IMPROVING TRAFFIC PROGRESSION ON AN URBAN ARTERIAL

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"In the name of Almighty Allah, the Most Beneficent, the Most Merciful"

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LIST OF ACRONYMS

LOS	Level of Service
HCM	Highway Capacity Manual
WHO	World Health Organization
GT	Grand Trunk (Road)
N-45	National Highway - 45
PCU/PCE	Passenger Car Unit/Equivalent
EPCU	Equivalent Passenger Car Unit
ADT	Average Daily Traffic
AADT	Annual Average Daily Traffic
PHF	Peak Hour Factor
NHA	National Highway Authority
SB	South Bound
NB	North Bound

ABSTRACT

Pakistan has experienced a rapid motorization in last one decade as motorized vehicle population increased from about 5.3 million in year 2002 to 11 million vehicles of all type in year 2012. Also, the large scale migration of people into cities has resulted into urban sprawl and is incurring huge social cost in term of traffic congestion and higher housing prices.

An unprecedented increase in vehicular traffic in Mardan City in last decade or so has resulted in severe traffic congestion causing excessive delays and higher travel time. A well-planned, efficient and sensible transportation system is necessary to ensure the better traffic movement and operational condition of road system. Our study aims to identify the traffic congestion problems of Mardan N-45 (from Ring Road Interchange to College Chowk) using advanced traffic simulation software (PTV VISSIM) to mimic real time traffic conditions. In addition different infrastructure intervention options involving the reduction of ill-placed U-turns, lane addition, channelization and provision of grade separated facilities have been explored.

Using economic efficiency analysis techniques to compare travel time and vehicle operation costs with their respective infrastructure construction and maintenance cost and to suggest suitable cost effective solution for relieving traffic congestion.

Chapter 1

INTRODUCTION

1.1 BACKGROUND

Transportation is the backbone of the progress and development of any country. It is an inseparable part of any society. Transportation has been responsible for the development of civilization over ages by:

- Meeting the travel demand of the public.
- Enabling the trade between people.
- Accomplishing the transport requirement of goods.

Transportation has become a vital part of any society. It has always played an important role in influencing the formation of urban societies. Daily a large no of people travel from one place to another for various purposes such as to go to work, school, college, recreational purposes, shopping etc. Road transportation remains the most imp mode of transport. In developed and developing countries, a very large portion of people travel daily for work, education, recreation, shopping and other amenities. Transport consumes a lot of resources like land and materials. Traffic during operations consume time and fuel. For the smooth flow of traffic it is required to reduce the traffic congestion.

With the passage of time, traffic demand has increased due to increase in population that resulted in traffic congestion characterized by

- Slow speeds
- Longer trip times
- More fuel consumption and
- Increased vehicular queuing.

All of this further leads to drivers becoming frustrated and impatient.

Traffic congestion increases vehicular emission and pollutes the air making it difficult and unhealthy to breathe. According to a study (World Bank, 1996) 70% of world's urban population breathes unsafe air. Every year millions of people die due to serious health effects from air population. As per a WHO study (2000), an estimated 3 million people die each year because of air pollution. Health of the people largely depends on the transport system for their economic survival and socio-environmental sustainability. Society or country having a good transportation system results in better development and progress. So in order to ensure the smooth flow of day to day activities there is a dire need to reduce traffic congestion.

1.2 PROBLEM STATEMENT

National highway-45 (N-45) is 309 km in length which extends from Nowshera District to the town of Chitral via Dir in Khyber Pakhtunkhwa. It is part of National Highway Road System of Pakistan. Major road development took place in early 1990s. National Highway is in the process of being converted into an international standard highway.

The section we have selected for mitigation of congestion is part of N-45 traversing through the city of Mardan, starting from Mardan Ring Road Interchange to College Chowk. Recently it was observed that the traffic travelling via this route experienced a lot of delay, especially due to ill placed U-turns. U-turns ease congestion. This increases congestion which further leads to:

- More consumption of fuel
- More delays
- Air and noise pollution
- Slow speeds
- And adds to frustration of road users.

We aim to streamline the traffic flow by introducing physical interventions within the selected route. This will lead in the reduction of travel time which in turn results in lesser costs and smoother flow.

1.3 OBJECTIVES

The main objective of our study is to reduce the travel time by streamlining the traffic flow. Reducing unnecessary U-turns and providing physical interventions where necessary will help us achieve our objective. The study necessitates:

- Conducting traffic count and other surveys with a view to assess existing traffic on the section.
- To acquire classified traffic data in field using tally sheets by manual count method
- To collect traffic counts at points of entries of main arterials during peak hour
- Simulating the current traffic conditions on VISSIM and determining the travel time
- Simulating the traffic conditions after introducing physical interventions and determining reduced travel time
- Determining the time period during which the cost on physical interventions will be returned in terms of saved time per user.

1.4 SCOPE

Analyzing a 6.3 km long section of N-45 from Mardan Ring Road Interchange to College Chowk and studying the impact of proposed infrastructure interventions on LOS.

Effects of attracted traffic due to:

- Increased commercial activities astride the concerned section.
- Intersections of minor road networks with the major arterial have not been included due to paucity of time.

1.5 SCENARIOS TO BE STUDIED

The following scenarios were analyzed and studied to collect the relevant data:

- Classified traffic count on the two points i.e. Ring Road Interchange and College Chowk were conducted to determine the peak hour and peak hour volume.
- Simulations on VISSIM before and after the physical interventions gave us the idea about the saved time and cost.
- Review of all the reasonable options to reduce the congestion.

1.6 LIMITATIONS

Less man hour to conduct survey on N-45 so the results developed with the help of surveys are not 100% accurate but it can provide us a draft of the on ground scenario.

1.7 JUSTIFICATION FOR THE PROJECT

1.7.1 Inadequate Capacity

Lane capacity varies widely due to neighboring lanes, lane width, elements next to the road, presence of parking, speed limits, number of heavy vehicles and so on. The range can be as low as 1000 passenger cars/hours to as high as 4800 passenger cars/hour but mostly falls between 1500 and 2400 passenger cars/hour. Inadequate lane capacity can be caused because of congestion as it results in low speed of vehicles resulting in less no of vehicles passing in an hour.

1.7.2 Noise Pollution

In rapid developing built – up cities, traffic noise has become a serious problem nowadays because of inadequate town and urban planning. The problem has been compounded by increase in traffic volumes far beyond the expectations. We should assess the impact on human activities due to traffic parameters and should identify the suitable mitigation abatement measures.

1.7.3 Air Pollution

Growing traffic and industrial activities lead to air pollution by emitting gases which contains arsenic, cadmium, nickel and other hydrocarbons. Air pollution is bad for our health and for our environment. The most problematic pollutants today are fine particles, nitrogen dioxide and ground level ozone.

1.7.4 Time Delay

The foremost thing that comes in mind when we think of congestion is the delay. Drivers undergo additional stress because delays caused by the congestion can result in approaching late for morning hours. However at the end of the day, the afternoon rush hour is again a frustrating time because people are done with their work and they want to go and relax but traffic is the main hurdle.

1.7.5 Fuel Consumption

The consumption of fuel is more as stopping and starting in traffic jams burns fuel at a higher rate than the smooth rate of travel on the open highway. Higher the rate of fuel, higher will be the cost and it will be very uneconomical and it also contributes to the amount of emissions released by the vehicles which in return results in more pollution

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

As discussed in chapter 1, one of the most important aspects of transportation is "Road transportation". In Pakistan, people prefer to mostly travel by road as compared to other modes of transportation. Most of the freight is carried by truck. The problem is that with increase in population there has been a rapid increase in cars on roads due to which the volumes often exceeds design capacity which leads to congestion and thus increase in travel time.

This chapter will give an overview of the literature regarding the objectives mentioned in chapter 1 and will also explain some terms regarding transportation engineering.

2.2 IMPORTANT ENGINEERING TERMS

2.2.1 Transportation Engineering

Transportation engineering is the application of technology and scientific principles to the planning, functional design, operation and management of facilities for any mode of transportation in order to provide for the safe, rapid, comfortable, convenient, economical, efficient, and environmentally compatible movement of people and goods.

2.2.2 Traffic Engineering

Traffic engineering is that phase of transportation engineering which deals with the planning, geometric design and traffic operations of roads, streets and highways, their networks, terminals, abutting land and relationships with other modes of transportation.

2.2.3 Congestion

Traffic congestion is a condition on transport networks that occurs as use increases, and is characterized by slower speeds, longer trip times, and increased vehicular queue. The most common example is the physical use of roads by vehicles. When traffic demand is great enough that the interaction between vehicles slows the speed of the traffic stream this results in some congestion. As demand approaches the capacity of a road (or of the intersections along the road) extreme traffic congestion sets in. When vehicles are fully stopped for periods of time, this is colloquially known as a traffic jam. In simple terms, it can be said that congestion occurs when volume exceeds design volume. Traffic congestion leads to Traffic jam.

2.2.4 Capacity

Capacity can be defined as, "The maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point or uniform segment of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions."

2.2.5 Average Annual Daily Traffic

The average 24 hour volume at a given location over a full 365 day year.

$$AADT = \frac{\text{Number of vehicles in a year}}{365} \quad (1)$$

2.2.6 Average daily traffic

The average 24-hour volume at a given location over a defined time period less than one year

$$ADT = \frac{\text{Number of vehicles}}{\text{Number of days}} \quad (2)$$

2.2.7 Traffic count

Count of traffic along a particular road is known as Traffic count. It can be done either manually or electronically.

2.2.8 Passenger Car Equivalent (PCE)

Passenger Car Equivalent (PCE) is a metric used in Traffic engineering for expressing highway capacity. A Passenger Car Equivalent is essentially the impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single car. Typical values of PCE are:

Table 2.1: Equivalent Passenger Car Units (EPCUs)

VEHICLES	PCE
Car (including Taxis, Jeeps, Land Cruisers, Hiace, Wagons, Minibus, Mazda)	1.0
Motorcycles, Rickshaw, Qingqi, Bicycle	0.5
Large Bus (> 30 seats)	3.0
All Trucks including construction vehicles	4.0
Tractors with or without trolley	5.0

2.2.9 Peak hour Volume

The single hour of the day that has the highest hourly volume is referred to as “Peak Hour volume”.

2.2.10 Peak hour factor

The relationship between the hourly volume and the maximum rate of flow within the hour is defined by the peak hour factor.

$$PHF = \frac{\text{Hourly volume}}{\text{Max. Rate of flow}} \quad (3)$$

2.3 CONGESTION

Congestion is slowly becoming a very major issue which is being faced by transportation system. Many theories exist which show different reasons of congestion. These theories also suggest the solution to congestion related problems however most of these solutions are ineffective when applied. This paper explains a general classification of those theories and the reason as to why the solutions have proven ineffective.

2.3.1 Theories

The theories which explain the causes of congestion can be generally classified into two groups:

1. Mathematical Theories
2. Economic Theories

2.3.1.1 Mathematical Theories

These theories include comparison of traffic flow to flow of fluid in a pipe. Traffic engineers have attempted to apply principles of fluid dynamics to traffic flow but have not been successful because traffic flow is affected by signals and other interruptions. Other theories like Boris Kenner's three phase traffic theory also exist. One failure of mathematical theories is that traffic engineers have not yet developed models which show actual traffic flow accurately. Mathematicians in MIT managed to make a model by which they solved traffic jam equations

2.3.1.2 Economic Theories

Economists believe that since roads in most places are free to use, so drivers do not hesitate in over using them, up to a point where it causes congestion which ultimately leads to traffic jam. Economic theories propose privatization of highways and road pricing as measures that might reduce congestion. A practical example of road pricing is comparison of GT road and Motorway. Congestion is a common problem on GT road where as it does not occur on motorway

2.3.2 Congestion Pricing and Conclusion

One thing common in both types of theories is that both suggest "Congestion pricing" as a phenomena that might reduce congestion. Congestion pricing is a method used to reduce traffic by charging the users during rush hours. The fee could vary depending on the time of the day or day of the week. For example, it could be high during peak hour and no fee at all when traffic is very low.

This has been implemented in some parts of the world and has been effective to some extent.

The question now arises, whether all users will have to pay toll? How and where will that toll be used?

Most solutions suggest that the toll money can be used to improve road network which will increase the capacity and will help in reducing congestion.

However, the answers to all the questions can be explained by Downs-Thomson paradox which states that improvement in road network will only increase traffic congestion. According to this paradox, improvement in road network will make travelling more convenient and hence will increase congestion. This paradox suggests making travelling inconvenient to discourage people from using their personal vehicles more.

The paradox could be the reason why most solutions are ineffective.

2.4 THE ECONOMIC COST OF CONGESTION

Congestion occurs when the traffic volume nears or exceeds the maximum capacity of the road. When this happens, authorities are required to provide reasonable solutions to do this. Congestion is not a temporary problem. It has become a permanent problem now. Surveys and statistics show that with rapid increase in population, number of vehicles on roads has also increased. Cars alone contribute 85% to total traffic on roads. Every year, Government sets aside specific amount for Transportation authorities to carry out surveys and provide measures to reduce congestion. In UK, earlier the cost was £20 billion but it is estimated that it will soon increase to £30 billion. These costs are estimated considering the proposition that all of Government’s policies are implemented fully and successfully.

Government has tried to reduce congestion by introducing initiatives like five year plan and ten year plan but has not fully succeeded because of rapid increase in population. However, in UK, it has been estimated that a cost of £4-£6 billion per year could be required to provide alternatives like signalization, providing priority and additional lanes, Public transport, cycling, freight and public trains and to implement policies to encourage the public to use public transport more. If successful, this can reduce congestion from 40%-50%.

People avoid using public transport because of its deteriorating conditions. As the Government plans to encourage people to use public transport, it has been estimated that it will cost £40,000 to £80,000 to maintain a respectable standard of public transport.

What must be known is that the costs above are not calculated using a stable or a definite relationship. The costs are mostly based on an estimate and have been calculated by using Average of the real speeds of vehicles as a factor and comparing them to Average of the ideal speeds which Is not accurate. The cost should be calculated by keeping in mind Variability and

Reliability. In real life, every vehicle moves with a different speed and level of congestion is not same throughout the day. Level of congestion varies with time; for example: it may be more during the peak hour. Location must also be taken into account for example: congestion is likely to be more on the roads passing by markets. All these factors must be accounted for before calculating the cost required to reduce congestion.

2.5 MEASUREMENT OF TRAFFIC CONGESTION

2.5.1 Introduction

To take measures to eliminate congestion, first it has to be identified. A paper by Amudapuram Mohan Rao and Kalaga Ramachandra Rao targets the variables that are used to measure congestion. The paper explains those variables by looking at how different countries measure congestion.

Factors affecting congestion are broadly classified into two groups:

- Micro level factors
- Macro level factors

Micro level factors relate to traffic on the road and macro level factors relate to overall demand for road use.

2.5.2 Variables used to identify congestion

Following variables are used worldwide, for identification of congestion:

- Speed
- Travel time and delay
- Volume
- Level of service
- Demand/Capacity
- Cost

2.5.3 Existing Practices

Different countries use different methods and techniques for identifying congestion. A brief review is discussed below:

2.5.3.1 USA

USA has a systematic system of identifying congestion. They use speed and time as variables to identify congestion e.g. In California if avg. speed drops below 35 mph for 15 minutes, they call it congestion meanwhile in Minnesota if traffic flows below 45 km/h between 6 and 9 am or 2 and 7 pm, for any length of time, they call it congestion. Michigan uses LOS to identify congestion e.g. For LOS F, when volume to capacity ratio is equal to or greater than 1, they call it congestion.

2.5.3.2 South Korea

Korea highway corporation (KHC) has defined standards whereby if the vehicle speed falls below 30 km/h it is characterized as congestion. They identify congestion spots where traffic congestion occurs for 2 hours a day for 10 days in a month.

2.5.3.3 Japan

If vehicle speed falls below 40 km/h for more than 15 minutes, it is characterized as congestion. Repeated stop and go flows for more than 1 km is also characterized as congestion.

2.5.3.4 Subcontinent (Pakistan and India)

Pakistan and India are developing countries and population has increased rapidly in both the countries in the last decade. With increase in road users, an efficient system should have been devised to identify congestion but unfortunately no such system has been devised. There is no way of identifying congestion in Pakistan and India. What the authorities do is they see where traffic jams are occurring frequently and they characterize it as congestion.

2.5.4 Congestion measurement methodologies

The above mentioned factors are not enough to measure congestion. Some of the other methods proposed to measure congestion are discussed below:

2.5.4.1 Empirical Relation (By Levinson and Lomax)

They developed the empirical relation:

$$Q = KS/ (\Delta_s f^{1/2}) \tag{4}$$

Where,

Q= quality of traffic transmission index

S= Average speed (mph)

f= number of speed changes after every 1 mile

K= constant

Δ_s= absolute of speed changes after every 1 mile

Result of this equation is relative to free flow speed which is often difficult to comprehend.

2.5.4.2 Travel time Index (By Schrank and Lomax)

They used Travel time index (TTI) to express traffic congestion in terms of time and space. The index is expressed by comparing travel time in peak hour and travel time in free flow condition.

$$TTI = \frac{\text{Peak period travel time}}{\text{Free flow travel time}} \quad (5)$$

The index can also be expressed by reversing both the values.

2.5.4.3 Travel rate index (By Levinson and Lomax)

TRI basically computes the amount of additional time that is required to complete a journey, due to interruptions. This index focuses on time rather than speed.

When a road is designed, the designers set a design speed and compute the time required to complete a journey between two locations. TRI characterizes it as congestion if a vehicle is continuously taking more time to complete the journey during the peak hour.

2.5.4.4 Roadway travel Index (By Shrank and Lomax)

This is also an empirical relation developed by Shrank and Lomax. The relation is developed on the basis of RCI. This index measures daily vehicle mile travel per lane, mile principal arterial streets and freeways. The index focuses on physical capacity of the road network and measures system performance based on that.

2.5.4.5 Lane mile duration index (By Cottrell)

LMDI, developed by Cottrell, measures duration of congestion on freeway. It is sum of product of congested freeway lane miles and congestion duration for individual roadway segments. It is calculated by using AADT volume per hourly capacity i.e. AADT/C. It assumed AADT/C > 9 or v/c > 1.

$$LMDI_F = \Sigma^{m}_{i=1} [\text{Congested Lane – Miles}_i * \text{Congestion Duration}_i)] \quad (6)$$

The congestion duration is in hours.

And,

i= individual freeway segments

m= total number of freeways segments

2.5.6 Conclusion

Traffic engineers are still trying to establish more efficient methods to identify and measure congestion. It is necessary to make the methods more efficient so adequate measures can be taken to reduce and eventually eliminate congestion completely.

2.6 MITIGATION OF CONGESTION

After congestion is identified, the next step is to take steps to mitigate it. Many models have been developed out of which a model developed by Kerner and colleagues has proven most effective.

2.6.1 Model (By Kerner and Colleagues)

A paper was published in 2011 by L.C.Davis in which he discussed mitigation of congestion. He described a three phase model.

The three phases of traffic flow are:

- Free flow
- Wide moving jams
- Synchronous flow

The calculations are done for a two lane road with an off-ramp and an on-ramp. The author addresses the model given by Kerner and colleagues.

. For explanation of this model, consider velocities of vehicles in a region of freeway near the on ramp of length, x = 500m. Average velocity (Vavg) is computed with respect to time (t).

The maximum speed on the off ramp is Vor= 15 m/s.

When Vavg < Vor, a fraction of vehicles in right lane divert. (7)

The probability that a driver in the right lane will divert is taken as:

P= 1- (Vavg/Vor) (8)

According to this model, a driver will also divert when the velocity of vehicle is less than the speed limit, that is:

V < Vor – Δ (9)

For this example, Δ= 2 m/s.

Eq.1 and Eq.2 is the response of the driver to advanced or new information whereas Eq.3 is a natural response of drivers to traffic congestion.

In addition to models, there are a few theories which explain different ways of mitigation of congestion.

2.6.2 Ride matching by Bee colony optimization (By Dušan Teodorović & Mauro Dell' Orco)

In a nutshell Ride matching theory suggests that people travelling to same destination can travel together. It suggests a system that will match people based upon their destinations and this can help in mitigating condition. The only real challenge will be to make people let go of their own personal vehicles to travel together via public transport. For this purpose, public transport will have to be made more efficient, safe and comfortable and more money will have to be spent on it to maintain its standard.

According to the theory, expanding road network and even congestion pricing won't help in mitigating congestion. It suggests that Travel demand management (TDM) techniques will be more helpful in mitigating congestion. TDM means strategies that will give more travel choices to travellers.

Many researchers have developed different TDM techniques:

- Vickery (1969)
- Sullivan and Harake (1998)
- Yang and Huang (1999)
- Phang and Toh (2004)
- Teodorović and Edara (2005)

However the most convenient technique is by Bee colony optimization since it can be applied to many complex problems. This theory basically compares a person to a bee. It believes that humans like bees can solve their problems if they put in a collective effort. The problem in this case is congestion. This theory states that when a swarm of bees encounter a problem, they communicate directly with each other and to bees of other hives and try to eliminate that problem. The technique uses analogy as a way of explaining its point i.e. Hive as roads and Swarm as Users. As congestion is increasing, users themselves should figure out a way to mitigate congestion and that can be done if they themselves start using same vehicle for a common destination.

The theory suggests that congestion can be mitigated this way.

2.6.3 Congestion Mitigation Strategies (By Derick Hayden Fesler)

In his paper, Fesler suggested following mitigation strategies. Keeping in view the cost, the strategies are arranged from least to most:

1. **Expand Roadway capacity**
   This is the quickest way to mitigate congestion. However it is not a long term solution as expanding a road will lead to more vehicles and it will eventually become congested again. Also, it costs a lot to expand a road and it is not really ideal to spend so much on a solution which won't work for a longer period.

2. **Expanding Transit capacity**
   Expanding transit capacity costs more than expanding roadway but is also not much effective because while in theory it provides an alternative to travelling by vehicles and should shift a portion of travellers to transit system, the reality is completely different.

A survey conducted revealed that cities with less density, a very small population use transit system.

3. **Increasing Residential Densities**

   Increasing residential density means a reduction in demand in demand for road space. This implies making public transport more viable. However, building more houses means changing the infrastructure of the city which will cost a lot more and will not be economical.

4. **Toll-ways**

   While toll ways are beneficial in reducing congestion to some extent, the cost associated with construction of toll ways is similar to that of a roadway. However, toll paid by users can help in moderating the cost.

5. **Ramp metering**

   A ramp meter, ramp signal or metering light is a device, usually a basic traffic light or a two-section signal (red and green only, no yellow) light together with a signal controller that regulates the flow of traffic entering freeways according to current traffic conditions. It is the use of traffic signals at freeway on-ramps to manage the rate of automobiles entering the freeway. Ramp metering systems have proved to be successful in decreasing traffic congestion and improving driver safety.

   According to Fesler even though this costs more than the other strategies, it reduces more congestion than any other strategy.

2.6.4 Conclusion

Fesler suggests that new infrastructure should not be developed until the government has gotten full use from the existing infrastructure. The new infrastructure will be costly and should be last resort. Also, new roads built shall be made integral part of transportation system for them to be of any use in mitigating congestion. According to him, some strategies which prove to be ineffective may become effective if combined together. For example: Expanding transit capacity and increasing residential density can be combined together to get better results.

Chapter 3

DATA COLLECTION

3.1 INTRODUCTION

N-45 is a Northern highway in the Pakistan National Highway network that has around 26 highways in total linking all the Major and many minor cities of the country. It is a Two-lane Highway that links the Khyber-Pakhtunkhwa district of Nowshera right through to the town of Chitral. It is relatively shorter than many of the major Highways having a total length of 309 kilometers. It starts from the city of Nowshera passing smaller cities such as Risalpur as it reaches Mardan (an Industrial city contributing major traffic on the N-45) then diverts at Batkhela towards Timegara leading ultimately to Chitral right through Dir. It is operated by the National Highway Authority (NHA). It accommodates traffic towards major trip generating sites of the Northern part of the country such as Mardan (Industrial hub of the province) and Chitral (A major tourist attraction), hence it can be considered both strategically and economically as one of the major highways of the country.

Figure 3.1: National Highway Network Map

Figure 3.2: Map of N-45 passing through Mardan

3.2 PROJECT LOCATION

The section of N-45 under consideration runs along the Malakand-Mardan road starting from the Mardan Industrial Estate till Bacha Khan Monument, College Chowk, Mardan. The selected portion of the highway is 6.3 km long. This highway passes right through the heart of the city surrounded by all the major trip generators of the city including residential colonies, major commercial centers, educational institutions, recreational centers and industrial zones. All the major trip generators along the section under consideration are as follows:

- Mardan Industrial Estate.
- The Mardan Lyceum.
- Mardan Sports Complex.
- ANSi College.
- Bacha Khan Medical College.
- Mardan Medical Complex.
- Khyber Tobacco Company.
- Ocean Mall.
- ANSI School and Degree College.
- Abdul Wali Khan University.
- Mardan Enclave Housing Society.
- Green Acres Town.
- Labor Colony.
- Sharifabad.
- New Bagh Colony.
- Ghulam Nabi Park.
- Mardan Mega Mart.
- Premier Sugar Mill.

3.3 EXISTING ROAD NETWORK

The section of N-45 and Malakand-Mardan road under consideration crosses many major roads which have been listed below:

3.3.1 Nowshera-Mardan Road

The section under consideration is a part of both the Nowshera-Mardan Road and Malakand-Mardan Road till Bacha Khan Monument roundabout after which Nowshera-Mardan Road is discontinued.

3.3.2 Mardan Ring Road

N-45 meets the Mardan Ring road 0.5 km from our starting point i.e. the Mardan Industrail Enclave.

3.3.3 Double Road

The double Road crosses N-45 some 2.5 km from Mardan Industrial Enclave.

3.3.4 Bypass Road

The bypass road crosses N-45 at a point about 1km away from the double road.

3.3.5 Canal Road:

The Canal Road crosses the highway under consideration about half a kilometer before College Chowk.

3.4 OVERVIEW

The data for N-45 Section Mardan Ring Road Interchange – College Chowk that was necessary for our project consists of the following:

1. Classified Traffic counts at ends of the section
2. Determination of Peak hour
3. Classified traffic counts on major intersections
4. Determination of percentage turning traffic on U-turns during peak hour
5. Spot Speeds during peak hours
6. Travel times during peak hours

3.5 CLASSIFIED TRAFFIC COUNTS AT ENDS OF THE SECTION

Two points of N-45 were selected for traffic data acquisition

- Mardan Ring Road Interchange
- College Chowk

We collected the classified traffic count data on both the locations mentioned above twice, maximum of the two was considered. The North Bound Traffic and South Bound Traffic was counted simultaneously. Northbound being the traffic traveling from Ring Road Interchange to College Chowk and southbound is the traffic travelling from College Chowk to Ring Road Interchange.

3.5.1 Methods for Classified Traffic Counts

Two methods are available for conducting traffic volume counts namely Manual counts and Jamar Counter. We used the manual method for conducting the traffic volume counts.

3.5.1.1 Manual Count

Tally sheets are used for the traffic count manually. Tally marks are the basic units of unary numeral system used for counting purpose. They are grouped in five so that calculation may become easier and legible.

Figure 3.3: Manual Count (Tally Bar)

3.5.1.2 JAMAR Counter

This is an efficient way of counting traffic volume. Because of its ease of use, and accurate results JAMAR traffic recorders are now used worldwide. It can save hundreds of hours of Data. PETRAPro is the software used for analyzing data gathered with the TDCUltra hand-held data collectors.

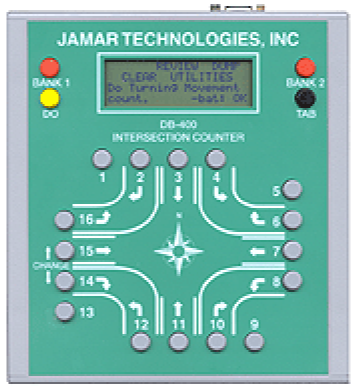

Figure 3.4 JAMAR Counter

3.5.2 Manual Count Method

First of all traffic was segregated into following classes.

- **Bikes**
  - Bicycles
  - Motor Bikes
- **Rickshaws/ Qingqi**
- **Cars**
  - Passenger Cars
  - Hiace
  - Suzuki
  - Coasters (less than 16 seats)
- **Buses**
  - Coasters (up to 24 seats)
  - Public Transport Buses
- **Trucks**
  - Construction Vehicles
  - 2-Axle Trucks
  - 3-Axle or above
  - Tractors (with or without trolley)

3.5.2.1 Selection of representative days

Traffic counts taken during Monday morning and Friday evening rush hour may show exceptional behavior of high traffic volumes and are not normally used in analysis therefore, counts are usually conducted on a Tuesday, Wednesday, or Thursday.

3.5.2.2 Selected time slot

Initial visits to the location were made to select timings for survey to determine peak hour. Timings selected were

Table 3.1: Time Slots

Morning	7:00 – 10:00 AM
Evening	1:00 – 4:00 PM

3.5.2.3 Manual Count, Recording Method and Timings

Recording data onto manual tally sheet is the simplest and easy method of taking counts. A stop watch is necessary to measure the desired count interval. Classified counts were conducted for three hours duration in the morning and evening, in 10 minutes time period at two locations. This was done twice on representative day. Maximum of the two was considered.

3.5.2.4 Personnel Involved in a Manual Count Study

The data collection team size depends on the counting period length, the type of count being performed and the volume level of traffic. The number of personnel needed also depends on the study data needed. For example, two observer can record certain types of vehicles in one direction while rest can count in other direction.

3.5.2.5 Determining Peak Hour Volume

Peak hour volume is the traffic volume that occurs during the peak hour. It is expressed in EPCUs per hour and it represents the highest traffic volume. For calculating peak hour first of all different types of vehicles were converted into EPCU (Equivalent Passenger Car Units) using the table 1.1

Traffic counts for each 10 minutes time period were converted to EPCU of different vehicles, added and total EPCU was determined. Peak hour volume was taken which yielded the max EPCUs for 60 consecutive minutes. EPCUs for the peak hour are tabulated as follows.

Table 3.2: Peak hour and peak hourly volume in Northbound and Southbound direction.

GT Road N-45		
Direction	North Bound	South Bound
Peak Hour	1:30-2:30 PM	1:30-2:30 PM
Traffic Volume	1619 EPCUs	1776 EPCUs

3.6 CLASSIFIED TRAFFIC COUNTS ON THE INTERSECTIONS

As the peak hour for South Bound and North bound was 1:30-2:30 pm. This was the time period during which we took the classified traffic counts on major intersections and percentage turning traffic data on U-turns. The manual procedure using tally marks was used again. This whole exercise gave us some idea regarding the vehicle share from major arterials on N-45. Classified counts were conducted for sixty minutes duration at each intersection, in 10 minutes' time period. The maximum volume (EPCUs) was used. Percentage of turning traffic on U-turns was also counted on all the 26 U-turns which come in the selected roadway section.

Table 3.3: Classified Traffic Counts on Intersections

Intersection	Traffic From Arterial to N-45	Traffic from N-45 to Arterial
Bypass Chowk	972	655
Turu Road Chowk	789	545
Double Road Chowk	847	612

Table 3.4: Turning Vehicles on U-turns

U-Turn	Number of Turning Vehicles	
	North Bound	South Bound
1	112	145
2	130	125
3	85	62
4	105	110
5	75	100
6	109	83
7	44	31
8	23	42
9	15	20
10	57	65
11	71	46
12	99	74
13	33	67
14	117	145
15	90	79
16	55	51
17	13	27
18	160	189
19	145	123
20	45	97
21	119	74
22	95	79
23	129	91
24	77	84
25	51	44
26	210	245

3.7 SPOT SPEED ANALYSIS

Speed is one of the most important characteristics of traffic and its measurement is a frequent necessity in traffic engineering studies. In simple words, speed is the distance covered in unit time. It can also be defined as the rate of movement of traffic or specific components of traffic and is expressed in metric units in kilometers per hour (km/h) and in customary units in miles per hour (mph). Study of speed characteristics is the most essential pre requisite for any improvement of traffic facilities. Different types of speeds are measured for unique purposes in traffic engineering.

- **Spot speed** is the instantaneous speed of a vehicle at a specified situation.
- **Running speed** is the average speed maintained by a vehicle over a given course while the vehicle is in motion. It is important to note the clause "while the vehicle is in motion" because while determining running speed the delay times in not incorporated.

$$\text{Running speed} = \frac{\text{Length of highway section}}{\text{Running time}} \qquad (1)$$

- **Journey speed** is the effective speed of a vehicle between two points. It is also known as overall travel speed because it considers the total time taken including all the delays.

$$\text{Journey Speed} = \frac{\text{Length of highway section}}{\text{Journey time}} \qquad (2)$$

- **Time- Mean Speed** is the average of the speed measurement at one point in space over the period of the time. It is the average of number of spot speed measurements.
- **Space- Mean Speed** is the average of the speed measurements at an instant of time over a space.

3.7.1 Use of Spot Speeds

There are many applications of spot speed analysis in traffic engineering and geometric design of roads including regulation and control of traffic operations, analyzing the causes of accidents etc. However the uses most relatable to the scope of our project are:

- For before and after studies of road improvement schemes it is necessary to have spot speed data, enabling a meaningful analysis to be carried out of the effects of improvements.
- For determining the problems of congestion on roads and relating capacity with speeds, spot speed data is useful.

3.7.2 Methodology

Spot Speed is measured at a single point of the highway to estimate the distribution of speed of vehicles in a stream of traffic at a particular location on a highway.

This is carried out by recording the speeds of a sample of vehicles at a specified location. A spot speed is measured the measuring the individual speeds of a sample of the vehicle passing a given spot on a street or highway. Spot speed data have a number of safety applications including the following:

- Speed trends
- Traffic control planning
- Accidental analysis
- Geometric design
- Research studies

Methods of spot speed studies are divided into two main categories:

1. Manual
    - Stop-Watch Method
2. Automatic
    - Enoscope
    - Pressure Contact Tubes
    - Short-Base Method for Determining Spot Speed

- Radar Speed Meters
- Photographic Method
- Video Camera Method

3.7.3 Stop-watch Method

We adopted the stop-watch method for the measurement of spot speeds.

Spot speeds may be measured by determining the time it takes for a vehicle to travel between two points, the distance between which is usually less than 90 meters. Distance between two points (base length) is generally dependent on the posted speed of the highway section.

The following base lengths for the long-base methods are adapted from the recommendations of the Traffic Engineering Handbook:

Table 3.5: Recommended Base Lengths for Spot Speed Survey

Average Speed of Traffic Stream (km/h)	*Base Length (meters)*
Less than 40	27
40 to 60	54
Greater than 65	81

Since the posted speed on our section of National Highway-45 is > 65km/h hence a base length of 81 meters was used.

3.7.3.1 Equipment Required:

The equipment used for stop-watch analysis was:

1. Stop Watch
2. Measuring tape
3. Bright post or flag

3.7.3.2 Stretch Selection Criteria:

1. Geometry of road should be plain without any adulation or slope.
2. Select a section where road condition is good and drivers drive comfortably.
3. The stretch should be free from speed breakers and precaution signs etc.
4. Drivers should not be aware of the experimentation going on otherwise they might be distracted.

Based on this criterion, a stretch of 81 meters, 500 meters ahead of Medical Complex in the northbound direction was selected. This stretch fulfilled all the above points.

3.7.3.3 Experimentation

We required minimum three observers to carry out this activity. After choosing the section, 81 meters stretch was measured on roadside using a measuring tape. Two observers, one carrying stop watch and the other carrying data sheet stood at the starting point of the stretch. The third observer stood at the ending point. For assistance fourth observer may be chosen to tell the details of the test vehicle to third observer. After assigning each observer his/her roles test samples were selected at random and the first observer starts the stop watch immediately, as soon as the vehicle crosses the second point the third observer signaled the first observer, stop-watch was stopped immediately and the second observer noted the time taken by the vehicle to cross the base length.

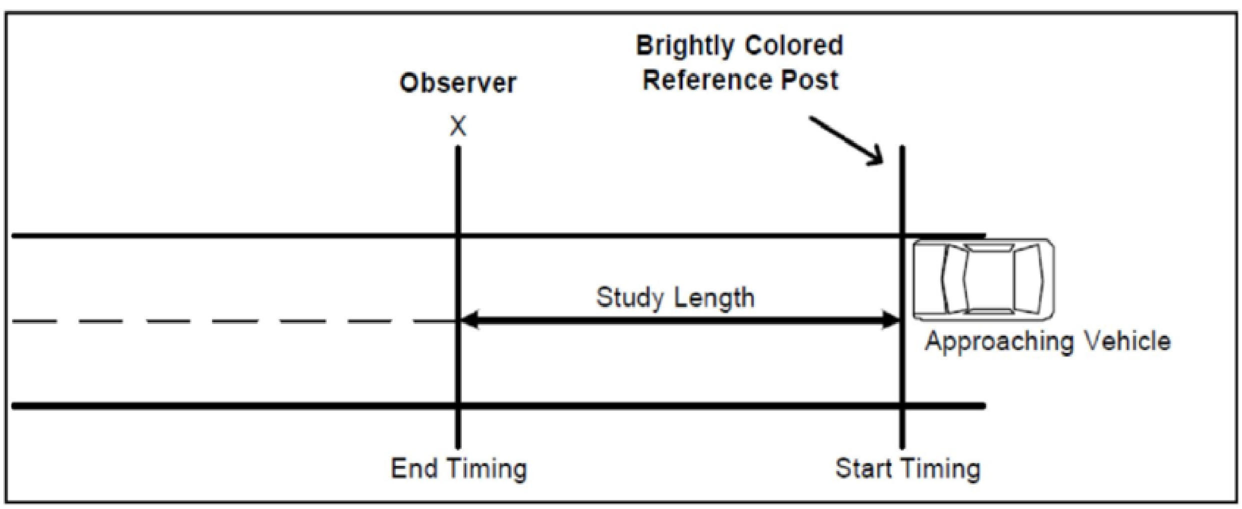

Figure 3.5: Pictorial Representation of Stop-Watch Method

Advantage of this method is that it is very simple and no set up installation is required, moreover reference point markings are easily renewed.

Disadvantage of this method is that large errors are likely to be introduced because of parallax effect.

3.7.4 Data Collection

Direction: Northbound (Ring-Road to College-Chowk)

Date: 27^{th} April, 2017

Time: 1:30-2:30 PM

Vehicle Type: Four-Wheelers

Table 3.6: Spot Speed Observations (Four-Wheelers)

Vehicle No.	Time (sec)	Speed (km/h)	Vehicle No.	Time (sec)	Speed (km/h)
1	7.0	55.70	11	7.3	53.42
2	7.4	52.70	12	7.1	54.93
3	6.9	56.52	13	6.5	60.00
4	6.2	62.90	14	7.9	49.37
5	7.0	55.71	15	7.1	54.93
6	7.5	52.00	16	7.7	50.65
7	5.6	69.64	17	5.6	69.64
8	6.7	58.21	18	6.2	62.90
9	7.7	50.65	19	7.0	55.71
10	7.1	54.93	20	5.4	72.22

Table 3.7: Frequency Distribution Table (Four-Wheelers)

Speed Range (km/h)	Frequency	% Frequency	Cumulative Frequency
27-29.9	2	3.45	3.45
30-32.9	3	5.17	8.62
33-35.9	2	3.45	12.07
36-38.9	8	13.79	25.86
39-41.9	3	5.17	31.03
42-44.9	2	3.45	34.48
45-47.9	4	6.90	41.38
48-50.9	6	10.34	51.72
51-53.9	5	8.62	60.34
54-56.9	6	10.34	70.69
57-59.9	8	13.79	84.48
60-62.9	5	8.62	93.10
63-65.9	1	1.72	94.83
66-68.9	1	1.72	96.55
69-71.9	2	3.45	100.00

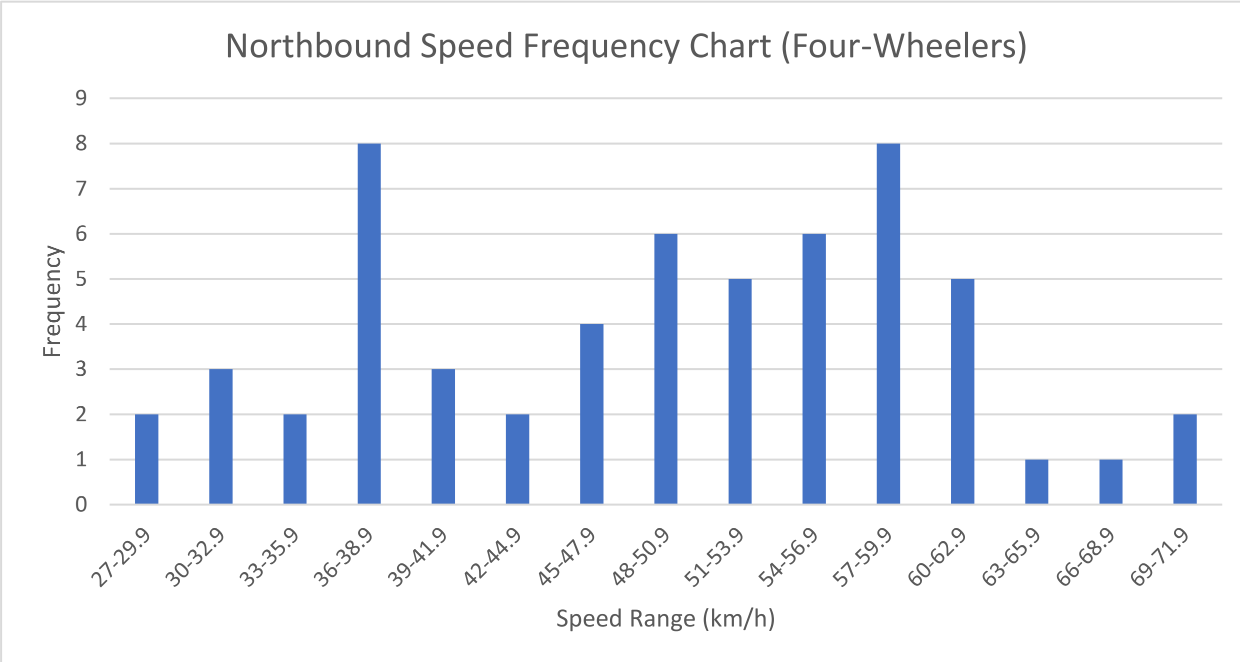

Figure 3.6: Northbound Speed Frequency Chart (Four-Wheelers)

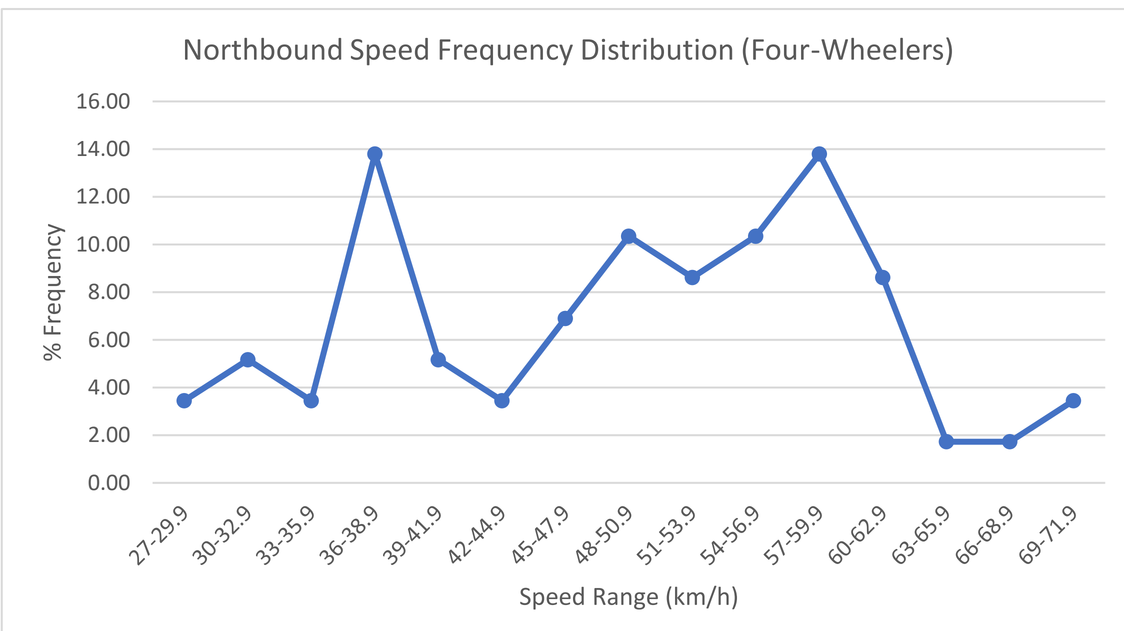

Figure 3.7: Northbound Speed Frequency Distribution

Direction: Northbound (Ring Road to College Chowk)

Date: 2nd March, 2017

Time: 1:30-2:30

Vehicle Type: Two-Wheelers (Bikes)

Table 3.8: Spot Speed Study (Two-Wheelers)

Vehicle No.	Time (sec)	Speed (km/h)	Vehicle No.	Time (sec)	Speed (km/h)
1	11.4	25.58	11	13.1	22.26
2	9.5	30.69	12	10.6	27.51
3	12.4	23.52	13	10.7	27.25
4	7.6	38.37	14	10.8	27
5	5.5	53.02	15	7.5	38.88
6	8.1	36	16	8.3	35.13
7	7.5	38.88	17	10.5	27.77
8	8	36.45	18	7.8	37.38
9	5.3	55.02	19	5.7	51.16
10	12	24.32	20	8.8	33.14

Table 3.9: Frequency Distribution Table (Two-Wheelers)

Speed Range (km/h)	Frequency	% Frequency	Cumulative Frequency
21-23.9	3	7.32	7.32
24-26.9	4	9.76	17.07
27-29.9	6	14.63	31.71
30-32.9	4	9.76	41.46
33-35.9	4	9.76	51.22
36-38.9	9	21.95	73.17
39-41.9	4	9.76	82.93
42-44.9	0	0.00	82.93
45-47.9	1	2.44	85.37
48-50.9	2	4.88	90.24
51-53.9	2	4.88	95.12
54-56.9	2	4.88	100.00

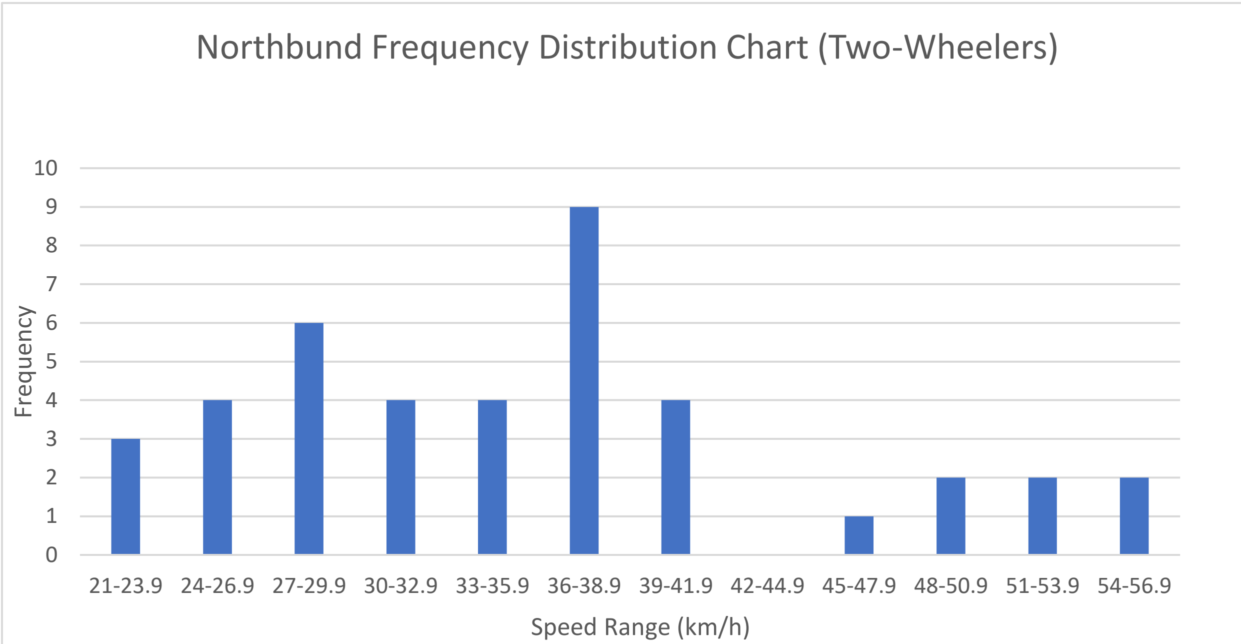

Figure 3.8: Northbound Frequency Distribution Chart (Two Wheelers)

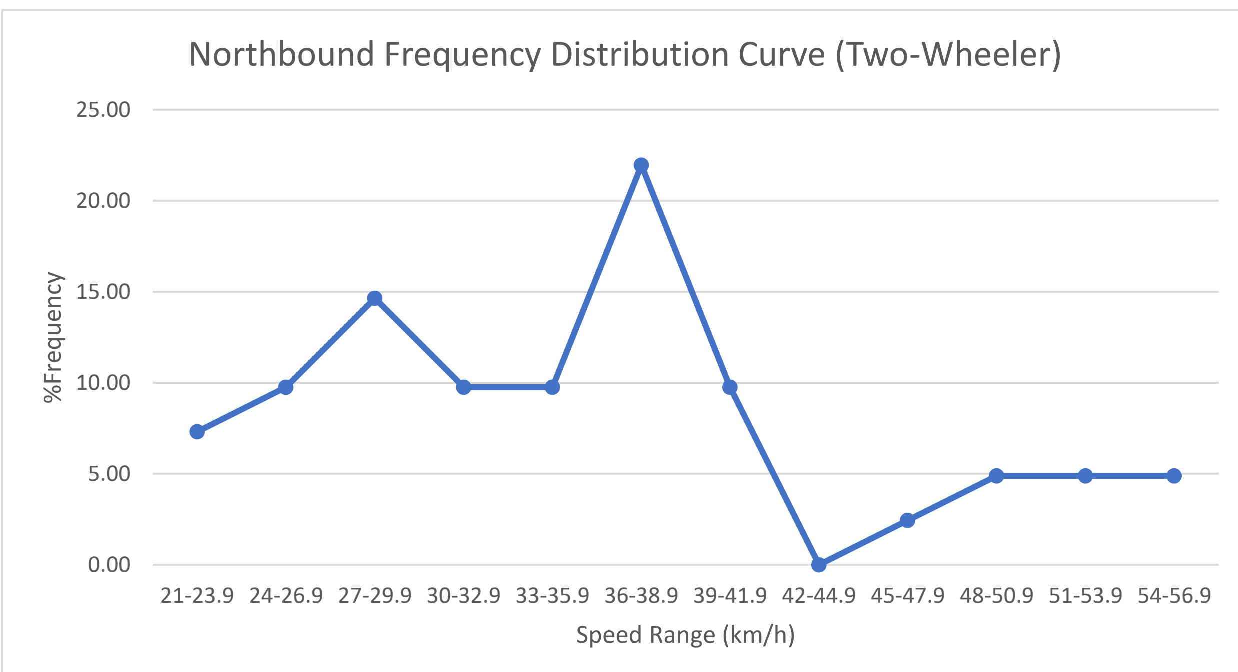

Figure 3.9: Northbound Frequency Distribution Curve (Two Wheelers)

Date: 2nd March, 2017

Time: 1:30-2:30

Direction: Southbound (College Chowk to Ring Road)

Length of Stretch: 81m

Table 3.10: Spot Speed Study (Four-Wheelers)

Vehicle No.	Time (sec)	Speed (km/h)	Vehicle No.	Time (sec)	Speed (km/h)
1	6.7	43.52	11	8.8	33.14
2	7	41.66	12	7	41.66
3	7.3	39.95	13	9	32.40
4	8.6	33.91	14	6.3	46.29
5	6	48.60	15	7.3	39.95
6	9.9	29.45	16	10.2	28.59
7	8.4	34.71	17	5.6	52.07
8	7.2	40.50	18	7.1	41.07
9	8.8	33.14	19	7.6	38.37
10	7.3	39.95	20	5.5	53.02

Table 3.11: Frequency Distribution Table (Four-Wheelers)

Speed Range (km/h)	Frequency	% Frequency	Cumulative Frequency
22-24.9	2	3.57	3.57
25-27.9	0	0.00	3.57
28-30.9	5	8.93	12.50
31-33.9	11	19.64	32.14
34-36.9	6	10.71	42.86
37-39.9	9	16.07	58.93
40-42.9	8	14.29	73.21
43-45.9	7	12.50	85.71
46-48.9	4	7.14	92.86
49-51.9	2	3.57	96.43
52-54.9	2	3.57	100.00

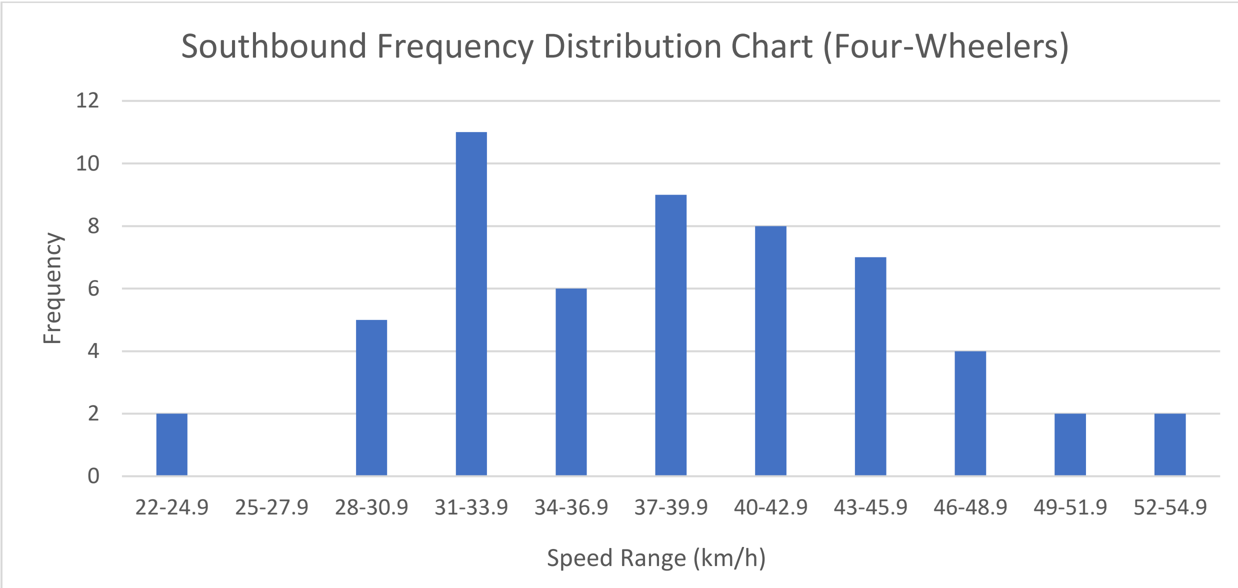

Figure 3.10: Southbound Frequency Distribution Chart (Four-Wheelers)

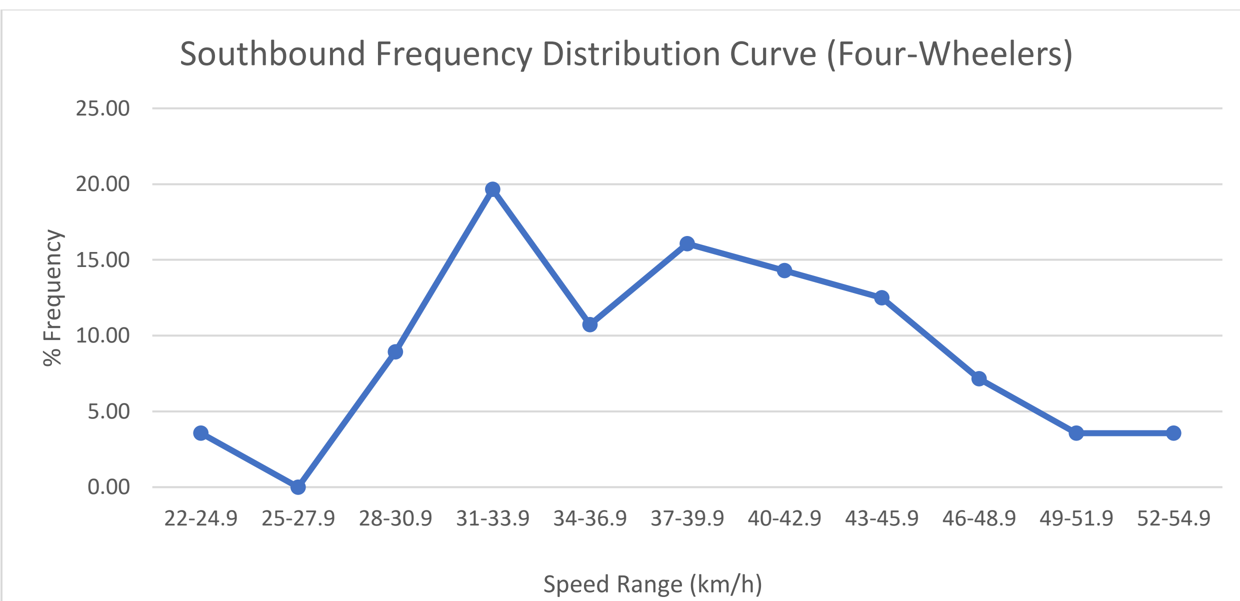

Figure 3.11: Southbound Frequency Distribution Curve (Four-Wheelers)

Date: 2nd March, 2017

Direction: Southbound (College Chowk to Ring Road)

Time: 1:30-2:30 pm

Table 3.12: Spot Speed Study (Two Wheelers)

Vehicle No.	Time (sec)	Speed (km/h)	Vehicle No.	Time (sec)	Speed (km/h)
1	7.1	41.07	11	9.4	31.02
2	9.2	31.70	12	9.7	30.06
3	7.1	41.07	13	9.5	30.69
4	8.3	35.13	14	10.2	28.59
5	9	32.4	15	11.9	24.5
6	9.8	29.76	16	10.8	27
7	11.2	26.04	17	7.9	36.91
8	14.1	20.68	18	7.7	37.87
9	11.2	26.04	19	8.4	34.71
10	6.8	42.88	20	9.1	32.04

Table 3.13: Frequency Distribution Table (Two Wheelers)

Speed Range (km/h)	Frequency	% Frequency	Cumulative Frequency
19-21.9	1	2.50	2.50
22-24.9	1	2.50	5.00
25-27.9	10	25.00	30.00
28-30.9	6	15.00	45.00
31-33.9	7	17.50	62.50
34-36.9	5	12.50	75.00
37-39.9	6	15.00	90.00
40-42.9	3	7.50	97.50
43-45.9	0	0.00	97.50
46-48.9	1	2.50	100.00

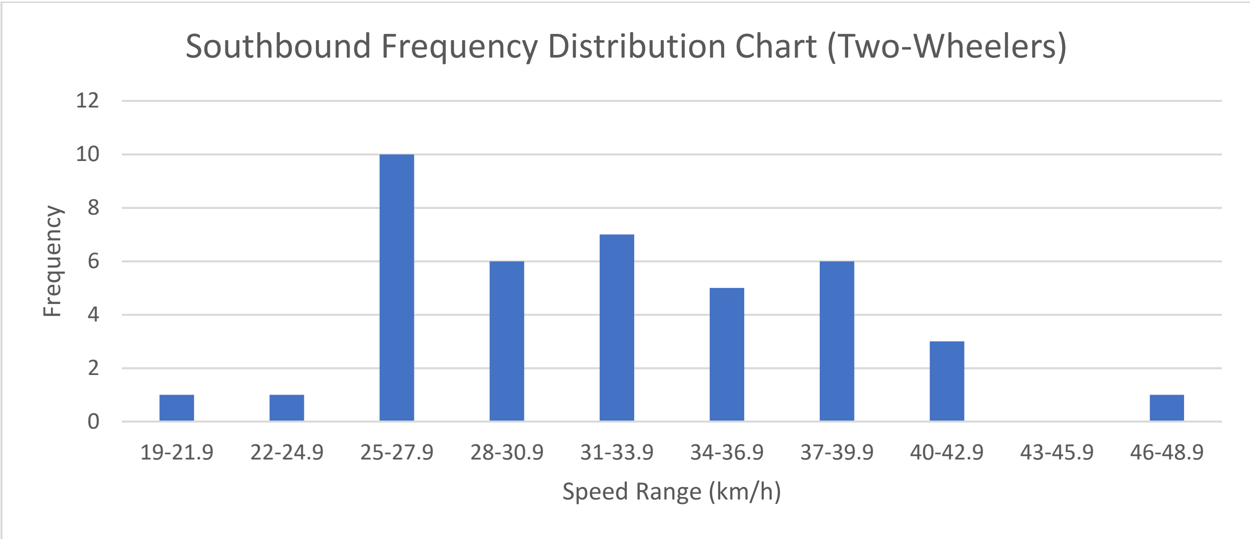

Figure 3.12: Southbound Frequency Distribution Chart (Two-Wheelers)

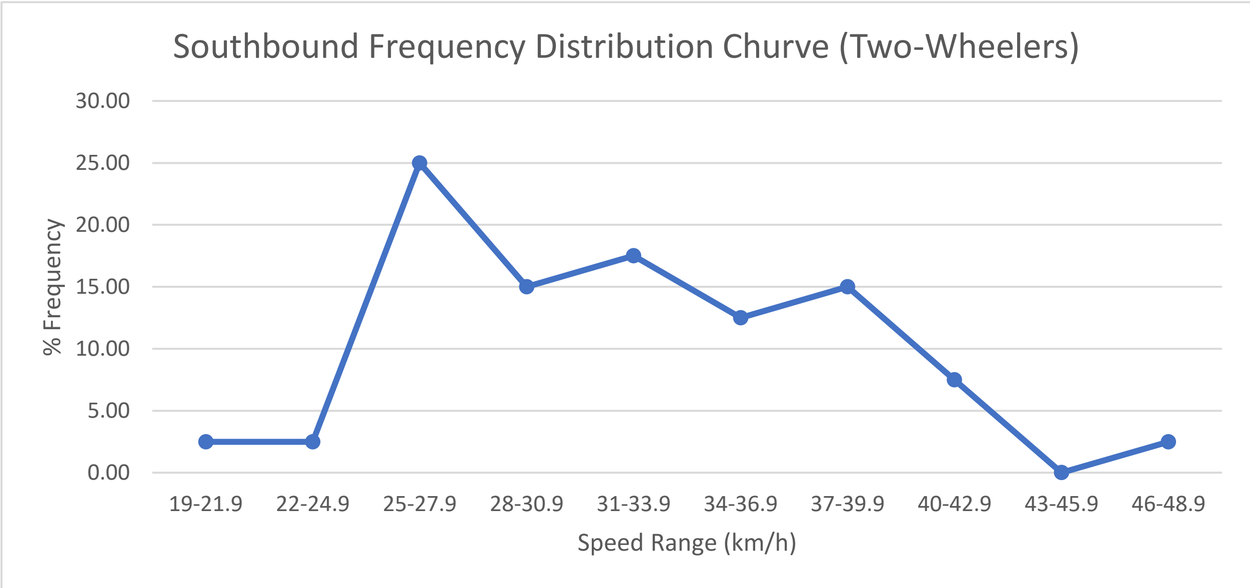

Figure 3.13: Southbound Frequency Distribution Curve (Two-Wheelers)

3.8 TRAVEL TIME COLLECTION

Travel time is broadly defined as "the time necessary to traverse a route between any two points of interest." It is composed of:

1. Running Time: Time in which the vehicle is in motion.
2. Stopped Delay Time: Time in which vehicle is stopped or moving sufficiently slow as to be stopped. (typically, less than 8km/h or 5mph)

Travel time can be directly measured by traversing the route that connects two or more points of interest.

Many travel time analysis techniques have been used in traffic studies.

1. **Test Vehicle Technique:**
    - Manual
    - Distance Measuring Instrument
    - Global Positioning System

2. **License Plate Matching Technique:**
    - Manual
    - Portable Computer
    - Video with Manual Transcription
    - Video with Character Recognition

3.8.1 Manual Test Vehicle Technique

Among all the test vehicle techniques the manual method is the oldest and the most common travel time data collection technique because of its simplicity.

This method requires a driver and a passenger to be in the car. Driver drives the car and passenger uses a pen and paper to note the time as well as the traffic conditions present. Because the driver is also a team member of the data collection team, his driving style can be controlled to match desired driving behavior. Three driving behaviors can be adopted:

1. *Average car* - test vehicle travels according to the driver's judgement of the average speed of the traffic stream.
2. *Floating car* - driver "floats" with the traffic by attempting to safely pass as many vehicles as pass the test vehicle.

3. *Maximum car* - test vehicle is driven at the posted speed limit unless impeded by actual traffic conditions or safety considerations.

In practice however drivers are likely to adopt a hybrid of floating car and average car because it is impractical to keep track of the number of cars overtaken or passed by.

Although a passenger can also use audio tape recorder to record the findings but pen and paper technique is more common.

Chapter 4

ANALYSIS AND RESULTS

4.1 INTRODUCTION

Ptv Vissim is a traffic simulation software created by PTV Planning transport Verkher A.G, A German based company. It is a very useful analysis tool that is being used for effective traffic planning all around the world. It is used to evaluate different alternatives and compare them in view of different aspects such as hourly volumes, travel times, delays, and economics etc. before implementation. The biggest benefit of this software is its multi-modal nature which means that it can be used to analyze different types of traffic such as:

- Motorized private transport (cars, bikes etc.).
- Freight transport (trains, trucks etc.).
- Public Transport (buses, trams etc.).
- Pedestrians.
- Cyclists.

4.2 EVALUATION OF ALTERNATIVES

The main emphasis of our project will be on evaluation of different alternatives and comparison of all along with the existing conditions on the basis of economics and travel times.

4.2.1 Existing conditions: (Length: 6.3 km)

As stated earlier in Ch-3 the location under consideration of our project is N-45 highway passing through Mardan city. The section under study is 6.3 kilometers long starting from Mardan Industrial Estate till just before Bacha Khan Monument roundabout.

The first phase of our project involved simulation of the existing condition of traffic without addition of any physical intervention. Following steps have been followed to simulate real-world situation:

4.2.1.1 Background image

The first step is to add a background image. This background image will be the aerial image of our section as shown below:

To accomplish this click on Background Image in the Network Objects panel on the left-hand side and add a background image by opening a drop down menu in the Network editor and choosing ‘Add New Background Image’.

4.2.1.2 Links

The second step is to click on links on top of the Network Objects panel then continue to add links according to the road geometrics on our background image.

If a horizontal curve exists then it can be formed by joining two links by means of a connector (adding number of spline points according to the shape of the curve) and for vertical curves split the link at the points of rise and fall of the curve increase the elevations of these points accordingly.

The section under consideration has many horizontal curves which have been drawn using connectors while in the existing condition there are no vertical curves or grade separations.

4.2.1.3 Vehicle Routing

The next step is to add the vehicle routes according to the routes being followed by vehicles in the existing condition. For this purpose choose Vehicle Routes from the Network objects and continue to add the routes by adding the start and the possible end points of each vehicle route in our road section.

4.2.1.4 Vehicle Inputs

After all the links have been drawn and the vehicle routes have been provided, the next step is to provide the vehicular inputs.

For this purpose select traffic from the Menu bar on top from there choose Vehicle Compositions, as a result a new window will open below the network editor where we have added our relative vehicle flow, on the basis of the composition of our traffic mix, under two categories i.e. Main roads and societies. In main roads we have divided the traffic composition into cars, buses, HGVs and bikes having relative flows as 0.610, 0.02, 0.05 and 0.32 respectively while in Societies we have cars, buses and bikes only with relative flows 0.620, 0.040, 0.34 respectively.

4.2.1.5 Conflict Areas

There are many sections on a road where conflicts may arise between vehicles directed to different directions or between turning vehicles and through traffic which may lead to congestion if priorities aren't set i.e. whether 1 will have priority over 2 or vice versa where 1 will be traffic moving in one direction and 2 in the other direction, the traffic in the other direction will have to wait for the one which has priority.

4.2.1.6 Signal Heads

Next step is to add signals where they exist and for that choose Signal Control from menu bar, from there select signal controllers, a window will open at the bottom of the network editor, add a new signal controller by clicking on edit signal control from the pop-up window, add new signal groups and assign stages after which define a sequence for the stages and provide the cycle time and the distribution for red, green and yellow.

4.2.1.7 Simulation

After all the geometrics, routes, inputs, signals have been created the next step is simulation. Simulation is used as a representation of the real-time situation and is used to evaluate the existing and the proposed conditions. To run the simulation just click on the play symbol  from the toolbar and to stop it click on the stop simulation button .

4.2.1.8 Data Output

The final step is data output which is used to obtain the results of the evaluation process carried out. Depending upon the quantity on which evaluation of the section under consideration is based, the following quantities may be used as basis of evaluation:

- Network performance results.
- Vehicles in network.
- Data collection results.
- Delay results.

- Link results.
- Node results.
- OD pair results
- Queue results.
- Vehicle and pedestrian travel time results.
- Meso lane results.
- Meso edge results.
- Pedestrians in network.
- Area results.
- Area measurement results.
- Ramp results.

Since, the quantity under consideration here is Vehicle Travel Time so after selection of the Data Collection start points and configuration click on the results tab in evaluation from where select Vehicle travel times and run simulation to obtain results. 11.5 minutes

4.2.2 After Intervention

Before discussing the proposed interventions it should be kept in mind that all the modification is to be done to the existing Vissim file which shows the current real-time traffic and road characteristics and as such the steps followed for addition of any intervention shall be the same as explained above from creation of links to simulation and evaluation of results. Thus, only the proposed interventions have been explained below along with the respective effects caused by them to the travel time results and their relative economics.

4.2.2.1 Infrastructure Intervention – 1

4.2.2.1.1 Reduction in Number of U-turns

In the first intervention scenario we have reduced the number of U-turns from 26 in the existing state to 7 in the proposed scenario which has led to reduction in travel time due to less delays caused by turning vehicles.

4.2.2.1.2 Uniform lane addition on both sides

Another intervention introduced in this scenario is addition of a lane on both sides of the road this has also led to sufficient reduction in travel times due to availability of additional space to the vehicular volume recorded.

4.2.2.1.3 Exclusive Turning lanes

Exclusive left turning lanes have been provided at Turu road, Double road, Bypass chowk in order to prevent congestion created by turning vehicles from any other lane which may have caused conflict between through and turning vehicles. This has also reduced the delay caused by these turning vehicles and as such has reduced the overall travel time.

4.2.2.1.4 Data Output (Travel time)

Travel Time = 9.6 mins

4.2.2.2 Infrastructure Intervention - 2

In this case we have modified the interventions proposed in option 1 by addition of roundabouts to the pre-defined reduced number of U-turns, additional lanes and exclusive turning lanes which has been explained below.

4.2.2.2.1 Addition of Roundabouts

We have proposed the addition of 3 roundabouts with exclusive turning lanes at Turu road, Double road and Bypass chowk respectively which has significantly reduced the total travel time to traverse the section under consideration.

4.2.2.2.2 Data output (Travel time)

Travel Time = 7.8 mins

4.2.2.3 Infrastructure Intervention - 3

In addition to the already proposed reduction in number of U-turns, addition of lanes and roundabouts with exclusive turning lanes, in this case we have proposed the addition of one Diamond Interchange which has been explained below:

4.2.2.3.1 Addition of Diamond Interchange

In this case we have proposed addition of a diamond interchange at Ring road interchange. This diamond interchange will also be grade separated having a fly-over for westbound traffic. After evaluation it is clear that there is sufficient reduction in travel time.

4.2.2.3.2 Data output (Travel time)

Travel Time= 6.9 mins

4.2.2.4 Infrastructure Intervention - 4

This is the final proposed physical intervention in addition to all the previous 3 options we have proposed an additional under-pass as explained:

4.2.2.4.1 Addition of Under-pass

This is a grade separated physical intervention provided for the Canal road through traffic at the Canal road intersection**.** After evaluation a reduction in travel time is evident.

4.2.2.4.2 Data Output (Travel time)

Travel Time= 5.62 mins

4.3 COST CALCULATIONS

4.3.1 Travel Time Cost

4.3.1.1 Factors from AASHTO Manual

- Cars= 4.91.
- Bikes= 2.28.
- Heavy Traffic (Buses + Trucks)= 3.38

Table 4.1: Travel Time Costs

Vehicles	Travel Time Cost (Million PKR)				
	Existing	**Intervention-1**	**Intervention-2**	**Intervention-3**	**Intervention-4**
Cars	1.07	0.89	0.73	0.64	0.52
Bikes	0.26	0.22	0.18	0.16	0.13
Heavy Traffic	0.085	0.07	0.058	0.05	0.04

4.3.2 Vehicle Operating Cost

4.3.2.1 Factors for fuel cost

- Cars= 8.46 Rs/min.
- Bikes= 2.12 Rs/min.
- Heavy Traffic= 76.16 Rs/min.

Table 4.2: Vehicle Operating Costs

Vehicles	Vehicle Operating Cost (Million PKR)				
	Existing	**Intervention-1**	**Intervention-2**	**Intervention-3**	**Intervention-4**
Cars	1.8	1.5	1.2	1.1	0.9
Bikes	0.24	0.2	0.16	0.14	0.12
Heavy Traffic	1.9	1.6	1.3	1.1	0.94

4.4 ECONOMIC EFFICIENCY ANALYSIS

4.4.1 Overview

Economic Efficiency analysis is the cost analysis of proposed conditions so as to define the best possible condition based on factors such as construction, maintenance, rehabilitation costs of the interventions under study in comparison with travel time cost savings and vehicular operating cost savings (obtained as difference of costs between the existing and proposed conditions).

To perform Economic Analysis the following conditions have been selected:

- Study Period= 20 years (2017-2037).
- Equivalent Uniform Annual Return.
- Interest Rate= 4%.

As stated above we have taken a study period of 20 years which means that the vehicular volumes will continue to increase as a result of which the travel time will also increase causing a decrease in overall travel time reduction. For simplicity we have assumed that the values of vehicular volumes and travel time reduction will remain constant since along with these changes the cost per minute of travel time will also increase meaning that the overall cost of travel time will remain constant.

4.4.2 Cash Flows

The methodology undertaken for economic efficiency analysis of our proposed interventions is Cash Flow Analysis by which we have compared costs and benefits of every intervention separately. The costs include construction costs, maintenance costs and rehabilitation costs which have been obtained by expert opinion and are as follows:

- **Lane Addition**: PKR 50 million per Lane-Km (NHA).
- **Lane addition Routine maintenance**: PKR 1 million per Lane-Km Annually
- **Lane Addition Major Rehabilitation**: PKR 40 million per Lane-Km (Once After 10 years).
- **Filling of U-Turn**: PKR 0.5 million per U-Turn.
- **Channelization**: PKR 10 million per Location.
- **Channelization Routine maintenance**: PKR 0.5 million per Location Annually.
- **Roundabout Construction**: PKR 50 million per Roundabout.
- **Roundabout Routine maintenance**: PKR 0.5 million per Roundabout Annually.
- **Remodeling of Interchange**: PKR 500 million.
- **Remodeling of Interchange Routine maintenance**: PKR 0.5 million per Location Annually.
- **Grade Separation**: PKR 1500 million per Location.
- **Grade separation Routine maintenance**: PKR 2 million per Location Annually.
- **Grade Separation Major Rehabilitation**: PKR 20 million per Lane (Once After 10 years).

The benefits include travel time cost savings and vehicular operating cost savings obtained by comparison between the existing and the proposed conditions.

The sums of all the costs and all the benefits have been shown as annual costs.

4.4.3 Annual Economic Benefits

After Cash flow analysis the difference of costs and benefits expressed as annual benefits of all the proposed interventions have been compared and are shown as under:

Details	Intervention-1	Intervention-2	Intervention-3	Intervention-4
Initial (Construction) Cost (Million)	539.5	689.5	1189.5	2689.5
Operation & Maintenance Cost (Million)	39.82	41.32	42.32	51.02
Total Annual Cost (Million)	106.34	126.34	188.5	380.2
Travel Time Benefits (Million)	85.52	166.57	207.1	264.72
Fuel Consumption Benefits (Million)	242	471	585.7	748.6
Net Annual Benefit(Million)	221.2	511.23	604.3	633.12

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

Our project was to analyze a segment of 6.3 km patch of N-45 between Ring Road and College Road, Mardan with the purpose of reducing the travel time by providing different physical infrastructure interventions at the lowest possible cost and the highest net annual benefits. The first step was to evaluate the site and identify the reasons due to which congestion occurs because congestion leads to increase in travel time. The second step was to determine the peak hour. This was done by visiting the site in four consecutive weeks. The traffic volume in the peak hour was then determined. After the data was recorded, it was inserted in Vissim to simulate the existing conditions to determine the delay and the travel time. Simulating the present conditions in Vissim gave us the travel time. The existing conditions were then simulated again but with different physical interventions, which were:

- **Intervention 1:** Reduction in U-turns, Increasing number of lanes to 3 and giving exclusive left turning lanes.
- **Intervention 2:** Reduction in U-turns, Increasing number of lanes to 3, giving exclusive left turning lanes and replacing signalized intersections with roundabouts.
- **Intervention 3:** Reduction in U-turns, Increasing number of lanes to 3, giving exclusive left turning lanes, replacing signalized intersections with roundabouts and construction of Diamond interchange on Ring road.
- **Intervention 4:** Reduction in U-turns, Increasing number of lanes to 3, giving exclusive left turning lanes, replacing signalized intersections with roundabouts, construction of Diamond interchange on Ring road and grade separation on canal road.

Simulation of all these interventions gave different travel time, shown in previous chapters. The travel times were then used to calculate the travel time cost and the vehicle operating cost by using travel time factors from Aashto.

Next, economic analysis of each intervention was done by taking into view the construction cost, maintenance cost, rehabilitation cost, total annual cost and net annual benefits. For this purpose cash flow diagrams were drawn taking 20 years as the Analysis period, 4% interest rate and calculating the net annual benefit and total annual cost. This was done just for simplicity because 20 years is a large period and it cannot be analyzed as the traffic volume is likely to increase with the increase in population.

All four interventions were then compared based on the travel time and the economic evaluation. The intervention ultimately selected was on the basis of the total travel time reduced and the total net annual benefits.

5.2 CONCLUSION

After a detailed analysis, we selected intervention 4 as the best among other interventions as the travel time reduction is more than any other intervention. The economic efficiency analysis show that its net annual benefits in long term are more than the other interventions.

5.3 RECOMMENDATIONS

Based on economic efficiency analysis, the intervention 4 is recommended for improving traffic progression on N-45.

- Reduction in number of U-Turns i.e. from 26 to 7
- Increasing number of lanes to 3 on both sides
- Giving Exclusive left turning lanes
- Roundabouts instead of signalized intersections
- Diamond interchange on ring road
- Grade separation on canal road

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