012,227342.7961	0	594.3
28	3825702.042	227350.3231	595.0230103	R20	PO	3825702.042,227350.3231	-TEXT	3825702.542,227349.7231	0	R20	-TEXT	3825702.542,227348.8231	0	595.0
29	3825735.313	227312.8034	598.7479858	R15	PO	3825735.313,227312.8034	-TEXT	3825735.813,227312.2034	0	R15	-TEXT	3825735.813,227311.3034	0	598.7
30	3825727.98	227319.2686	597.8120117	R15	PO	3825727.98,227319.2686	-TEXT	3825728.48,227318.6686	0	R15	-TEXT	3825728.48,227317.7686	0	597.8
31	3825720.52	227326.716	595.1779785	R15	PO	3825720.52,227326.716	-TEXT	3825721.02,227326.116	0	R15	-TEXT	3825721.02,227325.216	0	595.1
32	3825706.341	227340.6241	595.1740112	R15	PO	3825706.341,227340.6241	-TEXT	3825706.841,227340.0241	0	R15	-TEXT	3825706.841,227339.1241	0	595.1
33	3825698.829	227346.8542	595.6279907	R15	PO	3825698.829,227346.8542	-TEXT	3825699.329,227346.2542	0	R15	-TEXT	3825699.329,227345.3542	0	595.6
34	3825732.207	227309.0483	599.6010132	R10	PO	3825732.207,227309.0483	-TEXT	3825732.707,227308.4483	0	R10	-TEXT	3825732.707,227307.5483	0	599.
35	3825724.387	227315.8407	597.9840088	R10	PO	3825724.387,227315.8407	-TEXT	3825724.887,227315.2407	0	R10	-TEXT	3825724.887,227314.3407	0	597.9
36	3825717.608	227322.7817	595.5540161	R10	PO	3825717.608,227322.7817	-TEXT	3825718.108,227322.1817	0	R10	-TEXT	3825718.108,227321.2817	0	595.5
37	3825702.756	227336.3384	595.5960083	R10	PO	3825702.756,227336.3384	-TEXT	3825703.256,227335.7384	0	R10	-TEXT	3825703.256,227334.8384	0	595.
38	3825695.214	227343.6972	596.1040039	R10	PO	3825695.214,227343.6972	-TEXT	3825695.714,227343.0972	0	R10	-TEXT	3825695.714,227342.1972	0	596.
39	3825788.719	227297.1106	615.6129761	POPULATION A	PO	3825788.719,227297.1106	-TEXT	3825789.219,227296.5106	0	POPULATION A	-TEXT	3825789.219,227295.6106	0	615.6
40	3825806.947	227290.4859	618.223999	POPULATION A	PO	3825806.947,227290.4859	-TEXT	3825807.447,227289.8859	0	POPULATION A	-TEXT	3825807.447,227288.9859	0	618.2

Fig 3.1: Survey report Easting and Northing

The elevations and position coordinates given in the survey report were imported to excel. The points were converted into easting and northing and then imported into AutoCAD Civil 3d. The points provided the positioning of nullahs, trees, topographic features etc. Using the central line of this survey report distances for lanes on both sides were given in AutoCAD and the road was drawn. This very same process was carried for all the options and 4 different roads were drawn using AutoCAD Civil 3d.

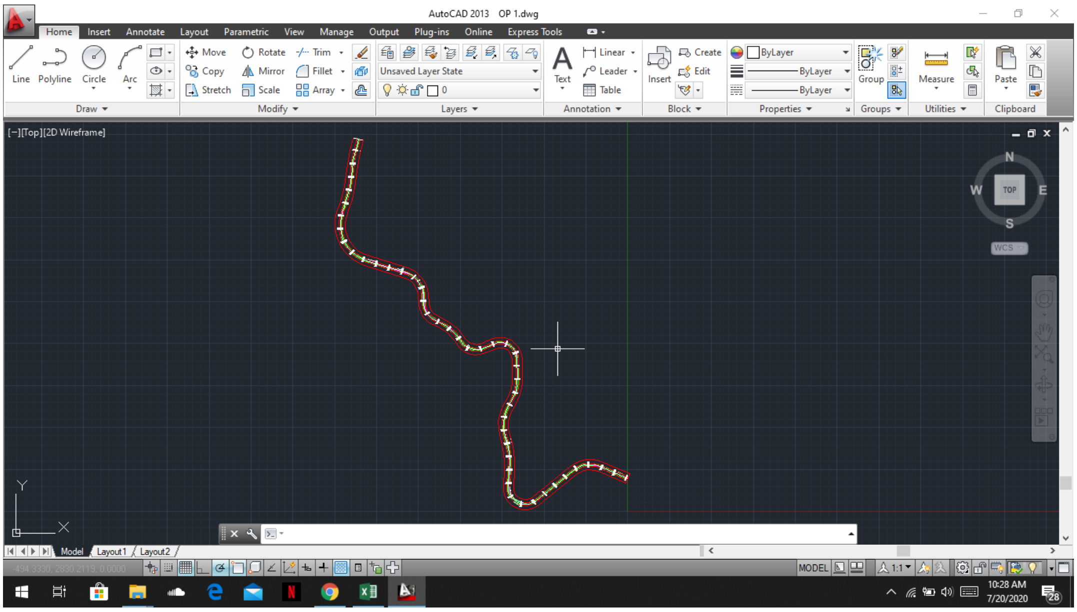


Fig 3.2: Initial DD&C Option

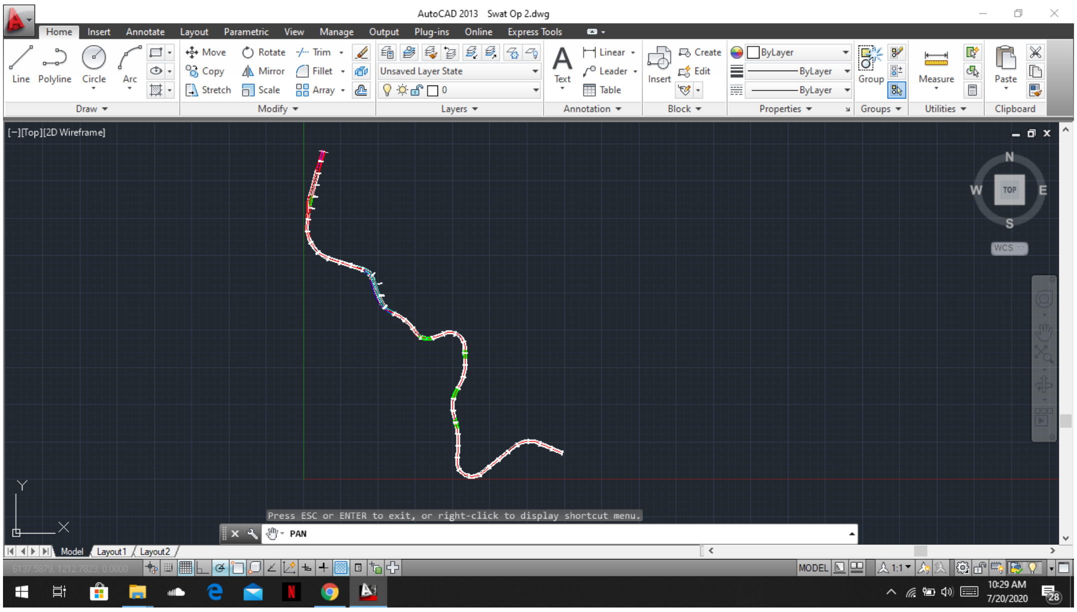


Fig 3.3: FWO Option

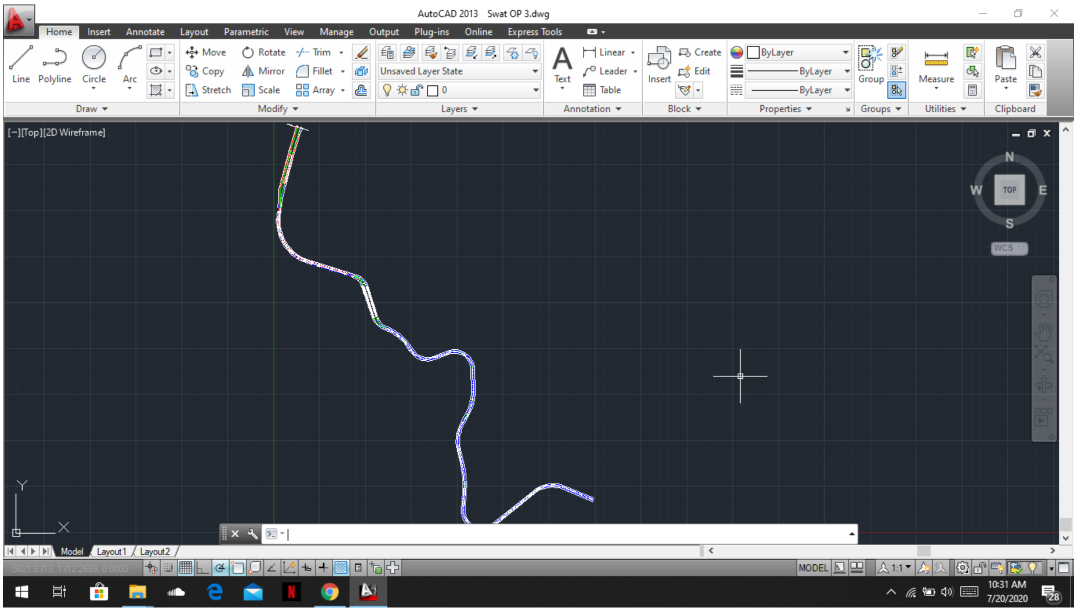


Fig 3.4: Revised DD&C Option

Fig 3.1, 3.2 and 3.3 show the drawings of the options made using AutoCAD. Revised DD&C option with three lanes was the same as Fig 3.3 with just an extra lane, hence, it wasn't drawn using AutoCAD but only traced into PTV Vissim using Revised DD&C Option.

3.1.2 PTV Vissim

The drawings were imported from AutoCAD Civil 3d to PTV Vissim for the tracing of road shape in 2 dimensions, i.e. the length of the road and the curves (not including slopes). Using the survey data, slope was to be added to the road, which was traced in PTV Vissim. To achieve this task with utmost accuracy, the 5 kilometer strip was divided into small segments of 10 meters when it was traced. This number was decided to be used because of the fact that the intervals of the slopes in the survey data were in the multiples of 10 meters. So, to achieve the best accuracy, the 5 kilometer strip was divided into minimum 456 and maximum 461 segments, depending upon the option. Both longitudinal and lateral slopes were added to individual road segments.

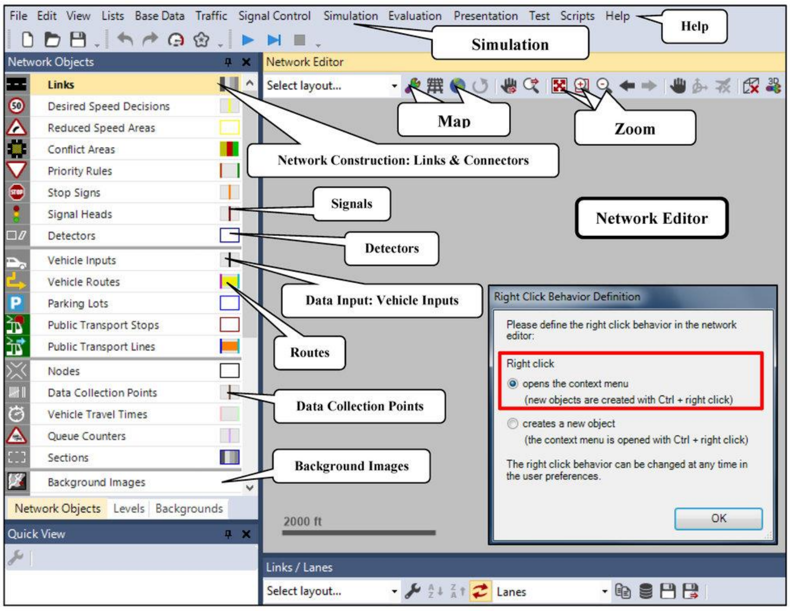


Fig 3.5: PTV Vissim Home Layout

3.1.2.1 Simulation Steps

The basic steps for the simulation of a freeway while including slope features are discussed in the following points.

- Go to base data for parameters

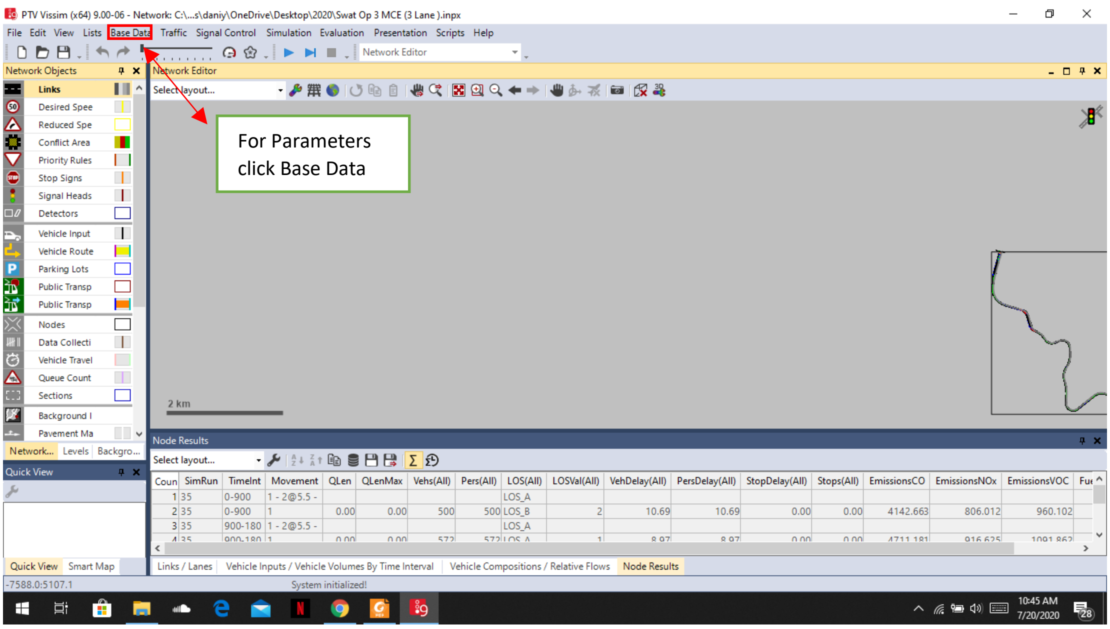


Fig 3.6: Base Data

- Amend the parameters in Network Settings.

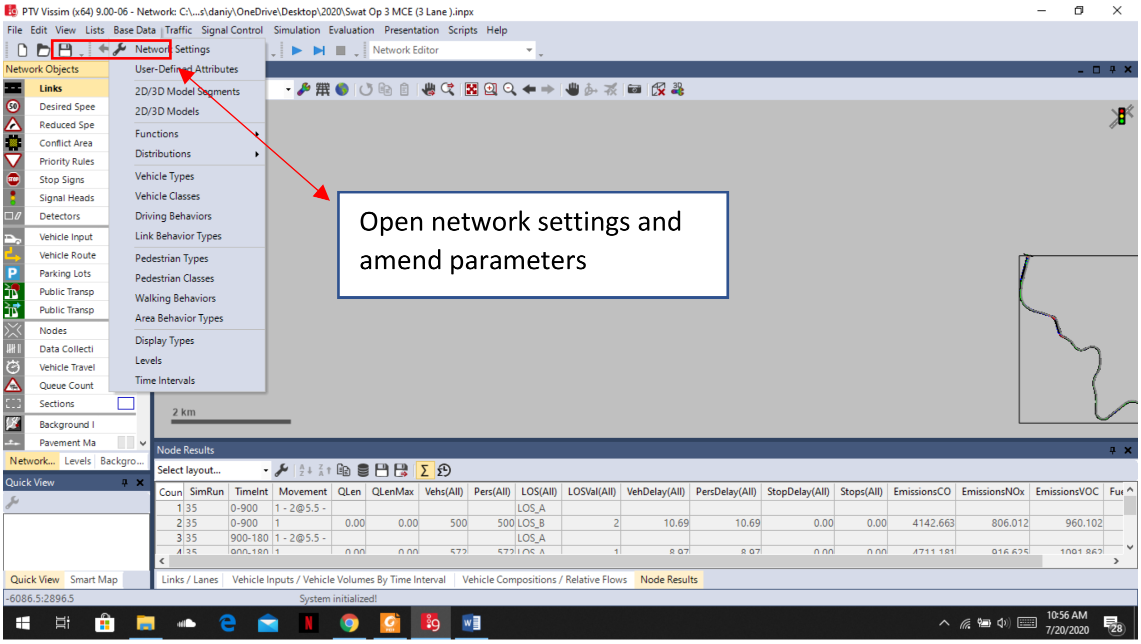


Fig 3.7: Network Settings

- Selecting metric units to define the desired units.

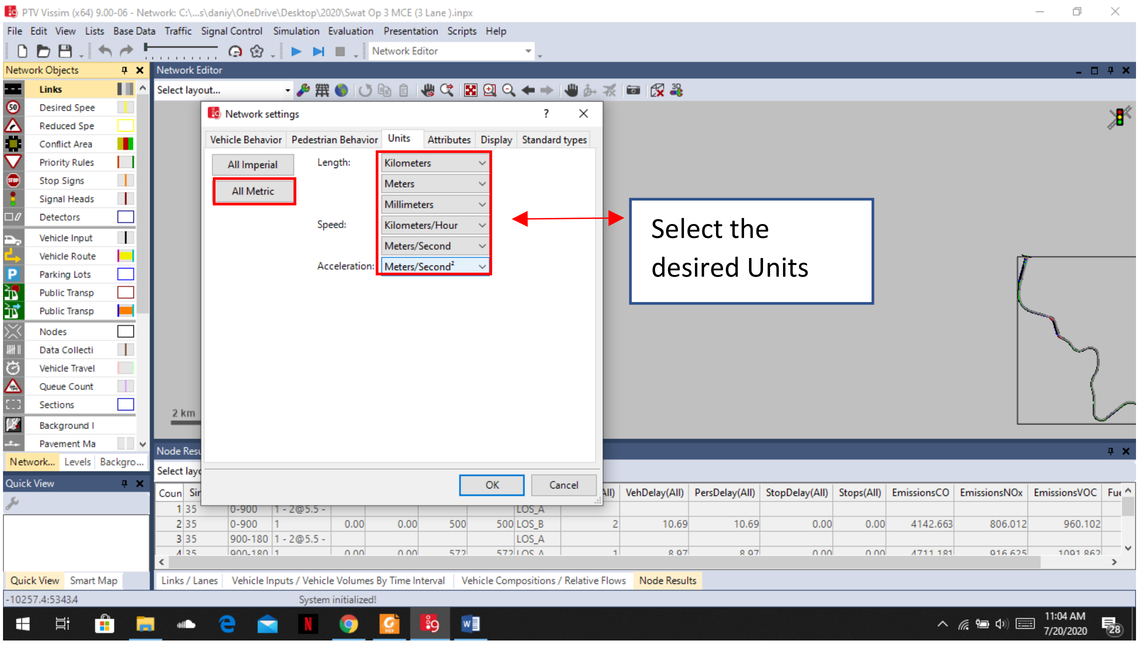


Fig 3.8: Metric Units

- Click on Links and provide Link information.

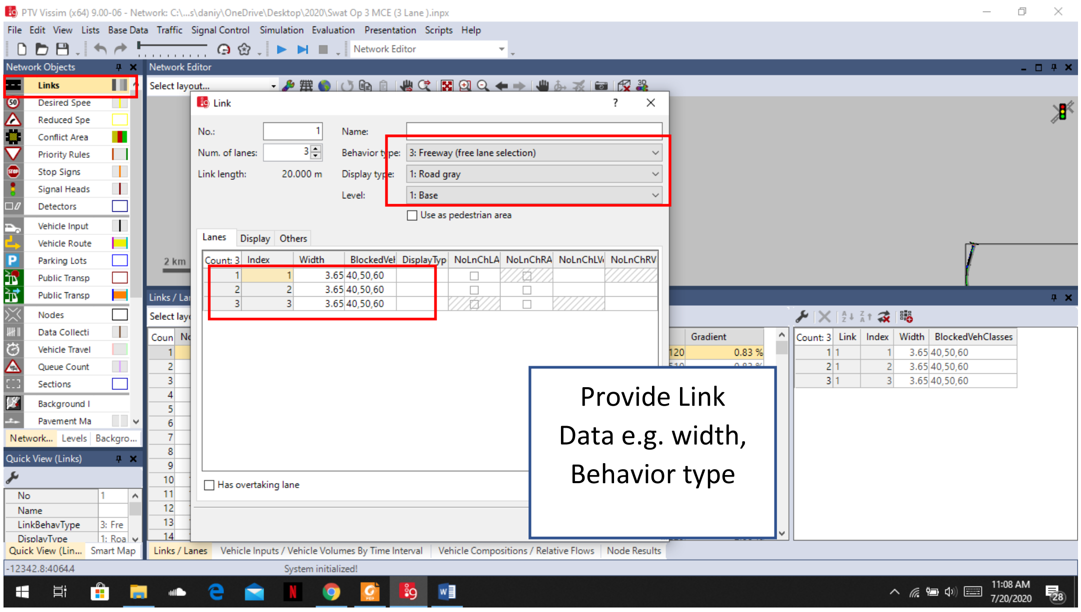


Fig 3.9: Link Information

- Right Click Links and select connectors and insert connector data.

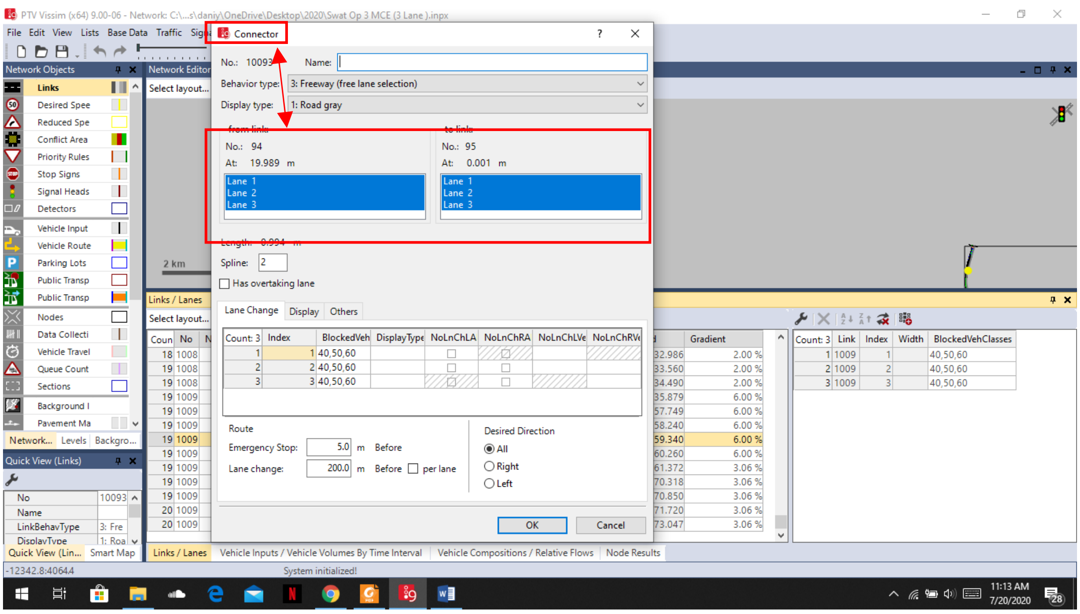


Fig 3.10: Connector Data

- Insert traffic volume through traffic input.

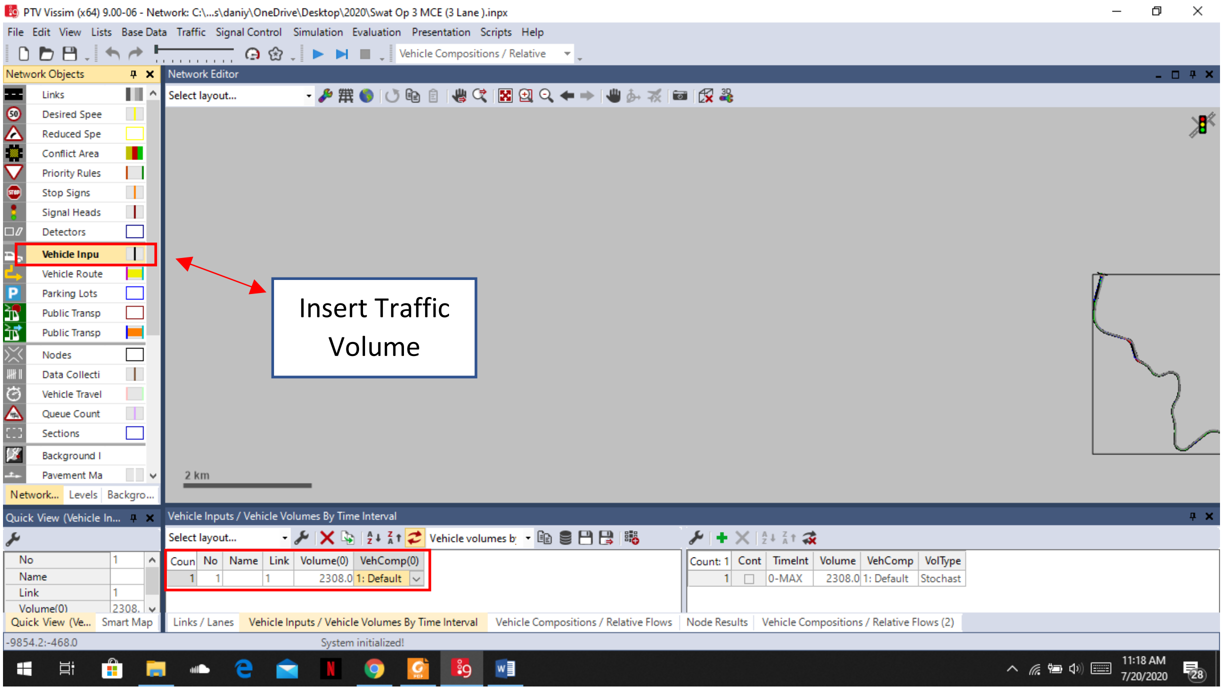


Fig 3.11: Traffic Volume Insertion

- Click on simulation and select the simulation parameters.

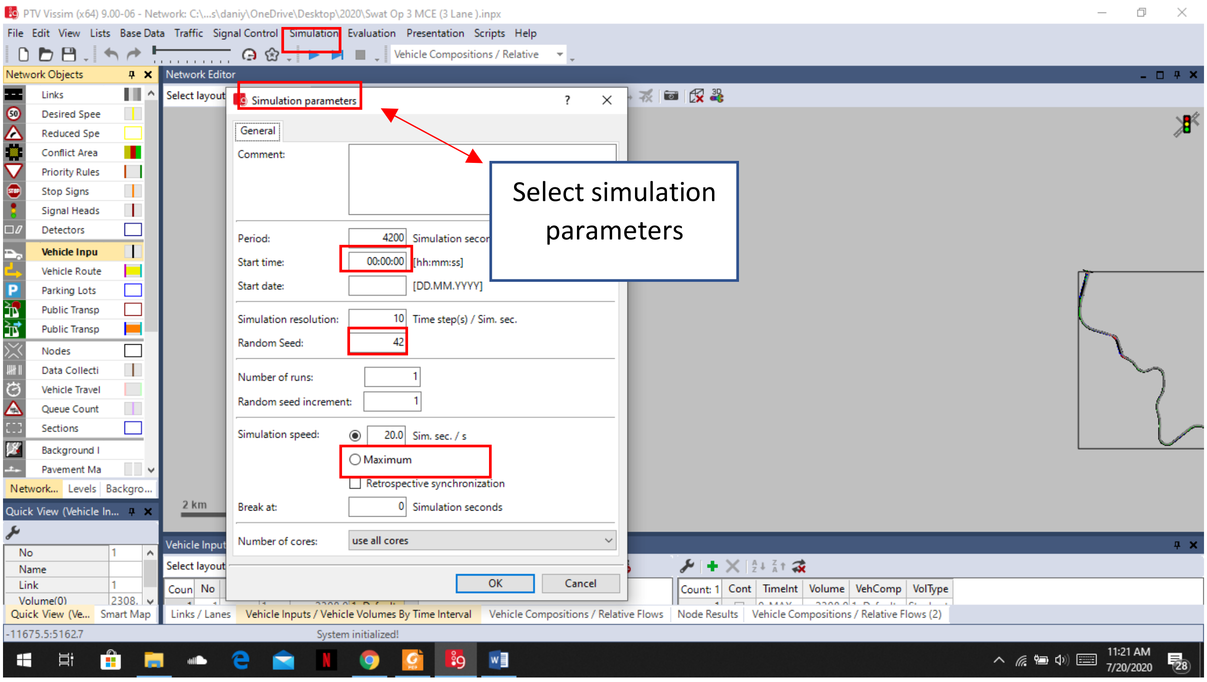


Fig 3.12: Simulation Parameters

- Select the nodes for the freeway.

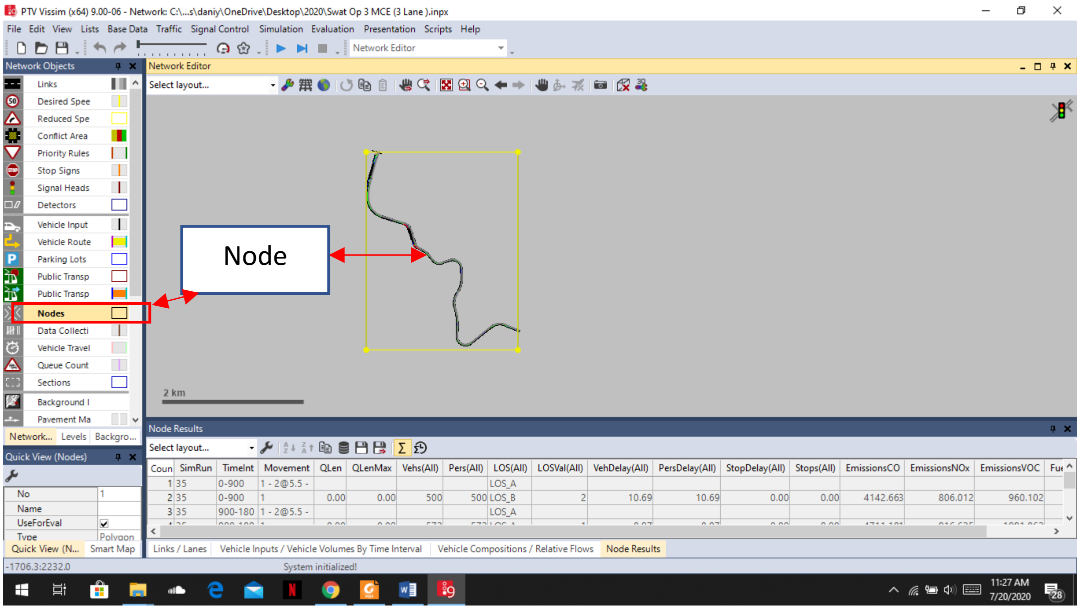


Fig 3.13: Nodes

- Add node time interval.

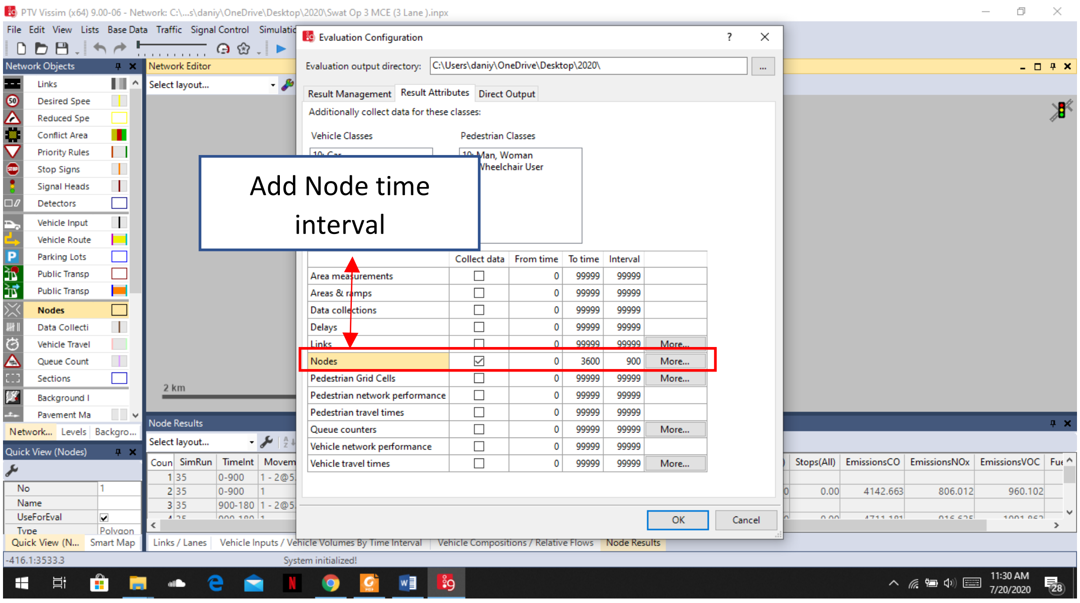


Fig 3.14: Time Interval

- Run the simulation by clicking the play icon.

3.1.3 Design Options

Three of the four options have different slopes for different lengths while DD&C proposed and DD&C (revised three lane) have the same slopes as the only difference is the addition of an extra lane.

Initial DD&C option		**FWO option**		**Revised DD&C option**		**Revised DD&C option with three lanes**	
RD	**Slope**	**RD**	**Slope**	**RD**	**Slope**	**RD**	**Slope**
65+000 – 65+080	0.885%	65+000-65+080	0.892%	65+000-65+080	0.835%	65+000-65+080	0.835%
65+080 – 65+340	5.739%	65+080 - 65+340	5.739%	65+080 - 65+340	5.739%	65+080 - 65+340	5.739%
65+340 - 65+530	2%	65+340 - 65+530	2%	65+340 - 65+530	2%	65+340 - 65+530	2%
65+530 - 65+860	6%	65+530 - 65+860	6%	65+530 - 65+860	6%	65+530 - 65+860	6%
65+860 - 66+060	2%	65+860 - 66+060	2%	65+860 - 66+060	2%	65+860 - 66+060	2%
66+060 - 66+380	6%	66+060 - 66+300	6%	66+060 - 66+380	6%	66+060 - 66+380	6%
66+380 - 66+670	2%	66+300 - 66+590	3.257%	66+380 - 66+590	2%	66+380 - 66+590	2%
66+670 - 66+900	6%	66+590 - 66+900	5.986%	66+590 - 66+900	6%	66+590 - 66+900	6%
66+900 - 67+090	2%	66+900 – 67+120	2.676%	66+900 – 67+120	2.676%	66+900 – 67+120	2.676%
67+090 - 67+410	6%	67+120 - 67+370	5.996%	67+120 - 67+380	5.996%	67+120 - 67+380	5.996%
67+410 - 67+610	2%	67+370 - 67+620	2.672%	67+380 - 67+610	2.557%	67+380 - 67+610	2.557%
67+610 – 67+930	6%	67+620 - 67+950	5.962%	67+610 - 67+930	5.993%	67+610 - 67+930	5.993%
67+930 - 68+120	2%	67+950 – 68+220	3.652%	67+930 – 68+160	3%	67+930 – 68+160	3%
68+120 - 68+450	6%	68+220 - 68+450	6%	68+160 - 68+450	6%	68+160 - 68+450	6%
68+450 - 68+640	2%	68+450 - 68+590	2.064%	68+450 - 68+640	2%	68+450 - 68+640	2%
68+640 - 68+960	6%	68+590 - 68+720	6%	68+640 - 69+090	6%	68+640 - 69+090	6%
68+960 - 69+160	2%	68+720 - 68+820	2.966%	69+090 - 69+460	3.059%	69+090 - 69+460	3.059%
69+160 - 69+480	5.993%	68+820 – 69+090	6%	69+460 – 69+570	6.037%	69+460 – 69+570	6.037%
69+480 - 69+610	2%	69+090 - 69+460	3.059%				
		69+460 - 69+560	6%				

Table 3.1: Detail Designs Slope Variations

The variations in slopes with respect to the RD, for all the 4 options, are given in table 3.1.

3.1.4 Traffic Report Study

The traffic study report prepared by Associates Consulting Centre Pvt. Ltd in 2016 was used to generate the traffic on the proposed motorway. The report was studied thoroughly, and traffic counts were calculated. The traffic report was generated after a survey being conducted at eight different locations, which was converted into origin-destination (OD) matrices.

3.1.5 Number of Cases

To get a complete comparison between the four designs, a few design criteria needed to be set for a comparison. Every design was divided into different categories with varying design speed and traffic for the year 2020, 2030 and 2040. By doing this, a total of 36 different cases were to be simulated.

3.1.5.1 Design Speed

Two different design speeds were taken into consideration to run the simulations, 50 km/h and 60 km/h.

3.1.5.2 Traffic Growth Over a Decade

The simulations were run keeping in mind the traffic at the present time, year 2020 and the growth it will receive over the next 20 years at a 10-year interval. This growth was determined in the traffic study report prepared by Associates Consulting Centre Pvt. Ltd. In the study report, the traffic volume growth for every year, up-to year 2045 was calculated. This input will help in understanding the serviceability of the road for the upcoming years when the traffic increases exponentially.

Year	Car	Pick up	Van	Minibus	Bus	Mini Truck	Truck 2 Axle	Truck 3 Axle and above	Total (Veh/d)
2020	11903	2138	714	298	107	840	1049	1217	17753
2030	17693	3328	1116	470	173	1311	1635	1926	27652
2040	27484	5173	1738	738	274	2041	2544	3025	43017

Table 3.2: Traffic Count for the Respective Years

3.1.5.3 Directional Factor

For the simulation of traffic, only the traffic going in the upward direction of the slope was to be considered. So, a directional factor of 0.6 was applied for the traffic going upwards which was to be used in the final simulations. This factor was chosen conservatively to tackle with unforeseen circumstances where the traffic going towards Chakdara may exceed the traffic on the other side. The values are written in table 3.3.

Year	Car	Pick up	Van	Minibus	Bus	Mini Truck	Truck 2 Axle	Truck 3 Axle and above	Total (veh/d)
2020	6834	1283	429	179	65	504	630	731	10652
2030	10615	1997	670	282	104	787	981	1156	16592
2040	16491	3104	1043	443	165	1225	1527	1815	25811

Table 3.3: Unidirectional Traffic Count

3.1.6 Peak Hour Volume

PTV Vissim requires peak hour volume to run the simulation. The traffic study report prepared by Associates Consulting Centre Pvt. Ltd. provided the hourly traffic volumes for all 8 locations that the survey was carried out on. As this was the only data available and no 15-min interval volume was available, the hourly traffic volumes for each location were studied and compared to the OD matrices to obtain the volume of traffic that will use the 5 kilometer strip. Comparing this data, a factor of 21.67% was decided upon as a conservative approach. The details of the calculations are as follows:

3.1.6.1 Year 2020

Total Volume per day, V = 10652 Veh/day

Peak Hour Volume, $V_{pk} = P_k * V$

$V_{pk} = 0.22167 * 10652 = 2308$ Veh/hr

3.1.6.2 Year 2030

Total Volume per day, V = 16592 Veh/day

Peak Hour Volume, $V_{pk} = P_k * V$

$V_{pk} = 0.22167 * 16592 = 3595$ Veh/hr

3.1.6.3 Year 2040

Total Volume per day, V = 25811

Peak Hour Volume, $V_{pk} = P_k * V$

$V_{pk} = 0.22167 * 25811 = 5592$ Veh/hr

3.1.7 Obtaining the Results

After input all the data, all that was left to do was to run the simulation. Running the simulation using PTV VISSIM generated an LOS report for every case that was run through it. The inputs for each individual case are mentioned along with the results in the chapter 4.

3.1.8 Simulation Process

Dynamics and kinematics theory say that when a vehicle runs on longitudinal section the vehicle is subjected to the combined action of traction and resistance, and the resistance includes air resistance, rolling resistance, slope resistance and inertia resistance. Before reaching the equilibrium speed, the running process of the vehicle can be simplified as a uniformly deceleration motion. VISSIM is used for simulation. It is a kind of traffic simulation modeling tool, which is microscopic and based on time interval and vehicle driving behavior. It can be used to simulate and analyze the traffic operation condition of various road traffic conditions, and it is an effective tool to evaluate road traffic geometric design.

3.1.9 Simulation Scheme

The objective of this simulation is the comparison of four different design alternatives of a freeway segment passing through a high mountainous terrain. The two design alternatives are two lanes in each direction while the third one is with addition of additional lane. The design speed of the freeway segment is 60 Km/hr however simulations are performed keeping two posted speeds of 40 and 50 Km/hr. The longitudinal gradient is generally not more than 6% and is followed by a relief grade of varying gradient in three alternatives.

Chapter 4

RESULTS

4.1 DETAILS

In this chapter, LOS reports for all the 24 cases, generated by the PTV Vissim simulation, will be set together. The input data will be mentioned right before the result itself for all the cases.

4.1.1 Initial DD&C Option

4.1.1.1 First Case

Refer to table 4.1

- Design speed 50km/h
- Traffic volume 2020

4.1.1.2 Second Case

Refer to table 4.2

- Design speed 50km/h
- Traffic volume 2030

4.1.1.3 Third Case

Refer to table 4.3

- Design speed 50km/h
- Traffic volume 2040

4.1.1.4 Forth Case

Refer to table 4.4

- Design speed 60km/h
- Traffic volume 2020

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	358	LOS_D	26.057	3068.153513	596.951184	711.074205	43.893469
1	900-1800	0	0	584	LOS_D	28.827951	5017.168481	976.158674	1162.777245	71.776373
1	1800-2700	0	0	560	LOS_C	22.103437	4772.317296	928.519531	1106.030618	68.273495
1	2700-3600	0	0	622	LOS_D	30.876124	5374.985405	1045.776846	1245.704772	76.895356

Table 4.1

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	534	LOS_E	45.202121	4721.263771	918.58637	1094.19847	67.543115
1	900-1800	0.004023	5.091165	873	LOS_F	51.254657	7806.86092	1518.931452	1809.315406	111.686136
1	1800-2700	0	0	916	LOS_F	57.469585	8267.704035	1608.594776	1916.120248	118.279028
1	2700-3600	0	0	857	LOS_E	44.821694	7578.652847	1474.530454	1756.425982	108.421357

Table 4.2

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0.035564	9.165898	621	LOS_F	62.206574	5644.178709	1098.152081	1308.09292	80.746477
1	900-1800	0.076189	9.226738	1050	LOS_F	75.104298	9829.85979	1912.533521	2278.16493	140.627465
1	1800-2700	0.076093	9.264542	1021	LOS_F	94.453428	10821.75004	2105.519321	2508.045073	154.817597
1	2700-3600	0.071039	6.309378	1063	LOS_F	88.237716	10569.95122	2056.528421	2449.688266	151.215325

Table 4.3

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	406	LOS_C	15.362435	3138.580561	610.653729	727.396353	44.901009
1	900-1800	0	0	561	LOS_B	14.834278	4323.235646	841.144561	1001.951609	61.848865
1	1800-2700	0	0	583	LOS_C	17.582825	4528.06518	880.996945	1049.422831	64.779187
1	2700-3600	0	0	598	LOS_C	18.936575	4651.687336	905.049324	1078.07346	66.547744

Table 4.4

4.1.1.5 Fifth Case

Refer to table 4.5

- Design speed 60km/h
- Traffic volume 2030

4.1.1.6 Sixth Case

Refer to table 4.6

- Design speed 60km/h
- Traffic volume 2040

4.1.2 FWO Option

4.1.2.1 First Case

Refer to table 4.7

- Design speed 50km/h
- Traffic volume 2020

4.1.2.2 Second Case

Refer to table 4.8

- Design speed 50km/h
- Traffic volume 2030

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	609	LOS_E	35.794097	4893.52951	952.103023	1134.122719	70.007575
1	900-1800	0	0	867	LOS_D	33.954171	6953.013793	1352.803828	1611.428089	99.47087
1	1800-2700	0	0	917	LOS_E	36.485635	7394.396161	1438.680798	1713.722716	105.785353
1	2700-3600	0	0	896	LOS_D	30.674775	7134.705903	1388.15451	1653.53699	102.070185

Table 4.5

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0.203987	11.830908	663	LOS_F	54.905613	5592.307561	1088.05984	1296.07128	80.0044
1	900-1800	0.117467	11.849544	1090	LOS_F	67.318416	9523.238281	1852.876118	2207.102434	136.240891
1	1800-2700	0.142162	8.907364	1118	LOS_F	66.745038	9791.553611	1905.080531	2269.287103	140.079451
1	2700-3600	0.368437	11.866193	1089	LOS_F	70.63828	9809.177377	1908.509475	2273.371581	140.331579

Table 4.6

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0.009935	11.639886	365	LOS_D	28.685232	3035.487803	590.595624	703.503611	43.426149
1	900-1800	0.016203	9.821296	581	LOS_D	30.93948	4838.096346	941.317744	1121.275548	69.21454
1	1800-2700	0	0	562	LOS_C	23.31931	4632.832737	901.380905	1073.703725	66.278008
1	2700-3600	0	0	615	LOS_D	32.356752	5142.613448	1000.565707	1191.850327	73.571008

Table 4.7

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0.185243	12.908853	526	LOS_F	53.720565	4586.353529	892.33774	1062.931719	65.613069
1	900-1800	0.02792	11.945746	852	LOS_E	48.275597	7366.303426	1433.214973	1707.211953	105.383454
1	1800-2700	0.008153	8.628412	920	LOS_F	60.198992	8115.222239	1578.92736	1880.78112	116.0976
1	2700-3600	0.079337	12.822424	854	LOS_E	43.755513	7321.508396	1424.499488	1696.830272	104.742609

Table 4.8

4.1.2.3 Third Case

Refer to table 4.9

- Design speed 50km/h
- Traffic volume 2040

4.1.2.4 Forth Case

Refer to table 4.10

- Design speed 60km/h
- Traffic volume 2020

4.1.2.5 Fifth Case

Refer to table 4.11

- Design speed 60km/h
- Traffic volume 2030

4.1.2.6 Sixth Case

Refer to table 4.12

- Design speed 60km/h
- Traffic volume 2040

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0.041913	7.589924	577	LOS_F	65.728882	5142.123441	1000.470369	1191.736763	73.563998
1	900-1800	0.052786	9.009364	983	LOS_F	80.861759	9134.386901	1777.219769	2116.982372	130.677924
1	1800-2700	0.154416	14.609445	1006	LOS_F	85.04414	10100.1817	1965.128343	2340.814644	144.494731
1	2700-3600	0.180756	9.192904	954	LOS_F	101.772347	10281.2888	2000.365203	2382.787963	147.085677

Table 4.9

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	411	LOS_C	16.695017	3090.168665	601.234533	716.176429	44.208422
1	900-1800	0	0	559	LOS_C	15.836083	4189.141495	815.054711	970.873995	59.930493
1	1800-2700	0	0	584	LOS_C	15.843241	4386.542897	853.461851	1016.623676	62.754548
1	2700-3600	0	0	602	LOS_C	20.115583	4554.034681	886.049666	1055.441514	65.150711

Table 4.10

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	616	LOS_E	37.713011	4803.085417	934.505889	1113.161427	68.713668
1	900-1800	0	0	863	LOS_D	34.585901	6697.929172	1303.17363	1552.309765	95.82159
1	1800-2700	0.017378	10.973124	940	LOS_E	38.38812	7366.644715	1433.281375	1707.29105	105.388336
1	2700-3600	0	0	872	LOS_D	33.722648	6748.595086	1313.031376	1564.05208	96.546425

Table 4.11

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0.012278	7.528116	659	LOS_F	53.765802	5424.838321	1055.476411	1257.258667	77.60856
1	900-1800	0.085368	8.164797	1064	LOS_F	74.441082	9063.678592	1763.462501	2100.595038	129.66636
1	1800-2700	0.069502	8.281153	1074	LOS_F	76.075821	9643.872152	1876.347085	2235.060499	137.966697
1	2700-3600	0.187858	15.927451	1035	LOS_F	61.132797	8734.019137	1699.322751	2024.193276	124.950202

Table 4.12

4.1.3 Revised DD&C Option

4.1.3.1 First Case

Refer to table 4.13

- Design speed 50km/h
- Traffic volume 2020

4.1.3.2 Second Case

Refer to table 4.14

- Design speed 50km/h
- Traffic volume 2030

4.1.3.3 Third Case

Refer to table 4.15

- Design speed 50km/h
- Traffic volume 2040

4.1.3.4 Forth Case

Refer to table 4.16

- Design speed 60km/h
- Traffic volume 2020

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	365	LOS_D	28.731153	3038.243332	591.13175	704.142231	43.46557
1	900-1800	0	0	580	LOS_D	30.481452	4830.579693	939.855276	1119.533491	69.107006
1	1800-2700	0	0	563	LOS_C	23.179212	4644.255772	903.603412	1076.351123	66.441427
1	2700-3600	0	0	615	LOS_D	31.844546	5142.794953	1000.601021	1191.892393	73.573604

Table 4.13

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0.025292	7.929836	531	LOS_F	53.738875	4604.170825	895.804338	1067.061049	65.867966
1	900-1800	0.016426	8.981708	848	LOS_E	47.870169	7287.630185	1417.908019	1688.97867	104.257943
1	1800-2700	0	0	917	LOS_F	58.501153	8017.789148	1559.970421	1858.20006	114.703707
1	2700-3600	0.049342	9.867135	857	LOS_E	44.357595	7316.730556	1423.569894	1695.722961	104.674257

Table 4.14

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0.018644	6.951179	589	LOS_F	63.315209	5255.075303	1022.446697	1217.914448	75.179904
1	900-1800	0.097104	12.973498	974	LOS_F	78.742852	8987.874822	1748.713842	2083.026783	128.5819
1	1800-2700	0.064443	7.177212	1031	LOS_F	81.249406	9511.954393	1850.680683	2204.487284	136.079462
1	2700-3600	0.051854	7.383905	1005	LOS_F	77.501207	9458.178452	1840.217839	2192.024191	135.310135

Table 4.15

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	411	LOS_C	16.860863	3083.78939	599.993358	714.69797	44.117159
1	900-1800	0	0	557	LOS_C	15.745604	4163.179601	810.00347	964.857075	59.559079
1	1800-2700	0	0	585	LOS_C	15.981217	4385.021095	853.165764	1016.270983	62.732777
1	2700-3600	0	0	601	LOS_C	19.413886	4530.106479	881.394107	1049.895922	64.80839

Table 4.16

4.1.3.5 Fifth Case

Refer to table 4.17

- Design speed 60km/h
- Traffic volume 2030

4.1.3.6 Sixth Case

Refer to table 4.18

- Design speed 60km/h
- Traffic volume 2040

4.1.4 Revised DD&C Option with three lanes

4.1.4.1 First Case

Refer to table 4.19

- Design speed 50km/h
- Traffic volume 2020

4.1.4.2 Second Case

Refer to table 4.20

- Design speed 50km/h
- Traffic volume 2030

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	616	LOS_E	37.815452	4799.444699	933.797538	1112.317656	68.661584
1	900-1800	0	0	863	LOS_D	34.506995	6690.359011	1301.700752	1550.555307	95.713291
1	1800-2700	0	0	937	LOS_E	37.020282	7293.325554	1419.016131	1690.298626	104.339421
1	2700-3600	0	0	873	LOS_D	33.171629	6743.01476	1311.945647	1562.758786	96.466592

Table 4.17

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0.028317	8.549268	670	LOS_F	57.151142	5429.96321	1056.473529	1258.446409	77.681877
1	900-1800	0.070942	8.551557	1039	LOS_F	64.76709	8715.487657	1695.717198	2019.898427	124.685088
1	1800-2700	0.20314	16.771444	1059	LOS_F	79.531788	9583.71412	1864.642518	2221.118294	137.106068
1	2700-3600	0.200072	16.714412	1035	LOS_F	71.25075	9477.865949	1844.04831	2196.586958	135.591788

Table 4.18

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	390	LOS_A	9.42924	3126.561563	608.315268	724.610834	44.729064
1	900-1800	0	0	567	LOS_B	10.236221	4543.137482	883.929467	1052.915983	64.994814
1	1800-2700	0	0	566	LOS_B	10.386257	4550.122214	885.288442	1054.534762	65.094738
1	2700-3600	0	0	609	LOS_B	10.948117	4896.473064	952.675732	1134.804916	70.049686

Table 4.19

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	596	LOS_C	21.650241	4872.631151	948.036962	1129.279322	69.7086
1	900-1800	0	0	845	LOS_C	18.747844	6880.291895	1338.654789	1594.574087	98.430499
1	1800-2700	0	0	934	LOS_C	23.017848	7663.495595	1491.03777	1776.089108	109.63513
1	2700-3600	0	0	864	LOS_C	17.875365	7019.56541	1365.752354	1626.852069	100.422967

Table 4.20

4.1.4.3 Third Case

Refer to table 4.21

- Design speed 50km/h
- Traffic volume 2040

4.1.4.4 Forth Case

Refer to table 4.22

- Design speed 60km/h
- Traffic volume 2020

4.1.4.5 Fifth Case

Refer to table 4.23

- Design speed 60km/h
- Traffic volume 2030

4.1.4.6 Sixth Case

Refer to table 4.24

- Design speed 60km/h
- Traffic volume 2040

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0.276103	14.684618	811	LOS_E	46.937631	6931.645097	1348.646256	1606.475688	99.165166
1	900-1800	0.08621	13.499035	1388	LOS_E	49.694961	11930.47757	2321.23741	2765.003385	170.679221
1	1800-2700	0.213562	13.083725	1336	LOS_E	42.498235	11345.89891	2207.499645	2629.521636	162.31615
1	2700-3600	0.297223	13.634234	1420	LOS_E	46.542989	12131.14831	2360.280644	2811.510767	173.550047

Table 4.21

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	423	LOS_A	6.01125	3102.013062	603.539022	718.921482	44.377869
1	900-1800	0	0	570	LOS_A	5.52618	4173.856358	812.080779	967.331517	59.711822
1	1800-2700	0	0	573	LOS_A	6.072878	4207.222943	818.572704	975.064545	60.189169
1	2700-3600	0	0	599	LOS_A	6.145884	4395.444942	855.193866	1018.68681	62.881902

Table 4.22

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	635	LOS_B	12.290769	4704.783723	915.379952	1090.37906	67.307349
1	900-1800	0.020355	17.123284	859	LOS_B	11.773845	6364.981036	1238.394021	1475.145819	91.058384
1	1800-2700	0	0	947	LOS_B	11.953758	7018.085144	1365.464349	1626.509003	100.40179
1	2700-3600	0	0	873	LOS_B	11.35368	6455.518697	1256.00936	1496.128797	92.353629

Table 4.23

Sim Run	TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)	VehDelly(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	Fuel Consumption
1	0-900	0	0	929	LOS_D	28.236052	7098.895639	1381.187134	1645.237616	101.557878
1	900-1800	0.181536	17.96179	1339	LOS_D	32.923109	10339.04024	2011.601535	2396.172417	147.911878
1	1800-2700	0.106427	18.852851	1388	LOS_D	31.520312	10682.53771	2078.433659	2475.781271	152.826004
1	2700-3600	0.103937	18.672648	1397	LOS_D	29.368123	10700.37061	2081.903294	2479.914218	153.081125

Table 4.24

Chapter 5

DISCUSSION

This chapter will introduce the final discussion related to the whole simulation of the 5 kilometer strip of Sway Motorway. This discussion will include the various important aspects including fuel consumption, average speed, queue length and the comparison of the LOS reports for all the options. This discussion will include explanation of the serviceability of the freeway till the year 2040. MS Excel, AutoCAD Civil 3d and PTV Vissim were used for this project.

5.1 LOS REPORTS

The level of service (LOS) reports help in discerning the selection of one design over the other. LOS goes from A to F, A being the best and F being the failure. After studying the results in the light of the level of service, it became very clear what conditions gave the best results. The simulation reports generated by PTV Vissim show clearly that all the designs operated better in terms of serviceability when the design speed was set to 60 kilometers per hour instead of 50 kilometers per hour. This can be observed by comparing the following two tables.

TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)
0-900	0	0	390	LOS_A
900-1800	0	0	567	LOS_B
1800-2700	0	0	566	LOS_B
2700-3600	0	0	609	LOS_B

Table 5.1: 3 lane revised DD&C year 2020 at 50 km/hr

TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)
0-900	0	0	423	LOS_A
900-1800	0	0	570	LOS_A
1800-2700	0	0	573	LOS_A
2700-3600	0	0	599	LOS_A

Table 5.2: 3 lane revised DD&C year 2020 at 60 km/hr

For both table 5.1 and table 5.2, same design is considered with the same traffic volume while only changing the design speed. This comparison holds true for all the designs which makes it clear that 60 kilometer per hour is a better design speed compared to 50 kilometers per hour.

Now, looking at the traffic volume change between cases while keeping other design criteria constant, it is quite obvious that traffic growth results in the deterioration of LOS.

TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)
0-900	0	0	423	LOS_A
900-1800	0	0	570	LOS_A
1800-2700	0	0	573	LOS_A
2700-3600	0	0	599	LOS_A

Table 5.3: 3 lane revised DD&C year 2020 at 60 km/hr

TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)
0-900	0	0	635	LOS_B
900-1800	0.020355	17.123284	859	LOS_B
1800-2700	0	0	947	LOS_B
2700-3600	0	0	873	LOS_B

Table 5.4: 3 lane revised DD&C year 2030 at 60 km/hr

TimeInt	Qlen	QLenMax	Vehs(All)	LOS(All)
0-900	0	0	929	LOS_D
900-1800	0.181536	17.96179	1339	LOS_D
1800-2700	0.106427	18.852851	1388	LOS_D
2700-3600	0.103937	18.672648	1397	LOS_D

Table 5.5: 3 lane revised DD&C year 2040 at 60 km/hr

5.2 FUEL CONSUMPTION

The simulation results for all the cases were put together in the previous chapter (Chapter 4). The last column in the tables results, i.e. the LOS reports, is the fuel consumption for the freeway in consideration. Hence, the fuel consumption for all the 24 cases are in chapter 4.

In terms of design speed, 60 kilometers per hour has less fuel consumption compared to 50 kilometers per hour. This makes 60 kilometers per hour a better design speed in terms of fuel consumption too.

When it comes to change in traffic, it is obvious that higher traffic will result in higher fuel consumption. Analyzing the results for queue length, it is found that there is no queue length for the year 2020. This

5.3 QUEUE LENGTH

Analyzing the results for queue length, it is found that there is no queue length for the year 2020. This holds true for all design options and both the design speeds. However, with traffic growth in year 2030 and 2040, queue length becomes a factor to be considered in order to differentiate between the four options. The initial design by DD&C has the highest queue length out of all the options.

When design speed is considered, 60 kilometers per hour fares a lot better than 50 kilometers per hour and has almost no queue length for all design options even for the year 2030, aside from the slight queue lengths present in two of the options (FWO design and revised DD&C 3 lane design). That queue length, however, is very small. As for the year 2040, there is queue length for all design options. Once again, initial DD&C design has the highest queue length while the other three options have somewhat similar queue length.

5.4 AVERAGE SPEED

After studying the LOS reports, it was clear that 60 kilometers per hour is a better design speed than 50 kilometers per hour. However, some further simulations were required to find the average speed of the vehicles on a freeway with 60 kilometers per hour as design speed. The simulations were also conducted on Vissim and the results are as follows.

Speed Avg Arith. All	Cars	HGV	Buses	Speed Avg Harm. All
57.101036 km/h	57.906882 km/h	48.671153 km/h	51.487801 km/h	56.114148 km/h
59.465794 km/h	59.752045 km/h	54.971694 km/h	52.580154 km/h	59.207778 km/h
59.100500 km/h	59.618344 km/h	52.126742 km/h	51.954307 km/h	58.702315 km/h
58.684796 km/h	59.457609 km/h	49.952361 km/h	52.397556 km/h	58.217439 km/h
58.387134 km/h	58.775060 km/h	51.752314 km/h	51.970707 km/h	57.958664 km/h
57.860584 km/h	58.417340 km/h	47.359430 km/h	51.181011 km/h	57.193023 km/h
58.295937 km/h	58.977889 km/h	49.378072 km/h	52.371709 km/h	57.667004 km/h

Table 5.6: Initial DD&C Option

Speed Avg Arith. All	Cars	HGV	Buses	Speed Avg Harm. All
58.155910 km/h	58.661204 km/h	52.405885 km/h	52.201973 km/h	57.688395 km/h
58.836904 km/h	59.332538 km/h	50.269428 km/h	52.089627 km/h	58.448380 km/h
58.510187 km/h	59.211308 km/h	51.647217 km/h	51.393099 km/h	58.037582 km/h
59.154901 km/h	59.610196 km/h	54.519282 km/h	53.126472 km/h	58.894127 km/h
58.274585 km/h	58.698694 km/h	51.463079 km/h	50.899138 km/h	57.788612 km/h
58.579471 km/h	59.070196 km/h	52.355337 km/h	51.993290 km/h	58.189752 km/h
59.167465 km/h	59.574879 km/h	51.429588 km/h	52.681541 km/h	58.846207 km/h

Table 5.7: FWO Option

Speed Avg Arith. All	Cars	HGV	Buses	Speed Avg Harm. All
58.187126 km/h	58.744897 km/h	51.775757 km/h	52.172341 km/h	57.703407 km/h
57.890514 km/h	58.426120 km/h	44.198203 km/h	51.130896 km/h	57.208775 km/h
59.158035 km/h	59.600747 km/h	54.519282 km/h	53.126472 km/h	58.870124 km/h
58.205621 km/h	59.022044 km/h	48.901747 km/h	51.321953 km/h	57.513186 km/h
57.903011 km/h	58.364175 km/h	49.731879 km/h	51.993275 km/h	57.449061 km/h
57.520739 km/h	57.945582 km/h	48.648251 km/h	51.251448 km/h	56.675148 km/h
58.079293 km/h	58.640784 km/h	50.687627 km/h	52.483599 km/h	57.360459 km/h

Table 5.8: Final DD&C Option

Speed Avg Arith. All	Cars	HGV	Buses	Speed Avg Harm. All
59.825642 km/h	60.540229 km/h	53.058604 km/h	51.558621 km/h	59.551866 km/h
60.396244 km/h	60.984212 km/h	51.747555 km/h	53.655137 km/h	60.178879 km/h
60.524231 km/h	61.205985 km/h	49.046494 km/h	52.556801 km/h	60.222315 km/h
59.666774 km/h	60.737574 km/h	51.473377 km/h	50.375792 km/h	59.289913 km/h
60.322340 km/h	60.858931 km/h	51.198715 km/h	53.786273 km/h	60.105476 km/h
60.817049 km/h	61.262766 km/h	51.233376 km/h	51.457499 km/h	60.587535 km/h
58.937483 km/h	60.337841 km/h	52.133552 km/h	49.736932 km/h	58.448541 km/h
60.497280 km/h	60.966593 km/h	47.573844 km/h	53.812457 km/h	60.275934 km/h
60.322283 km/h	60.584913 km/h	50.867607 km/h	51.305320 km/h	60.097627 km/h
60.572366 km/h	61.284315 km/h	52.890252 km/h	53.449027 km/h	60.325740 km/h
60.650901 km/h	61.170834 km/h	50.310820 km/h	52.035397 km/h	60.339069 km/h
60.241967 km/h	61.057194 km/h	53.786840 km/h	51.159599 km/h	59.940595 km/h

Table 5.9: Proposed three lane option

5.5 FINAL CONCLUSION

The comparison of the design options in terms of level of service reports, fuel consumption, queue length and average speed, the initial DD&C design is not adequate and the other three design options are a lot better than the initial option. The FWO design and revised DD&C design performed equally in all the aspects. The 6 cases of FWO design and the 6 cases of DD&C revised design had nearly the same findings after the simulation. But both of these design options start failing for the traffic growth of 2030 and fail complete for the traffic of year 2040. The 3 lane revised DD&C design is the only option that doesn’t fail even in the year 2040.

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