IMPACT OF MALAKAND TUNNEL PROJECT ON N-45 TRAFFIC OPERATIONS

Final Year Project UG 2013

By:

Shawal Shuaib (G.L) (NUST201304945)

Muhammad Saim Saleem (NUST201305275)

Muhammad Husnain Saeed (NUST201305626)

Muhammad Yahya Arshad (NUST201305336)

Project Advisor: Dr. Muhammad Jawed Iqbal

NUST Institute of Civil Engineering (NICE)

School of Civil and Environmental Engineering (SCEE)

National University of Sciences and Technology (NUST)

Islamabad, Pakistan (2017)

CERTIFICATION

This is to certify that thesis entitled

IMPACT OF MALAKAND TUNNEL PROJECT ON N-45 TRAFFIC OPERATIONS

Submitted by

Shawal Shuaib (G.L)	(NUST201304945)
Muhammad Saim Saleem	(NUST201305275)
Muhammad Husnain Saeed	(NUST201305626)
Muhammad Yahya Arshad	(NUST201305336)

Has been accepted towards fulfillment

Of the requirements

for

Bachelors in Civil Engineering

Dr. Muhammad Jawed Iqbal

National Institute of Transportation

School of Civil and Environmental Engineering

National University of Sciences and Technology, Islamabad, Pakistan

Dedicated

To

OUR PARENTS AND TEACHERS

Who gave us

Courage, inspiration

And

Guidance

ACKNOWLEDGMENT

It is utmost necessary to acknowledge and thank our advisor and mentor, Dr. Muhammad Jawed Iqbal for his admirable direction, guidance, assistance and motivation for the current extent of our project. It is with his support that we have been successful in achieving our objectives.

We are absolutely grateful to Dr. Kamran Ahmad for his support, which in fact became the crux in the progress of this project.

We would also like to thank A/P Malik Saqib Mehmood who guided us and assisted us in this project. Without his guidance and cooperation this project would not have seen the light of dawn.

ABSTRACT

Malakand pass is a mountainous pass in Malakand District, Khyber Pakhtunkhwa, which begins at Dargai and ends at Batkhela at an altitude of 470 meters and 663 meters respectively. It connects district Mardan with distrct Dir lower, Dir upper, Swat and Chitral. The existing road traverses steep gradients and dangerous winding curves with various recurring landslides. This makes movement of freight carriers difficult besides causing extra-consumption, breakdowns and accidents. The National Highway Authority has suggested the construction of Malakand tunnel to provide a short route for the people of Malakand, Upper Dir, Lower Dir and Swat.

The focus of our study is to identify the existing problems at Malakand pass between Dargai (starting point) and Batkhela (end point) and the impact of this project on the traffic operations of N-45. The comparative analyses between existing road and proposed alignment in terms of geometry, travel time benefits, fuel consumption savings, crash cost savings and vehicular emissions savings have been carried out and the analyses revealed that the traffic operations at proposed alignment yields more savings.

The economic efficiency analyses of this project has also been carried out which shows the benefits of undertaking this project.

TABLE OF CONTENTS

List of Figures

List of Tables

Chapter 1

INTRODUCTION

1.1 Background

N-45 is one of the Pakistan's busiest national highway running from Nowshehra district to Chitral via Malakand, Batkhela and Dir. It is a two lane highway with total length of 309 km. 14km road passes over Malakand between Dargai and Batkhela. Due to the mountainous terrain, a large number of accidents occur on the way causing delays and congestion.

The National Highway Authority (NHA) has decided to build the Malakand tunnel to shorten distance for travelers belonging to Dir, Malakand, Swat and adjacent areas. The 9.7 km project includes three bridges and approach roads on both sides of the tunnel.

The recommended alignment considers Dargai as the starting point and Batkhela as the ending point.The Korean government had pledged $78 million through Economic Development Cooperation Fund (EDCF) for the construction of a 9.7 km Malakand Tunnel project.

There is a need to evaluate the Malakand tunnel project in terms of its cost and benefits.

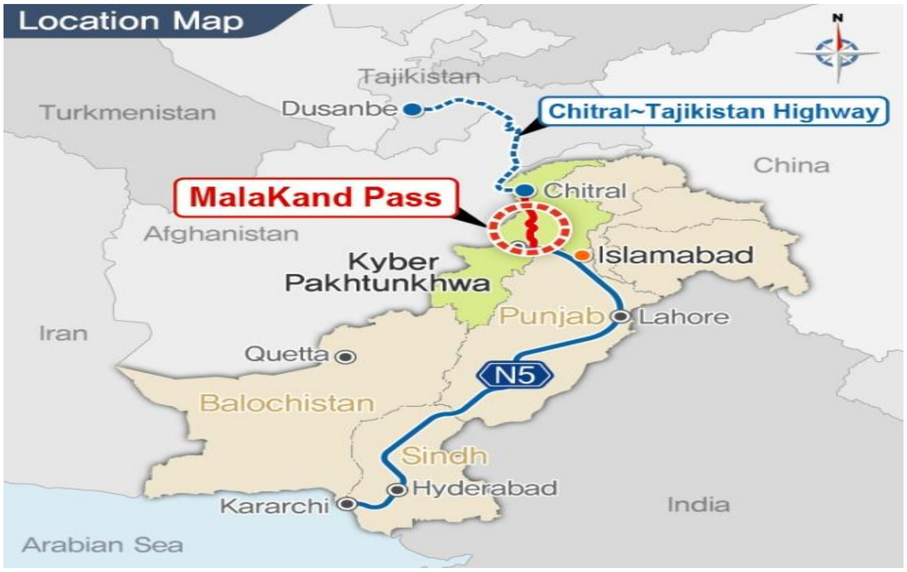

Figure 1.1: Existing Malakand pass

1.2 Proposed Malakand Tunnel Details:

The details of the proposed Malakand tunnel project are given in table 1.1.

Project Name	**Malakand Tunnel Construction Project**
Location	**Malakand Dist. Khyber Pakhtunkhwa Prov.**
Road Class	**Main arterial road, N45**
Total Length	**9,777m**
Design Speed	**90 km/h (flat area)**
Tunnel	**1 No 3.15 Km (two way)**
Bridges	**3**

Table 1.1: Details of the Malakand tunnel project

1.3 Existing Route and Proposed Malakand Tunnel

The following satellite image shows the existing route and proposed alignment.

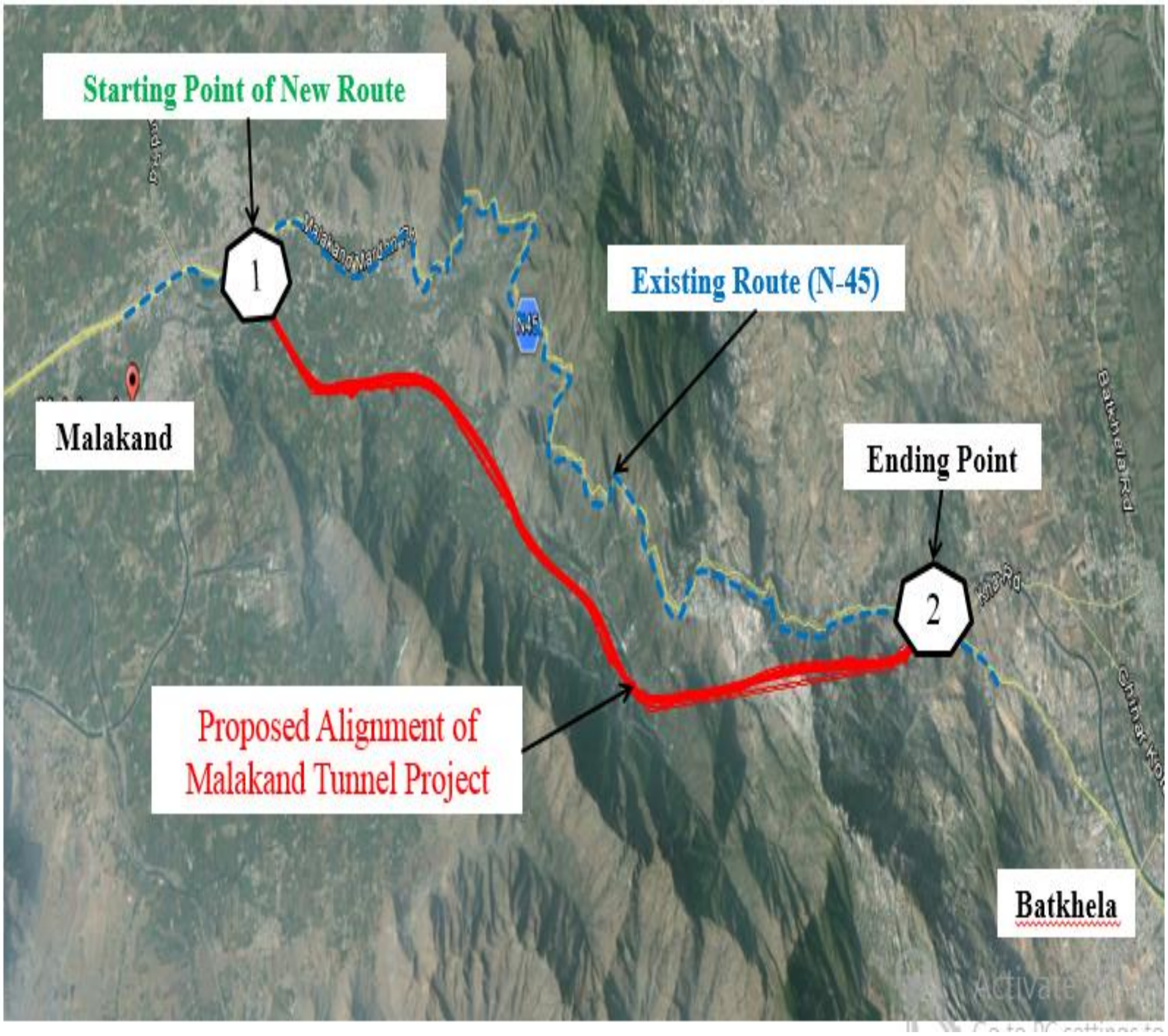

Figure 1.2: Existing and proposed alignment

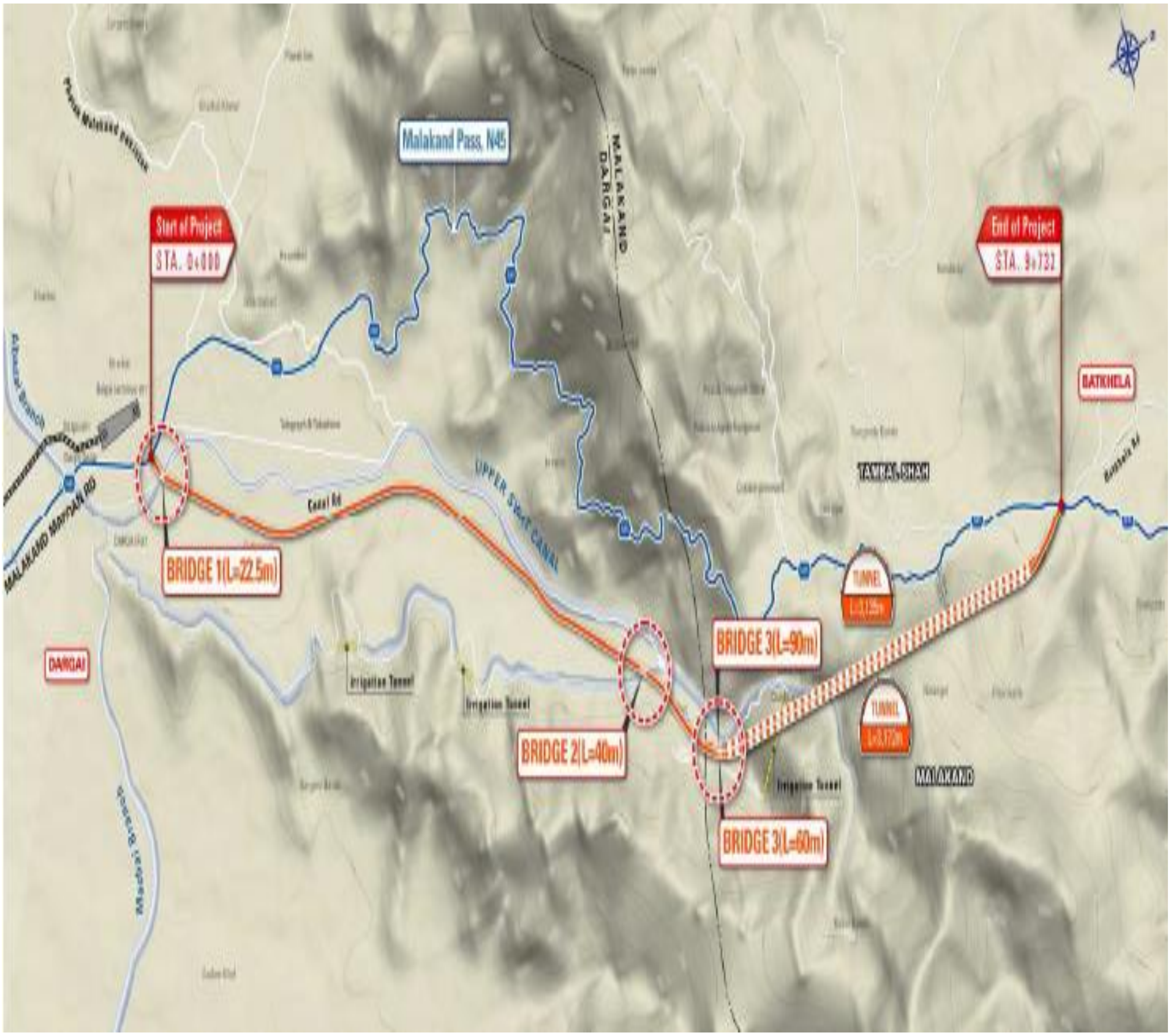

Figure 1.3: Details of the Malakand Tunnel project

1.4 Problem Statement

Malakand pass is a two lane, two way highway and is the solo route for traffic from Dir upper and lower and Chitral. Since in the modern era traffic is increasing rapidly and the demand on the roads has increased. Further there are a lot of geographical constraints and land variation along this road in form of rugged mountainous having very sharp curves and steep gradients. Moreover this road is prone to landslides and blockage due to bad weather which causes road accidents and safety concerns.

Due to these issues the traffic delays increases and so does the travel time which in turn increases the fuel consumption, vehicular emissions and accidents. For the sake of comfort, economy and safety it is imperative to carry out the detailed analyses of proposed project.

1.5 Project Objectives

The purpose of this study is to compare and analyze the impact of Malakand tunnel on N-45.
This study intends to achieve the following objectives:

- To identify existing problems on N-45 from Dargai to Batkhela passing through Malakand.
- The impact of Malakand Tunnel project on N-45 in terms of its traffic operations.
- Economic Efficiency analysis of this project

1.6 Existing Problems:

Following are the problems faced on N-45 between Dargai and Batkhela via Malakand:

- High traffic volume passing through this portion
- High percentage of heavy vehicles
- Large number of accidents occurring on this portion
- Longer travel time due to steep gradient
- Visibility issues due to obstructed line of sight
- Sharp and successive curves

1.7 Organization of Report

The report has been arranged in five chapters.

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Methodology

Chapter 4: Analysis and Results

Chapter 5: Conclusions and Recommendation

Chapter 2

LITERATURE REVIEW

This chapter covers the different methodologies being followed to calculate the LOS, to estimate the travel time savings, crash cost savings, fuel consumption savings, vehicular emissions savings and cost benefit analysis.

2.1 Level of Service (LOS)

"Level of Service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures such as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience." Every facility type has LOS defined in terms of a specific Measure of Effectiveness (MOE).

There are six defined levels of service i.e. A-F which describes operations from best to worst for each type of facility. LOS criteria for basic freeway segments and multilane highways are shown in Table:

Level of Service	Density Range for Basic Freeway Sections (pc/mi/ln)	Density Range for Multilane Highways (pc/mi/ln)
A	$\geq 0 \leq 11$	$\geq 0 \leq 11$
B	$> 11 \leq 18$	$> 11 \leq 18$
C	$> 18 \leq 26$	$> 18 \leq 26$
D	$> 26 \leq 35$	$> 26 \leq 35$
E	$> 35 \leq 45$	$> 35 \leq$ (40–45) depending on FFS
F	Demand Exceeds Capacity > 45	Demand Exceeds Capacity $>$ (40–45) depending on FFS

Table 2.1: LOS criteria for basic freeways and multilane highways

(Roess et al., 2011b)

2.1.1 Two Lane, Two Way Highway:

There are two types of two lane two way highways which are briefly discussed below:

a. <u>Class I Highway:</u>

- Motorists expect to travel at high speeds
- Major intercity routes
- Efficient mobility is paramount
- Daily commuter routes

b. <u>Class II Highway:</u>

- Mobility is less critical
- Relatively lower speeds
- Serves as access routes to class I facilities

2.1.2 Base Conditions:

The base conditions for a two-lane highway are the absence of restrictive geometric, traffic, or environmental factors. Base conditions are not the same as typical or default conditions. The base conditions include:

- Lane widths greater than or equal to 12 feet
- No no-passing zones
- All passenger cars
- No impediments to through traffic

For the analysis of two-way flow (i.e., both directions), a 50/50 directional split of traffic is also considered a base condition. Most directional distribution on rural two-lane highways ranges from 50/50 to 70/30. On recreational routes, the directional distribution may be as high as 80/20 or more during holiday or other peak periods. Some variation in speed and percent time-spent-following occurs with changing directional distribution and volume. For directional analysis (i.e., separate analysis of each direction), directional distribution is not a base condition.

2.1.3 LOS Analysis:

Level of service analysis of a two way two lane highway can be can be found by the average travel speed (ATS) and the percent time spent following (PTSF).

1. **Average Travel Speed:** It is the average speed of all vehicles traversing the defined analysis segment for the specified time period, which are usually the peak 15-minutes of a peak hour.
2. **Percent time spent following**: It is the aggregate percentage of time that all drivers spend in queues, unable to pass, with the speed restricted by the queue leader.

- LOS for class I highway is found by calculating ATS and PTSF.
- LOS for class II highway is found by calculating PTSF only.

2.2 Passenger Car Equivalents (PCE):

A Passenger Car Equivalent is essentially the effect that a specific mode of transport has on traffic parameters (such as headway, speed, density) compared to that of a single car. PCE can be selected for one of three conditions i.e. extended general multilane segments, specific upgrades and specific downgrades. The extended general multilane segment consist of level terrain, mountainous terrain and rolling terrain.

The values of PCE's used in this study are:

Bikes and Rickshaws: 0.5

Hiace: 1.5

Buses and Coaster: 2

Trucks: 3

2.3 Travel Time Savings:

The value of travel time savings refer to the benefits from reduced travel time costs. Travel-time savings typically generate the greatest amount of benefit. These savings are calculated based on the difference in travel time between the Base Case and an Alternative. Travel time is often expressed as vehicle-hours traveled (VHT) and can be estimated using computer models, spreadsheets, and/or travel time runs, depending on the level of analysis needed and data availability.

Travel time is primarily the function of two components speed and distance. The overall goal of travel time impacts involves the estimation of travel time amounts, unit travel time value and the overall saving due to travel time delay cost.

2.4 Fuel Consumption Savings:

Fuel consumption saving refers to the benefits achieved from the reduced fuel consumption costs. Fuel consumption cost depends upon the travel time, terrain, fuel economy and type of vehicle. Fuel consumption savings can be found by comparing the fuel consumption costs of one alternative with another and the finding the difference between the two alternatives.

Fuel consumption is one of the key factor in carrying out the economic efficiency analyses of a project .

2.5 Crash Cost Savings:

Crash cost is also one of the major components of user cost and its value depends upon average unit crash cost and crash rate (Lamptey et al., 2005). Unit crash cost depends on crash severity [fatality, injury and property damage only (PDO)] with fatality having the highest unit crash cost and property damage having the lowest (National Safety Council, 2001). Crash rate have the inverse relationship with highway physical and operational condition and also depends upon highway geometry, and traffic conflicts etc. (Sinha and Labi, 2007).

There are two types of crashes i.e fatal crashes and non-fatal crashes.

As an international rule the unit crash costs for a fatal and non-fatal crash are taken as:

Unit cost of fatal crash = 70 times the GDP per capita

Unit cost of non-fatal crash = 18 times the GDP per capita

Crash cost savings can be determined by comparing the crash costs of two alternatives and then finding the difference between the two alternatives.

2.6 Vehicular Emissions:

Vehicular emissions consist of poisonous gases such as Carbon monoxide, Nitrogen oxides, volatile organic compounds which adversely affect the environment and human life.

Environment Impact Assessment is a formal process of predicting the impacts of any activity, plan or policy on the environment. It is used to analyze whether the effects of the project or plan are within the acceptable limits.

Vehicular emission cost can be determined by multiplying the cost of each emission with the amount of gas emitted. Vehicular emissions savings can be found by comparing the costs of the alternatives and then finding the difference between them.

2.7 PTV VISSIM:

PTV vissim is microscopic multi modal traffic flow simulation software package developed by PTV Planung Transport Verkher AG, A German based company. In this software micro simulation is done, means that each entity (Car, Train, Person Etc.) of reality that is to be simulated is simulated individually, i.e. it is represented by a corresponding entity in the simulation, thereby considering all relevant properties.

A salient feature in this software is the multi-modality, means more than one kind of traffic can be simulated by this software. Such as:

- Vehicles (Cars, Buses, Trucks)
- Public Transport (Trams, Buses)
- Cycles (Bicycle, Motorcycles)
- Pedestrians

2.7.1 Benefits of VISSIM:

Other Than multi modelling, there are some other features that make this software more effective.

Maximum Accuracy:

With the help of this software maximum accuracy can be achieved. In this software, we can map network and any desired geometry can be achieved, i.e. from a standard node to a complex intersection.

Realistic behaviour of all road users within the existing and planned infrastructure is possible in this software.

Ease of Use and Productivity:

We can build our efficiently by using various inter-faces (Driver Model, Driving simulator etc.) to import existing networks. The interface with flexible dock able windows allows for efficiently creating and editing network objects and their attributes as well as gives results for numerous variables, which makes it more users friendly.

Flexibility and Integration Capacity:

The Generic COM interface allows interacting with external applications. It enables you to have manual settings for drivers and vehicle properties at different levels. For current studies it helps you to test the environment. Besides this, you can connect your work to any other PTV software.

Visualization in 2D and 3D:

Switch perspective helps you to display you analysis results in both 2D and 3D. This assists in publicdecision-making processes with the help of detailed reports. This salient feature makes the trafficsimulations more appealing and understandable to all.

Chapter 3

METHODOLOGY

This chapter includes the methodology used in this project. The data comprises of traffic counts, geometric features and accidents data. These measures are taken to determine the LOS, travel time, fuel consumption, crash costs and vehicular emission costs.

Level of service for both existing and proposed alignment is determined and the comparison is done. The detailed economic, environmental and safety analysis for both existing and proposed alignment is done. Also the economic efficiency analysis is also carried out.

3.1 Project Methodology Approach:

The following flow chart shows the methodology and the procedure we have followed to reach our conclusions:

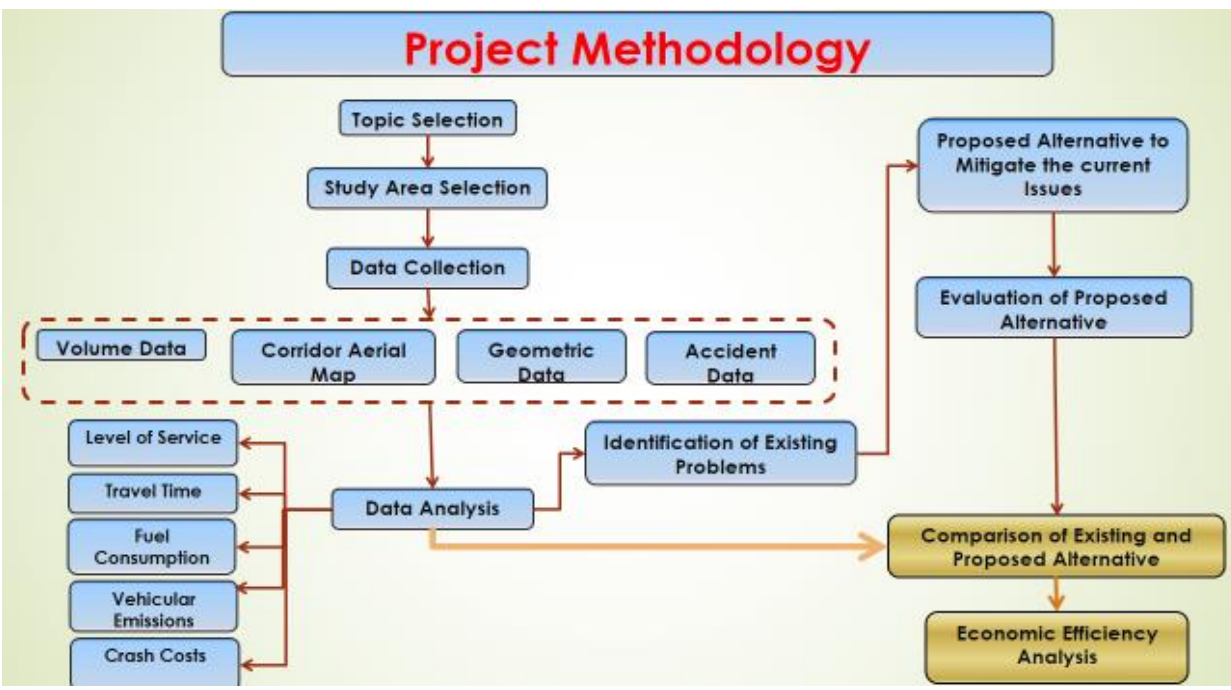

Figure 3.1 : Project Methodology

3.2 Data Collection:

After the selection of study area, the second step of our project methodology comprises of data collection. The field data includes:

- Traffic data collection
- Road geometry and site investigation
- Accidents data collection

3.2.1 Traffic Volume:

The traffic volumes were extracted from the video recordings obtained from NHA. Cameras were installed at both the starting point and the end point to extract the number of vehicles passing from that area in 24 hours. The detailed traffic data is given in the following tables.

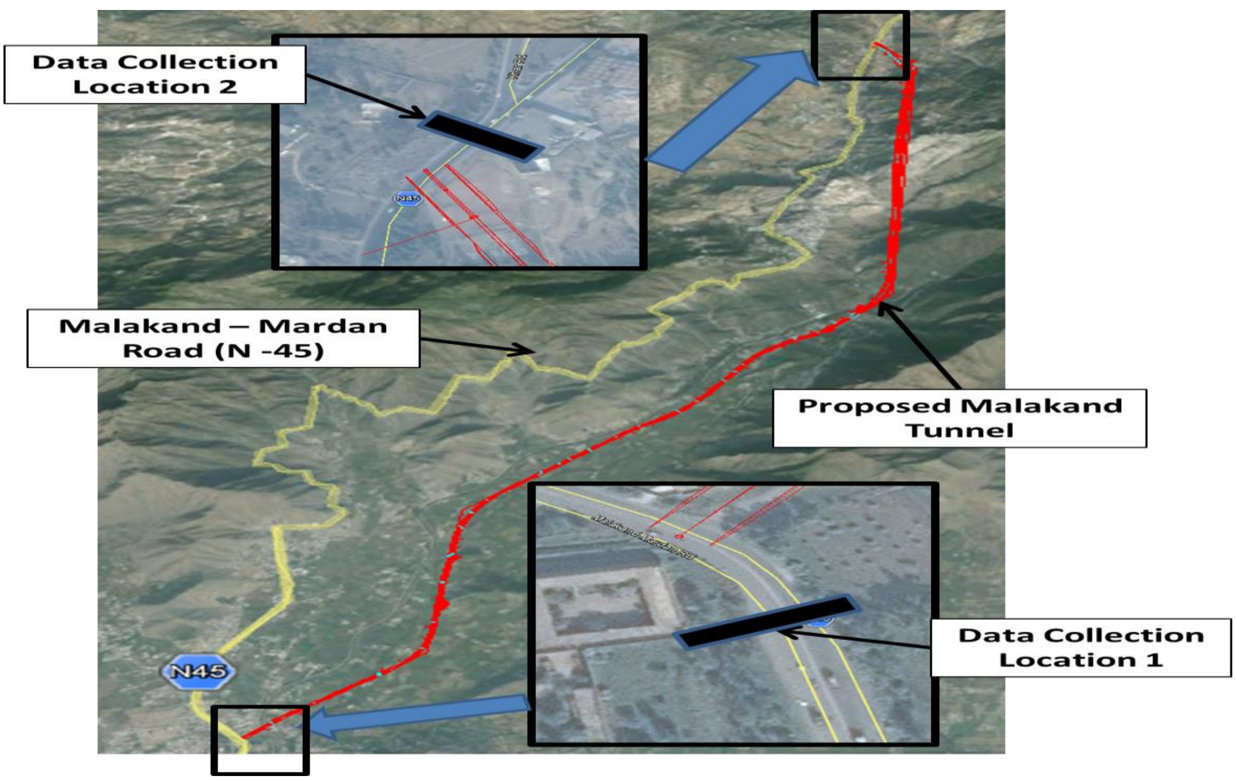

Figure 3.2 : Cameras installed at start point (Location1) and end points (Location 2)

Time		Bikes	Rickshaws	Cars	Hiace
9:00 AM	**9:15 AM**	12	3	150	12
9:15 AM	**9:30 AM**	18	3	175	16
9:30 AM	**9:45 AM**	15	4	189	15
9:45 AM	**10:00 AM**	13	0	187	20
10:00 AM	**10:15 AM**	14	5	188	22
10:15 AM	**10:30 AM**	20	4	170	18
10:30 AM	**10:45 AM**	25	3	190	23
10:45 AM	**11:00 AM**	30	1	207	26

Coaster	Bus	2-axle trucks	3- axle trucks	Articulated	PCE's
0	0	4	3	2	202.5
3	0	7	2	3	250
5	1	6	1	1	254.5
4	0	3	0	0	238.5
6	1	4	1	0	256.5
4	2	8	3	3	261
8	0	6	2	2	280.5
7	1	9	3	1	313

Time		Bikes	Rickshaws	Cars	Hiace
11:15 AM	**11:30 AM**	29	4	159	19
11:30 AM	**11:45 AM**	35	5	155	30
11:45 AM	**12:00 PM**	33	6	138	34
12:00 PM	**12:15 PM**	39	4	164	21
12:15 PM	**12:30 PM**	36	2	187	33
12:30 PM	**12:45 PM**	47	2	200	34
12:45 PM	**1:00 PM**	37	3	217	21
11:15 AM	**11:30 AM**	29	4	159	19

Coaster	Bus	2- axle trucks	3-axle trucks	Articulated	PCE'S
5	2	11	5	4	325
9	0	7	1	1	244.5
5	2	7	5	1	270.5
11	1	9	5	3	278
5	0	11	11	2	296.5
5	2	8	9	3	327
9	2	10	4	3	344
11	1	19	10	2	380

Time		Bikes	Rickshaws	Cars	Hiace
1:00 PM	**1:15 PM**	30	0	185	31
1:15 PM	**1:30 PM**	40	7	181	26
1:30 PM	**1:45 PM**	34	4	187	22
1:45 PM	**2:00 PM**	39	2	177	26
2:00 PM	**2:15 PM**	29	3	157	26
2:15 PM	**2:30 PM**	30	6	145	38
2:30 PM	**2:45 PM**	32	8	162	38
2:45 PM	**3:00 PM**	19	2	204	24

Coaster	Bus	2-axle trucks	3-axle trucks	Articulated	PCE's
9	0	16	4	1	323
7	0	9	2	1	290
8	2	10	7	2	312
9	1	12	2	5	309
11	0	11	6	3	288.5
7	1	13	2	1	280.5
12	0	17	9	1	338
12	0	16	11	2	355.5

Time		Bikes	Rickshaws	Cars	Hiace
3:00 PM	**3:15 PM**	25	1	183	30
3:15 PM	**3:30 PM**	21	3	195	30
3:30 PM	**3:45 PM**	30	4	194	31
3:45 PM	**4:00 PM**	34	3	200	29
4:00 PM	**4:15 PM**	25	2	210	33
4:15 PM	**4:30 PM**	20	3	188	23
4:30 PM	**4:45 PM**	20	4	186	29
4:45 PM	**5:00 PM**	22	4	184	23

Coaster	Bus	2- axle trucks	3- axle trucks	Articulated	PCE's
8	0	10	3	1	295
7	3	14	4	0	322.5
11	1	18	7	3	360
7	1	22	8	1	367.5
9	0	11	9	2	352.5
4	1	13	1	2	290
10	1	17	7	0	330.5
8	1	14	8	1	314.5

Time		Bikes	Rickshaws	Cars	Hiace
5:00 PM	**5:15 PM**	26	4	226	26
5:15 PM	**5:30 PM**	23	3	177	24
5:30 PM	**5:45 PM**	23	0	162	19
5:45 PM	**6:00 PM**	16	4	221	20
6:00 PM	**6:15 PM**	12	0	226	12
6:15 PM	**6:30 PM**	17	1	213	10
6:30 PM	**6:45 PM**	6	0	170	10
6:45 PM	**7:00 PM**	9	0	188	15

Coaster	Bus	Two axle trucks	Three axle trucks	Articulated	PCE'S
4	1	14	5	2	351
4	0	9	4	3	280
1	1	11	6	4	268.5
6	0	13	8	1	336
9	1	13	5	1	322.5
4	2	11	11	1	316
4	0	8	8	1	245
4	1	13	6	0	280

time		Bikes	Rickshaws	Cars	Hiace
7:00 PM	**7:15 PM**	5	0	196	8
7:15 PM	**7:30 PM**	6	1	140	12
7:30 PM	**7:45 PM**	1	1	172	21
7:45 PM	**8:00 PM**	2	1	165	25
8:00 PM	**8:15 PM**	6	2	145	19
8:15 PM	**8:30 PM**	2	0	124	17
8:30 PM	**8:45 PM**	0	1	117	13
8:45 PM	**9:00 PM**	1	4	115	15

Coaster	Bus	Two axle trucks	Three axle trucks	Articulated	PCE'S
5	1	9	4	0	259
9	0	10	9	1	235
6	2	14	7	1	283.5
6	4	21	8	2	314
1	1	16	10	2	265
5	1	21	17	1	277
1	4	10	5	1	194.5
2	1	13	10	1	217

time		Bikes	Rickshaws	Cars	Hiace
9:00 PM	**9:15 PM**	3	3	96	7
9:15 PM	**9:30 PM**	1	1	99	6
9:30 PM	**9:45 PM**	0	1	101	9
9:45 PM	**10:00 PM**	1	1	77	12
10:00 PM	**10:15 PM**	0	3	94	10
10:15 PM	**10:30 PM**	0	0	69	0
10:30 PM	**10:45 PM**	0	0	75	7
10:45 PM	**11:00 PM**	0	0	54	3

Coaster	Bus	Two axle trucks	Three axle trucks	Articulated	PCE'S
2	2	24	3	0	197.5
0	2	13	5	1	170
1	2	20	8	2	210.5
1	3	16	12	2	193.5
0	5	15	4	2	183.5
1	1	21	5	3	159.5
1	2	18	3	2	160
1	1	19	6	0	137

time		Bikes	Rickshaws	Cars	Hiace
11:00 PM	**11:15 PM**	0	1	55	2
11:15 PM	**11:30 PM**	0	2	46	1
11:30 PM	**11:45 PM**	0	0	45	4
11:45 PM	**12:00 AM**	0	0	41	1
12:00 AM	**12:15 AM**	0	0	33	2
12:15 AM	**12:30 AM**	0	0	37	2
12:30 AM	**12:45 AM**	0	0	48	1
12:45 AM	**1:00 AM**	0	0	27	5

Coaster	Bus	Two axle trucks	Three axle trucks	Articulated	PCE'S
0	0	20	6	2	142.5
1	1	16	4	1	115
1	0	13	7	0	112.5
0	0	10	7	1	96.5
1	0	22	6	0	121.5
0	1	19	10	2	135
1	0	7	5	2	93
0	0	9	8	1	88.5

Time		Bikes	Rickshaws	Cars	Hiace
1:00 AM	**1:15 AM**	0	0	37	4
1:15 AM	**1:30 AM**	0	1	26	0
1:30 AM	**1:45 AM**	0	0	33	3
1:45 AM	**2:00 AM**	0	0	30	1
2:00 AM	**2:15 AM**	0	0	26	2
2:15 AM	**2:30 AM**	0	0	15	1
2:30 AM	**2:45 AM**	0	0	16	1
2:45 AM	**3:00 AM**	1	0	18	0

Coaster	Bus	Two axle trucks	Three axle trucks	Articulated	PCE'S
0	0	19	7	2	127
0	0	7	9	1	77.5
1	0	11	9	0	99
0	0	14	10	2	109.5
0	0	11	17	0	113
1	1	13	5	1	77
1	0	10	7	0	70
1	0	11	2	2	65

Time		Bikes	Rickshaws	Cars	Hiace
3:00 AM	**3:15 AM**	0	1	24	2
3:15 AM	**3:30 AM**	0	3	19	0
3:30 AM	**3:45 AM**	1	4	20	4
3:45 AM	**4:00 AM**	0	2	27	1
4:00 AM	**4:15 AM**	0	0	22	0
4:15 AM	**4:30 AM**	0	0	16	1
4:30 AM	**4:45 AM**	0	0	38	0
4:45 AM	**5:00 AM**	2	1	30	0

Coaster	Bus	Two axle trucks	Three axle trucks	Articulated	PCE,S
1	3	6	4	0	65
0	0	2	3	0	35.5
1	0	7	5	0	66
2	1	3	5	2	64.5
0	3	4	7	0	61
0	0	6	6	0	53.5
0	1	12	12	0	112
2	2	7	10	1	92.5

Time		Bikes	Rickshaws	Cars	Hiace
5:00 AM	**5:15 AM**	0	1	17	0
5:15 AM	**5:30 AM**	2	0	33	0
5:30 AM	**5:45 AM**	0	0	34	2
5:45 AM	**6:00 AM**	0	0	33	2
6:00 AM	**6:15 AM**	0	0	34	1
6:15 AM	**6:30 AM**	0	0	44	3
6:30 AM	**6:45 AM**	1	1	27	5
6:45 AM	**7:00 AM**	3	0	37	11

Coaster	Bus	Two axle trucks	Three axle trucks	Articulated	PCE'S
0	0	11	3	2	65.5
1	2	8	1	0	66.5
0	4	7	5	2	87
0	3	11	2	0	81
1	5	11	2	1	89
0	2	11	3	1	97.5
1	2	5	2	1	65
2	1	3	6	1	90

Time		Bikes	Rickshaws	Cars	Hiace
7:00 AM	**7:15 AM**	0	0	51	6
7:15 AM	**7:30 AM**	4	0	55	13
7:30 AM	**7:45 AM**	2	1	66	21
7:45 AM	**8:00 AM**	9	1	66	13
8:00 AM	**8:15 AM**	13	1	89	9
8:15 AM	**8:30 AM**	14	1	74	21
8:30 AM	**8:45 AM**	19	2	115	18
8:45 AM	**9:00 AM**	9	1	90	25

Coaster	Bus	Two axle trucks	Three axle trucks	Articulated	PCE'S
3	2	7	6	0	107.5
2	1	8	2	0	111.5
2	0	8	4	2	144
3	0	6	8	0	137
7	3	3	9	1	165
1	1	4	2	0	134.5
9	0	1	10	0	199
5	0	8	3	0	173

3.2.2 Summary of Tables:

Bikes	Rickshaws	Cars	Hiace	Caoster	Buses	2 axle trucks	3 axle trucks	Articulated	PCE's
1134	166	10815	1341	365	104	1075	563	122	15685

Table 2.1: Summary of traffic volume

Peak Hour = 3:15 pm – 4:15 pm

Peak Hour volume = 1402.5 PCE's

Peak hour factor = 0.95

3.2.3 Road Geometry and Site:

It is a two lane, two way road with Dargai taken its starting point and Batkhela as its end point.

- Elevation of the starting point = 1555 ft
- Elevation of end point = 2300 ft
- Elevation of highest point = 2750 ft
- Difference in elevation of starting and highest point = 1195 ft or 365 m
- Gradient = 3%

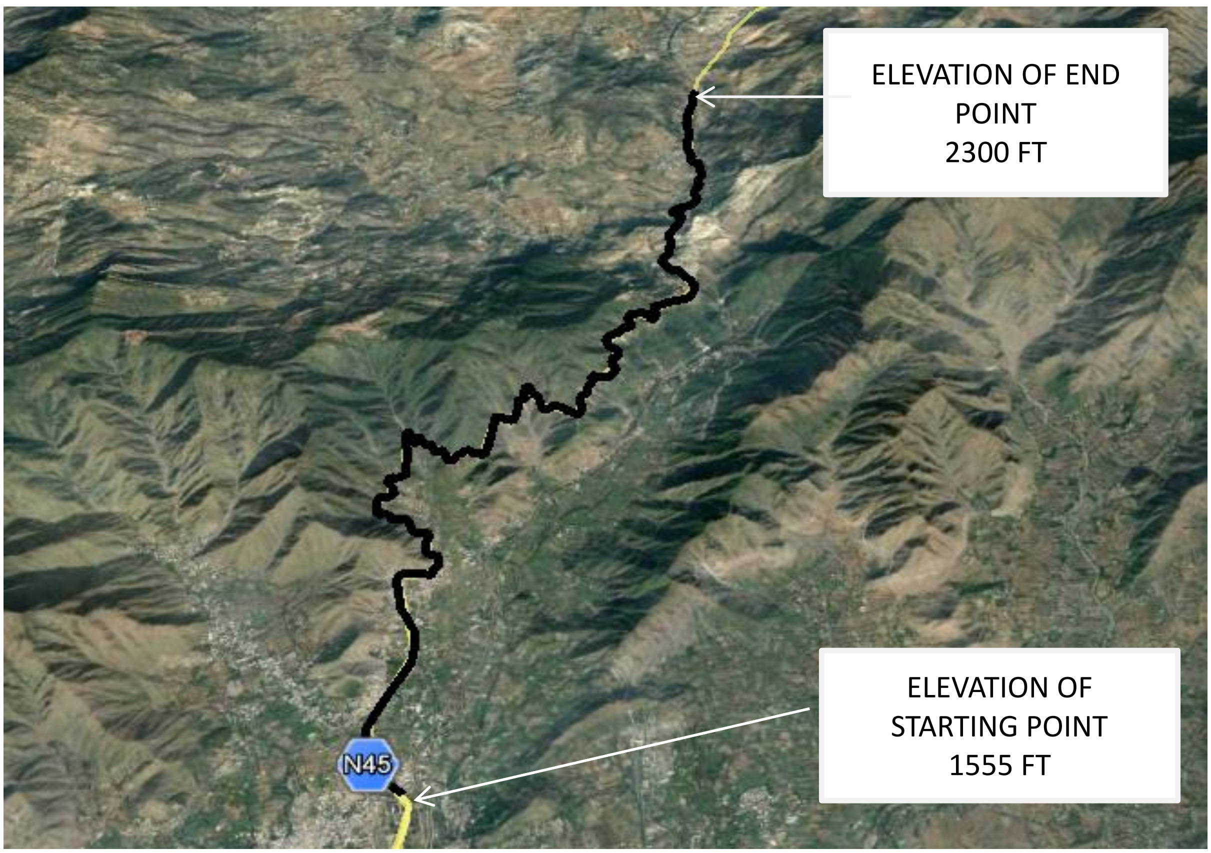

Figure 3.3: Elevation of Starting and End Points

3.2.4 Accidents Data:

Accidents data and crash reports were collected from local hospital for this particular area.

The main causes of accidents are:

- Higher percentage of heavy vehicles passing through this road.
- Sharp turns limiting the line of sight.
- Steep gradient.
- Land sliding.

Around 2 to 3 fatal and 7 to 8 non-fatal accidents occur on this road monthly. The following data shown in table has been collected from District Head Quarter Hospital Batkhela.

	Fatal accidents	**Non-fatal accidents**
January	2	7
February	3	6
March	1	6
April	3	8
May	0	5

Table 3.1: Accidents data

Chapter 4

DATA ANALYSIS AND RESULTS

Introduction:

This chapter includes the detailed comparison of the existing and proposed alignment. The analyses comprises of level of service (LOS) comparison, travel time comparison, Fuel consumption comparison, crash costs comparison and vehicular emissions comparison. The software used for analysis is PTV VISSIM 7. The data which has been collected as discussed in chapter 3, is used as an input parameter in VISSIM. VISSIM then processes the data and provides analysis results.

4.1 Analyses of Existing Conditions:

The existing road is a two lane, two way road with a length of 14 km.

The design speed for LTV's is 40 km/hr while that for HTV's is 20 km/hr.

4.1.1 Level of Service (LOS):

Highway capacity manual (HCM) methodology for capacity analysis of a two lane two way highway was adopted. Highway Capacity Software (HCS) 2000 was first consulted for carrying out capacity analysis of existing structure of the alignment but then it was revealed that it was not having the provision to carry out capacity analysis of two-lane two way highways therefore it could not be used. Only updated version of HCS 2000 i.e. HCS 2010 had the provision to carry out capacity analysis of two-lane two way highways but it was not available. Therefore the LOS was found out by direct calculations using the HCM.

Methodology for the Level of service analyses of a two lane two way highway according to HCM 2000 is explained in the fig 4.1:

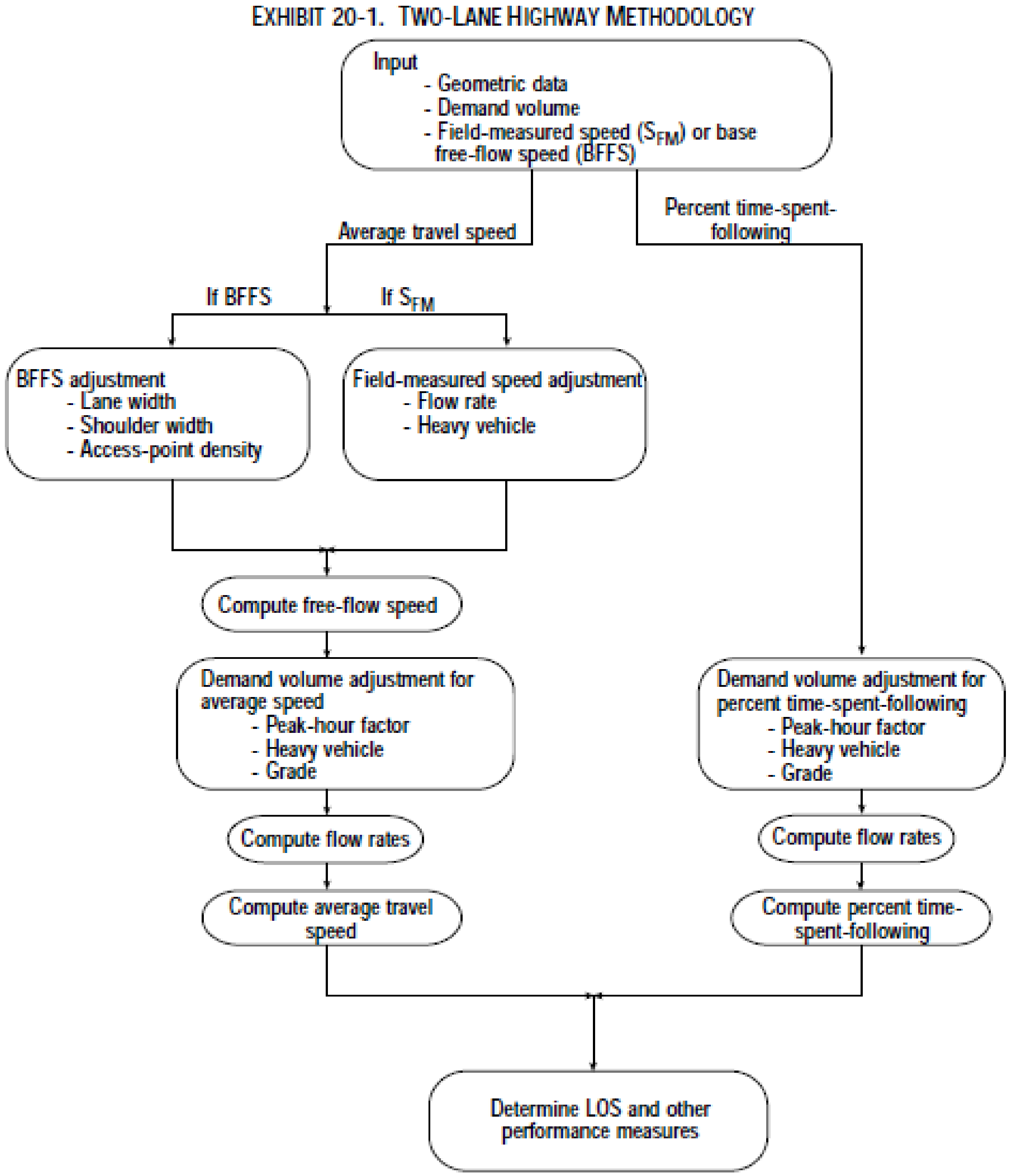

Figure 4.1: Methodology for the LOS for two lane two way highway

Ref: Highway capacity manual 2000

4.1.1.1 Peak Hour Factor:

The peak hour factor was calculated from the traffic volumes and it came out to be 0.95.

4.1.1.2 Directional Split:

The directional split was taken to be 60/40. No passing zones were supposed to be 100%.

4.1.1.3 Measure of Effectiveness:

As it is a class I highway so the MOE’s for calculating the LOS are average travel speed (ATS) and percent time spent following (PTSF).

4.1.1.4 Type of Analysis:

Single directional analysis for specific upgrades and downgrades.

4.1.1.5 Demand Flow Rate:

For single-direction analysis, there are four different determinations of demand flow rate: two demand flow rates in each direction, one for ATS determination and one for PTSF determination. The demand flow rate is determined by the following equation:

$Vp = V/(PHF*fg*fhv)$

Vp = Demand flow rate pc/hr   V = Hourly demand volume

fg = Grade adjustment factor   fhv = Heavy vehicle factor

Grade adjustment factor were calculated from the the following table:

One directional analysis for specific upgrade and dpwngrade for both ATS and PTSF determination.

The upgrade vehicular volume was taken, Vu = 842 pc/hr

The downgrade volume was taken, Vd = 541 pc/hr

4.1.1.6 Demand Flow Rate (ATS):

The fhv and the fg for all the four cases were calculated from the tables.

The demand flow rate for upward traffic was calculated to be:

Vp(u) = 1364 pc/hr

For downgrade:

Vp(d) = 604 pc/hr

4.1.1.7 Demand Flow Rate (PTSF):

Vp(u) = 914 pc/hr   Vp(d) = 561 pc/hr

4.1.1.8 Estimating the Average Travel Speed (ATS):

ATSd = FFSd – 0.00776(Vd+ Vo) – fnp

FFS = free flow speed for the directional analysis

Vd = demand flow rate in direction of analysis

Vo = demand flow rate in opposing direction

Fnp = no passing zones

FFS was taken as 45 mi/hr

ATS(u) = 45 – 0.00776(1364+604)-0.754

ATS(u) = 27.94mph

ATS(d) = 29.17 mph

4.1.1.9 Estimation of Percent Time Spent Following (PTSF):

PTSF =   + $f$np

BPTSFu = 80.97

PTSFu = 80.97 + 18 = 98%

BPTSFd = 78.69

PTSFu = 78.69+8.38 = 87%

4.1.1.10 Level of Service (LOS):

Level of service criterion for two lane two way highway:

EXHIBIT 20-2. LOS CRITERIA FOR TWO-LANE HIGHWAYS IN CLASS I

LOS	Percent Time-Spent-Following	Average Travel Speed (km/h)
A	≤ 35	> 90
B	> 35–50	> 80–90
C	> 50–65	> 70–80
D	> 65–80	> 60–70
E	> 80	≤ 60

Note:
LOS F applies whenever the flow rate exceeds the segment capacity.

Table 4.1: LOS criteria for two lane highways (HCM 2000)

LOS criteria for two lane highways

Based on the calculations done the LOS for existing alignment, the level of service for existing alignment came out to be **E.**

LOS = E

4.1.2 Travel Time:

The travel time for existing conditions was calculated from video recordings and site visit. Two cameras were installed each at both end points. From the video recordings the travel time was calculated for different vehicles. Table 4.2 shows the travel time for different vehicles:

Vehicle Type	Starting Time	End Time	Travel Time (Minutes)
Coaster	11:08:00	11:30:00	22
Car	11:09:02	11:31:54	22
Two Axle	11:21:58	12:16:16	45
Three Axle	11:09:00	12:07:00	58
Three Axle	11:03:04	12:09:16	66
Bus	3:23:03	3:49:49	26
Articulated	12:41:37	1:38:00	57
Hiace	1:17:44	1:39:46	22

Table 4.2 : Average travel time for existing condition

Average travel time for Passenger cars was taken as 22 minutes.

Average travel time for Trucks was taken as 60 minutes.

4.1.3 Fuel Consumption Cost:

Fuel consumption is the main parameter for calculating the traffic flow efficiency on a highway. The fuel consumption on existing alignment is very high due to

- Increased travel time
- Steep gradient and curves
- Sudden acceleration and deceleration of the vehicles.

Fuel consumption for existing alignment was calculated using VISSIM. Using the inputs of vehicular volume, travel time, fuel consumption rate and fuel cost, the annual fuel consumption costs were calculated.

For peak hour volume, VISSIM gave the following results:

Alignment	Vehicles arrived	Fuel consumption (gallons/hr)
Existing(2019)	1311	700

Table 4.3: Fuel consumption during peak hour

Fuel consumption = 700 gal/hr

Fuel consumption for 1 vehicle = 700*3.78/1311 = 2 lit /hr/veh

Average travel time = 22 min AADT = 23268 PCE's

Fuel cost = Rs 80/lit

Fuel cost for AADT = 22*80*2*23268/60 = 13151430 PKR.

Annual fuel cost = 13151430*365 = **493 million PKR**

4.1.4 Vehicular Emission Cost:

Vehicular emissions are very important to analyze in order to check whether the effects of a project or an activity are within acceptable limits.

Emission of CO, which is emitted in huge quantity by daily traffic, increases the amount of carbon in the air. Increased carbon contents in the atmosphere are causing greenhouse effect. Greenhouse effect raises the temperature of the earth resulting in climate changes. NOX emitted by the vehicles are another source of environmental pollution. They are the compounds of Nitrogen and Oxygen combine together in different proportions to form a series of compound. They are the main source of acid rain which is causing both environmental and infrastructure damage. VOCs are also having adverse effect on the environment.

The vehicular emissions are obtained from VISSIM .

Alignment	CO(g/hr)	NOx(g/hr)	VOC's(g/hr)
Existing	49949	10387.2	10450

Table 4.4 the vehicular emissions in g/hr

Vehicular emission costs are obtained from HERS-ST and are shown in the following table.

Table 33. HERS-ST estimates of air pollutant damage costs in 2000 dollars.			
Pollutant	Damage Costs ($/ton)	Adjustment Factors	
		Urban	Rural
Carbon Monoxide	$100	1	0.5
Volatile Organic Compounds	$2,750	1.5	1
Nitrogen Oxides	$3,625	1.5	1
Sulfur Dioxide	$8,400	1.5	1
Fine Particulate	$4,825	1	0.5

Table 4.5: Vehicular emission cost in $/ton

4.1.4.1 Vehicular Emission Cost:

The vehicular emission costs in dollars/hr are calculated by converting the emissions into ton/ hr and then multiplying by its respective costs in dollars/ton. Then the annual cost is calculated by calculating the emission for one vehicle and then multiplying it by number of vehicles, travel time and 365.

Cost of CO = 0.055*100 = $5.5/hr

Adjusted cost of CO = 5.5*0.5 = $2.75/hr

Cost of NOx = 0.0114*3625 = $41.33/hr

Cost of VOC's = 0.0115 * 2750 = $31.63/hr

Total vehicular emission cost = $75.71/hr

ANNUAL EMISSION COST = **16.8 MILLION**

4.1.5 Crash Costs:

Transportation projects either directly or indirectly reduce the crashes rates or severity. Enhancing the safety is considered as a key transportation user benefits pertaining to the physical or policy changes in transportation system.

The federal highway authority (FHWA) method was used for the calculation of crash costs and the following steps were taken:

1. Data regarding section details and the AADT was taken from the tables as given in chapter 4.

2. Annual VMT per 100 million VMT were calculated as:

[Annual VMT] = [AADT * Section Length * 365] / 10^8

3. Number of fatal and non-fatal crashes were collected from local hospitals.

4. Unit fatal crash costs = 70 times GDP per capita

5. Unit non-fatal crash costs = 18 times GDP per capita

The following table shows the crash costs calculated for existing alignment:

Alignment	Sec length	AADT(veh/day)	Annual VMT	Annual VMT per 100 million VMT	Fatal crashes	Non-fatal crashes
Existing	8.70 miles	18705	59397727.5	0.593	30	108

Fatal crashes	**Non-fatal crashes**	**GDP per capita USD**	**Total fatal crash costs USD**	**Total non-fatal crash costs USD**	**Total crash costs USD**
30	108	1429	3000900	2777976	5778876

Table 4.6: Total crash costs for existing route

Total crash costs = $5778876

= **606 Million PKR**

4.2 Analysis of Proposed Malakand Tunnel Project (2019 and 2039):

The proposed alignment consists of a tunnel having length of 3.15 km having approach roads at both ends of the tunnel. The road is a one way road with two lanes in each direction. The proposed alignment has been analyzed for 2019 i.e at the year after it is constructed and at 2039 i.e 20 years after its construction.

Design speed for LTV's = 90 km/hr

Design speed for HTV's = 70 km/hr

4.2.1 Level of Service (LOS):

The traffic was projected at a growth rate of 4.5% per year.

The traffic was modelled through VISSIM and the level of service was found from the average vehicular delay. The average vehicular delay was **9.76 sec** which means that the proposed facility would operate at level of service (LOS) **A.**

If the traffic is projected for 20 years and then it is modelled through VISSIM the vehicular delay comes out to be **32 sec** and the facility would operate at **LOS C** even 20 years after its construction.

The following table shows how the level of service changes with change in delay.

Control Delay Per Vehicles	LOS by Volume to Capacity Ratio	
	≤1	≥1
≤10	A	F
>10 and ≤20	B	F
>20 and ≤35	C	F
>35 and ≤55	D	F
>55 and ≤80	E	F
>80	F	F

Table 4.7: LOS criteria based on vehicular delay

4.2.2 Travel Time:

The travel time for the proposed alignment for both 2019 and 2039 was calculated using VISSIM. The input parameters used were vehicular volume, geometric features such as number of lanes, and no gradient. Following are the tables which shows the travel time for proposed alignment for the years 2019 and 2039.

4.2.2.2 for 2019:

Vehicle type	Travel time (Min)
Car	7
Hiace	7
Bus	8
Bikes	10
Trucks	11

Table 4.8 shows the travel time for proposed Malakand tunnel project (2019)

4.2.2.2 for 2039:

Vehicle type	Travel time (Min)
Car	7.5
Hiace	7.5
Bus	8
Bikes	11
Trucks	13

Table 4.9 shows the travel time for proposed Malakand Tunel Project (2039)

4.2.3 Fuel Consumption Cost:

Fuel consumption for proposed alignment is calculated through VISSIM which gave the following results:

4.2.3.1 for 2019:

Alignment	Vehicles arrived	Fuel consumption (gallons/hr)
Proposed(2019)	1311	240

Table 4.10: Fuel consumption for proposed Malakand tunnel project (2019)

Fuel consumption = 240 gal/hr

Fuel consumption for 1 vehicle = 240*3.78/1311 = 0.69 lit /hr/veh

Average travel time = 7 min AADT = 23268 PCE's

Fuel cost = Rs 80/lit

Fuel cost for AADT = 7*80*0.69*23268/60 = 149848 PKR.

Annual fuel cost = 149848*365 = **55 million PKR**

4.2.3.2 for 2039:

For 2039, the peak hour volume was projected at 4.5% per year, due to which the volume increased to 56116 PCE's.

Alignment	Vehicles arrived	Fuel consumption (gallons/hr)
Proposed(2039)	3024	570

Table 4.11: Fuel consumption for proposed Malakand tunnel project (2039)

Fuel consumption = 570 gal/hr

Fuel consumption for 1 vehicle = 570*3.78/3024 = 0.72 lit /hr/veh

Average travel time = 7.5 min AADT = 56116 PCE's

Fuel cost = Rs 80/lit

Fuel cost for AADT = 7.5*80*0.72*56116/60 = 145016988 PKR.

Annual fuel cost = 145016988*365 = **145 million PKR**

4.2.4 Vehicular Emission Cost:

The following results are obtained from VISSIM for proposed alignment 2019 and 2039.

4.2.4.1 for 2019:

Alignment	CO(g/hr)	NOx(g/hr)	VOC's(g/hr)
Proposed(2019)	16687	3246	3867

Table 4.12: Vehicular emissions for proposed Malakand tunnel project (2019)

Cost of CO = 0.018*100 = $1.8/hr

Adjusted cost of CO = 1.8*0.5 = $0.9/hr

Cost of NOx = 0.0036*3625 = $13.05/hr

Cost of VOC's = 0.0042* 3867= $11.55/hr

Total vehicular emission cost = $25.5/hr

ANNUAL EMISSION COST = **1.9 MILLION**

4.2.4.1 for 2039:

Alignment	CO(g/hr)	NOx(g/hr)	VOC's(g/hr)
Proposed(2039)	39888	7760	9244.45

Table 4.13: vehicular emissions for proposed Malakand tunnel project (2039)

Cost of CO = 0.0044*100 = $4.4/hr

Adjusted cost of CO = 4.4*0.5 = $2.2/hr

Cost of NOx = 0.0085*3625 = $30.81/hr

Cost of VOC's = 0.01* 3867= $27.5/hr

Total vehicular emission cost = $60.5/hr

ANNUAL EMISSION COST = **5.3 MILLION**

4.2.5 Crash Costs:

The crash costs for proposed alignment are calculated using the same method as that used for existing alignment. The number of crashes for the proposed alignment are calculated from the black spots in the alignment. If 18 black spots in the existing alignment causes 138 accidents yearly then 3 black spots in the existing alignment would cause 23 accidents out of which 5 have been assumed fatal and 18 as non-fatal. The GDP per capita for 2039 is assumed to be $2500.

Alignment	Sec length	AADT(veh/day)	Annual VMT	Annual VMT per 100 million VMT	Fatal crashes	Non-fatal crashes
Proposed (2019)	8.70 miles	18705	40963950	0.41	5	18
Proposed (2039)	6 miles	45110	98790900	098	12	44

Fatal crashes	Non-fatal crashes	GDP per capita USD	Total fatal crash costs USD	Total non-fatal crash costs USD	Total crash costs PKR
5	18	1429	500150	462996	**101 million**
12	44	2500	2100000	1980000	**428 million**

Table 4.14: Crash costs for proposed Malakand tunnel project (2019 &2039)

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

The analysis on the Arterial segment suggests that the existing condition is not satisfactory in providing efficient movement and with the increasing traffic; the situation is becoming even worse. The level of service in the existing condition is not adequate.

5.1 Conclusions:

The existing condition of this corridor does not facilitate the traffic flow and it needs some improvements. Level of service on these conditions is not satisfactory and if these conditions persist then it will cause major traffic congestion problem in the next few years. Following are the summaries of the results for existing versus proposed alignment (2019)

5.1.1 Non-monetary Benefits:

5.1.1.1 Level of Service

The existing alignment operates at level of service **E** but the level of service at proposed alignment is **A** at 2019 and **C** at 2039

5.1.1.2 Travel Time benefits:

The travel time comparison of existing and proposed alignment shows the non-monetized benefits of undertaking this project.

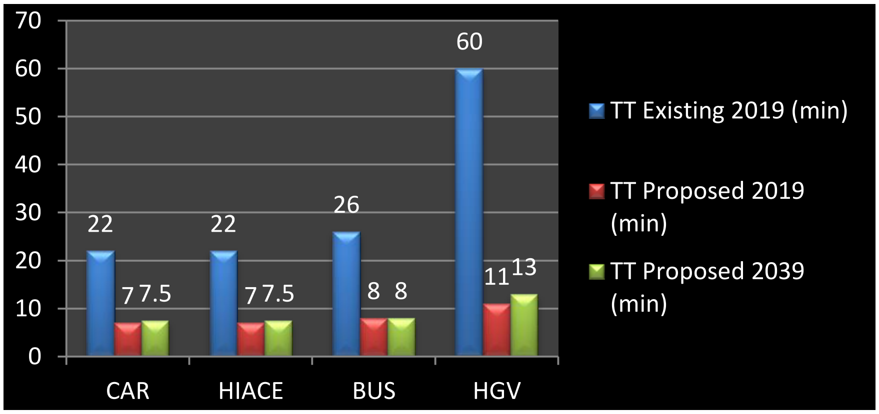

Figure 5.1: Travel time comparison (Existing and proposed alignment)

From the above graph it is very clear that there is large reduction in travel time due to the proposed alignment and the travel time does not increase even after 20 years.

5.1.2 Monetary Benefits:

5.1.2.1 Fuel Consumption Savings:

The following tables show the savings in terms of fuel consumption and the benefits of the new alignment.

Existing alignment	Proposed alignment	savings
493 million	55 million	438 million

Table 5.1: Fuel consumption savings

5.1.2.2 Emission Cost Savings:

Existing alignment	Proposed alignment	savings
16.8 million	1.9 million	14.9 million

Table 5.2: Emissions cost savings

5.1.2.3 Crash Cost Savings:

Existing alignment	Proposed alignment	savings
606 million	101 million	505 million

Table 5.3: Crash costs savings

5.1.2.4 Total Savings Per Year:

Total savings per year = 438 million + 14.9 million + 505 million

= **957.9 million**

5.1.3 Recovery Period:

Total cost of project = 15 billion

Annual benefits = 957.9 million

Cost recovery = 16 years

5.2 Recommendations:

- The above results show the problems faced on the existing alignment and if no measures are taken to improve the facility, the situation will get even worse.
- Therefore keeping in mind the benefits of the proposed alignment, it is recommended to undertake this project.
- Due to the issues on existing alignment, Batkhela faces huge problems of traffic congestion therefore it is also recommended to construct a by-pass for Batkhela.

REFERENCES

- *Crash costs estimation*, Federal Highway Administration, Washington DC, 2000. (Available on the FHWA) website: http://www.mutcd.fhwa.dot.gov
- William R. McShane, Roger P. Roess, Elena S. Prassas. *Traffic Engineering*, 3rd Edition
- Highway Capacity Manual (HCM-2000)
- Kumares C. Sinha, Sameul Labi. *Transportation Decision Making: Principles of project evaluation and programming*
- Muhammad Adeel *Multi-dimensional capacity analysis of Burhan–Khunjarab alignment in CPEC scenario*
- PTV Group *VISSIM manual*
- Highway capacity Software (HCS)