# PCU Estimation for Different Vehicle Classes on Highways and Freeways and its variation with traffic parameters

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**NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY ISLAMABAD, PAKISTAN**

**(2022)**

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**Thesis Supervisor: Dr. Kamran Ahmed**

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**Dedicated**

**To**

**My Parents & Siblings**

**Acknowledgments**

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

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## Abstract

Traffic flow is not homogeneous in many parts of the world. There are different vehicle types present in a traffic stream at a time. The traffic stream is usually more heterogenous in developing countries like Pakistan. As the volume and number of vehicle types in a traffic stream increase, their interaction and influence on each other increase. To reduce the complexity of such situations Passenger Car Unit (PCU) is used. This is a commonly used approach to convert this heterogeneous traffic into a homogeneous volume having the same impact. PCU estimation is needed for each of the vehicle types present in a traffic stream to analyze and design the performance of various traffic facilities and to manage the regulation of the traffic stream.

This study attempts to determine the PCU factor for highways and freeways in Pakistan. Four locations are selected for the purpose where MetroCount@5600 is installed to collect speed data along with classified traffic counts. Two of the location selected are median-separated four-lane highways, one a two-lane highway section and another a six-lane freeway section. The methods used include Speed methods (Chandra Method, Modified Chandra Method), Headway method, and Equal Density method (EDM) based on simulation techniques. Roads geometric data and vehicle dimensions are obtained from the field. PTV VISSIM which is a micro-simulation software is used for the calculation of density at different volumes at the DCPs.

The PCU values estimated by different methods give satisfactory results. The value given by speed methods falls close to each other. PCU values estimated by the Equal Density method are more reliable than all the methods. The PCU factors vary with different factors which include speed, volume, traffic composition, and road class. It is recommended to use other methods for PCU calculation and determine its variability with other parameters like LOS, geometric features of roadways, and pavement condition.


**Key words:** PCU, ED Method, HCM 2010, Traffic Volume, Speed, VISSIM.

# CHAPTER 1: INTRODUCTION

## 1.1 Background

Traffic flow is normally not homogeneous. It is usually heterogeneous and the level of heterogeneity varies from case to case. It varies with the road class under consideration. It also varies depending on the general traffic environment. Traffic streams in under-developed and developing countries are relatively more heterogeneous than in developed countries. Due to this non-homogeneous traffic flow, the studies usually become more critical. The commonly used method to convert this heterogeneous traffic into uniform homogeneous traffic is by using Passenger Car Unit (PCU). PCU is defined as "the quantity of interaction between a traffic stream and a particular vehicle type compare to that of a standard passenger car under prevailing traffic and roadway condition" (CSIR – Central Road Research Institute, 2017). PCU estimation is needed for each of the vehicle types present in a traffic stream to analyze and design the performance of various traffic facilities and to manage the regulation of the traffic stream. The use of suitable PCU for different vehicle types will result in accurate quantification of homogeneous traffic volume in varied traffic conditions which holds greater importance in providing the desired level of service. Further, unsuitable adoption of PCU can lead to unpredictable congestion scenarios. Many studies have shown that the PCU is an absolute value for a specific type of vehicle but studies in the recent past showed that it changes significantly with factors such as traffic volume, geometric features of the roadway, and the composition of the traffic stream. Many different methods are used in the literature to determine the PCU factors for different vehicle types. Hence, traffic engineer usually gets confused in determining 'if which method can be more suitable?' Each of the method used in history has its pros and cons. These methods include the Multiple Linear Regression Method, Headway Method, Huber Method, Homogeneous Coefficient Method, Simultaneous Equations Method, Walker’s Method, Speed Based Model, and Simulation Technique.

Data collection for traffic studies is also a big challenge because of the constraints of time, money, and manpower. Currently, many different methods are in use for the collection of data. For traffic count data the methods used include manual traffic count, videography of the project road, Inductive loops, radar detectors, and pneumatic tubes. Pneumatic tubes are placed on the top of road surfaces at locations where traffic counting is required. As vehicles pass over the tube, the resulting compression sends a burst of air to an air switch. The accuracy of these methods varies, and their use depends on many different factors.

## 1.2 Problem Statement

The road transportation system is the oldest and the most accessible mode of transportation across the world. Unlike other modes like railways and airways, this mode of transport is readily available on the doorstep of every household. Like every other developing country, road transport is the core of passenger trips and freight movement. It accounts for ninety percent of passenger traffic and ninety-six percent of freight transport. Current road density in Pakistan is 0.32km/km-sq. The Road network of Pakistan plays a pivotal role in the movement of public goods which is vital for the country's integrity, economic growth, and improving the life standard of the general public. Our country has a network of roads comprising of 259,618 kilometers which include 179,290 km of good quality of roads and 80,328 km of low quality of roads. Like other third-world countries, Pakistan's road infrastructure is not up to international standards and the approach to it is reactive and not proactive. Moreover, there are many flaws in the design and then execution of a road project. One of the main reasons is the nonavailability of accurate data for the design. The primary data required for the design of a road project is the traffic number that will use the facility now and in the future. Different methods are available for traffic count data collection each one with its advantages and drawbacks. One of the methods which are popular in the near past and are evolving with time is the use of the pneumatic tube. The manufacture of the technology clams 99% accuracy of the equipment but the research shows it is up to 90% accurate. Pneumatic tubes are not common in Pakistan and their accuracy is not evaluated for the heterogenous condition of traffic in the country. The traffic count data collected by these means are in raw form and it needs to be converted into a uniform unit of traffic. The unit which is used across the world is Passenger Car Unit (PCU). It is defined as the number of a passenger cars which have the same effect on the traffic stream as a given category of vehicle. The PCU factors vary a lot for different classes of roads and even for a given class of road for different conditions. The PCU is calculated for different roads in Pakistan in the early 90s and they are still used even though the conditions have changed a lot with time.

## 1.3 Scope

The use of pneumatic tubes for traffic count and speed data collection is not very common in parts of the world. The manufacturer of this technology clams about 99% of accuracy while research in foreign countries established its accuracy around 90 percent. The first objective of this research is to establish the accuracy of pneumatic tubes and their calibration for this purpose. Once the data from pneumatic tubes are validated and calibrated, the data will be then used to calculate the Passenger Car Units for freeways and highways across the country and determine their variation with other factors e.g., geometric features, traffic volume, and composition. Different methods will be used for this purpose which include speed methods (Chandra Method & Modified Chandra’s method) and Simulation techniques. PTV VISSIM which is a microsimulation software is used for simulation purposes. The equal Density Method (EDM) will be employed on the output of the PTV VISSIM for the calculation of PCU factors. A total of four Data Collection Points (DCPs) are selected for the purpose.

## 1.4 Research Question

The primary research questions which will be addressed in this research include:

- Calculation of Passenger Car Units for the highways and motorways of Pakistan using classical methods.
- Determining the variation of Passenger Car Unit factors with different parameters.
- The use of micro-simulation software i.e., PTV VISSIM for the calculation of Passenger Car Units for different vehicle classes using an equal density method.
- Comparison of different methods for PCU estimation

## 1.5 Research Methodology

The following flow chart in Figure 1-1 shows the research methodology that will be followed during the research.

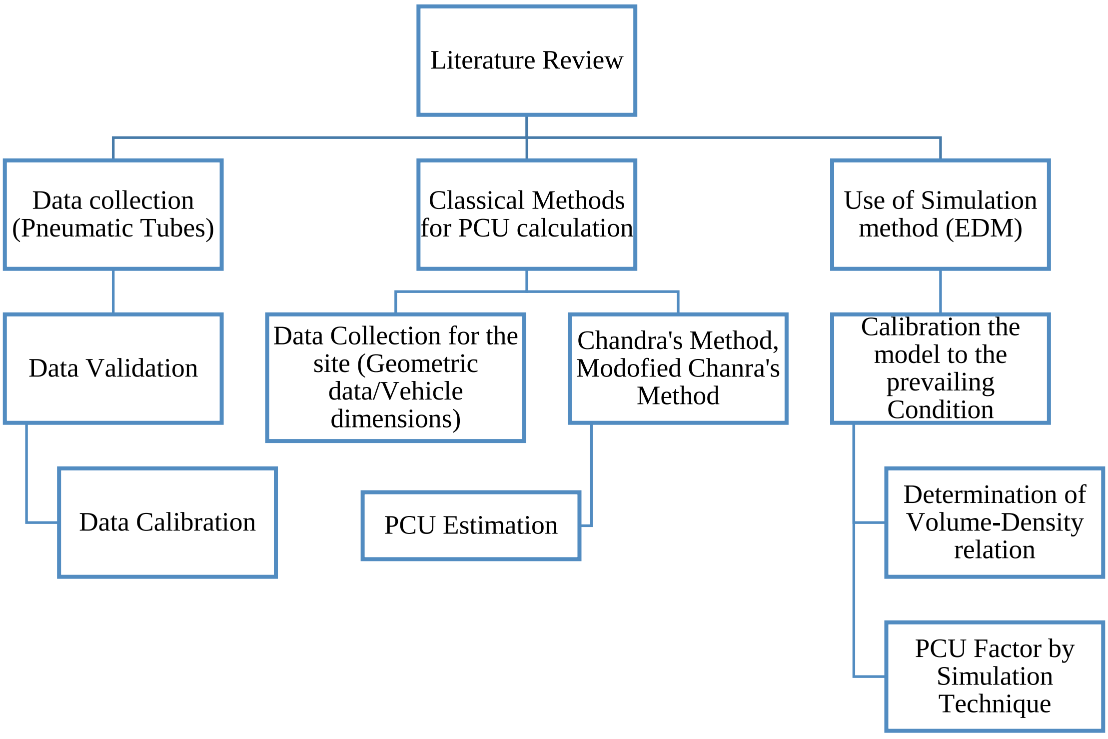



**Figure 1-1:** Research methodology followed

## 1.6 Organization of the Thesis

The thesis includes seven chapters in which chapter 1 provides an introduction followed by the problem statement and objectives of the research. Chapter 2 includes a comprehensive review of the past literature regarding the calculation of Passenger Car Units (PCU). Chapter 3 discusses the data collected for this research work. This includes the geometric data from the site. Vehicle dimensions for different types and speed data for the locations selected. Chapter 4 discuss the methodology followed in the research work. This includes the methodology from the stage of data collection to the point of PCU estimation. The data collected is then analyzed in Chapter 5 for a better understanding and statistical results. Chapter 6 is comprised of the results obtained from different methods used. Chapter 7 gives the conclusions of the work and recommendations for future studies related to it.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 General

The characteristics of road traffic in developing and developed countries are generally different. In most of the developed countries, the traffic stream is homogeneous, where the drivers follow lane discipline and the traffic stream is composed of a few types of vehicles. Distinctly, heterogeneous traffic is composed of an extensive variety of vehicles with varying static and dynamic characteristics, where drivers may not follow lane discipline and traffic rules. Due to these differences in static and dynamic characteristics of homogeneous and heterogenous traffic complications arise in the design and operation of roads. To overcome these issues and to make the traffic stream flow simple to analyze and design, a uniform measure of vehicle called Passenger Car Unit (PCU) or Passenger Car Equivalent (PCE) is introduced. Highway Research board in 1965 define PCU for the first time in the Highway Capacity Manual (HCM) as "the number of passenger cars replaced in the traffic flow stream by a truck or a bus, under the prevailing traffic and roadway condition." After five decades in 2010, the National Research Council of Transportation Research Board Defined Passenger Car Unit as the number of passenger cars which will have the same outcome as a particular single heavy vehicle under prevailing traffic and roadway condition. Transport and Road Research Laboratory (TRRL) in London in 1965 define PCU as on any specific portion of road under prevailing traffic conditions, if the adding of one vehicle of a specific type per hour will decrease the mean speed of the other vehicles by an equal amount as the addition of 'x' number of cars of regular size per hour, then one vehicle of this kind is equivalent to x PCU. Indonesian Directorate of Highways published Indonesian Highway Capacity Manual (I-HCM) in 1997 where PCU is defined as it is a conversion factor for different vehicle types concerning their effect on the capacity as compared to a passenger car. On the other hand, the Indian road Congress (IRC) in 1990 suggested PCU based on traffic composition for each type of vehicle. For different facility types like uncontrolled intersections, signalized intersections and midblock sections different methods have been used for calculation of Passenger Car Units (PCU) for a different levels of heterogenous traffic.

## 2.2 Important Terminologies and Concepts

In this section, some of the significant terminologies and concepts used in this research work have been discussed shortly.

### 2.2.1 Homogeneous Traffic

As the term describes homogeneous traffic is one in which there are very few types of vehicles present and where there is no alternation done to them. It also takes the driver's behavior into account. The drivers in homogeneous traffic flow follow lane discipline and other traffic rules. Homogeneous traffic usually means it includes Passenger Cars (Sedan, Hatchback, and Sport-utility vehicles (SUV)) and Heavy vehicles of some specified dimensions. This type of traffic flow is present in developed countries where there are strict traffic regulation rules along with standards for vehicles on the roads.

### 2.2.2 Heterogeneous Traffic

Contrary to homogeneous traffic flow, in a heterogeneous traffic flow stream, there are many different types of vehicles present with poor lane discipline and violation of traffic rules. Heterogeneous traffic flow is common in developing countries of the sub-continent like India, Bangladesh, and Pakistan. In these developing countries composition of vehicle types, the behavior of drivers, and level of roadside activity is different altogether. The traffic stream in these countries generally consists of a large percentage of motorized two-wheelers (motorcycles) or three-wheelers and other nonmotorized slow-moving vehicles such as animal-driven carts. So, there is a mix of traffic comprising motorized vehicles and manually driven vehicles whose dynamic, static, and operational characteristics differ considerably. Such traffic condition is discussed as 'heterogeneous' or 'mixed' traffic. Vehicle entering and leaving characteristics at uncontrolled urban intersections are complex due to heterogeneous conditions and so they need more care and attention during analysis and design.

Different types of vehicles in heterogeneous traffic conditions do not operate in the same manner. The static and dynamic characteristics of fast-moving motorized vehicles and slow-moving unmotorized differ considerably and can cause turbulence in traffic operations.

### 2.2.3 Size of Vehicles

Usually, different vehicle classes have distant physical dimensions i.e height, length, and width. Heterogeneous traffic may have many motorized vehicles such as bicycles, motorcycles, three-wheeler (auto-rickshaws), cars, mini-buses, buses and trucks and animal-driven carts sharing the same lane. Traffic operations get disturbed by this variability. Smaller vehicles tend to accept narrow gaps between traffic streams to fit in and occupy roadway space unusually.

### 2.2.4 Headway

Headway is defined as the distance between the front bumper of one vehicle to the front bumper of another vehicle following it. Headway can also be defined in terms of time where it can be defined as the time difference between two consecutive vehicles to pass a given point on the roadway. Longitudinal and lateral spacing is a major factor that influence Passenger Car Unit (PCU). Light vehicles such as passenger cars and HiAce usually keep more distance from a heavy truck compared to that of their class because they feel comfortable adjacent to the same type of vehicle. Figure 2-1 illustrates how headway between two vehicles is defined.

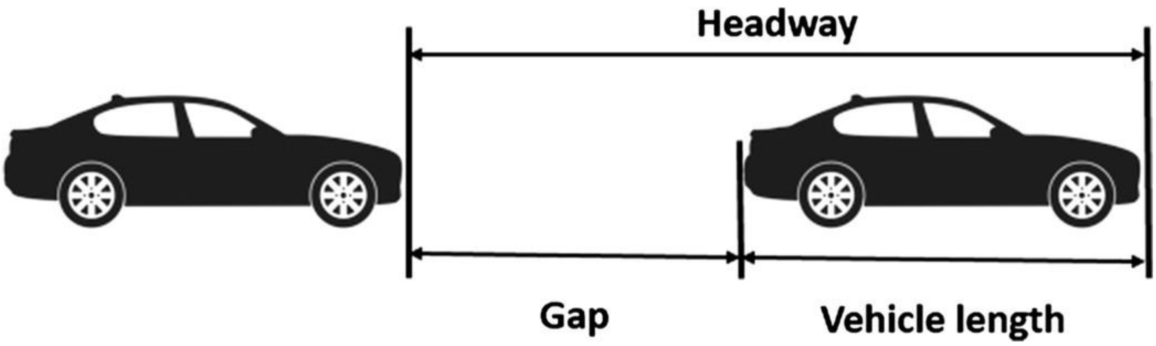



**Figure 2-1:** Headway between two vehicles

### 2.2.5 Lane Discipline

Heterogeneous traffic flow is also defined by poor lane discipline. Lane discipline is not present in heterogeneous traffic not only because the driver behavior is different, but because of the sideways interaction of diverse types of vehicles. Smaller vehicles try to occupy lateral gaps available in between vehicles. Every driver wants to reach the front of the queue which results in the disturbance of the position of the vehicle in high-volume traffic conditions. On the other hand, in homogeneous traffic, there is a slight width difference among vehicles and drivers find it optimal to adopt lane discipline given the narrowness of the width range between vehicles. Figure 2-2 shows lane discipline in homogeneous and heterogeneous traffic flow.

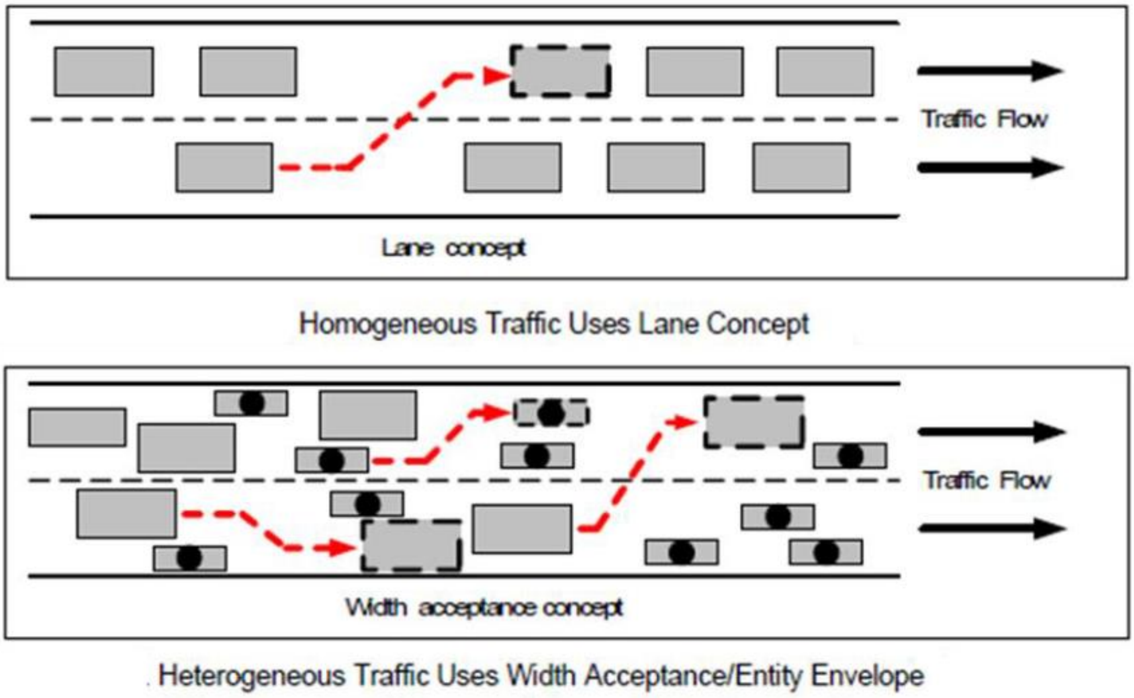



**Figure 2-2:** Lane change behavior in homogeneous and heterogeneous

### 2.2.6 Volume

Volume is defined as the number of vehicles passing a given point on the roadway in a given amount of time. For instance, if one determines the number of vehicles passing a point for 15 minutes of time interval then it can be said that ‘n’ volume of vehicles passes the point in 15 minutes of time interval.

$$Volume = \frac{number\ of\ vehicles\ (n)}{time\ interval\ (t)}$$

Volume do not distinguish what type of vehicles are present in the volume determined. It accounts a motorcycle and a 6-axle truck equal.

### 2.2.7 Density

Density is defined as the number of vehicles present in a particular section of road at a given instant of time. Like volume density all count all types of vehicles as a single unit. Unit of density is vehicle/ kilometer(n/km) or vehicle/lane/kilometer(n/ln/km). It is the reciprocal of headway whose unit is meter/vehicle (m/n) or simply meter(m). Density is equal to the traffic stream flow divided by the mean speed of the traffic stream.

$$Density = \frac{Flow}{mean\ Speed}$$

Keeping the mean speed constant, the density increases with the stream flow to a certain point, and then it starts decreasing and results in jam density at the end.

### 2.2.8 Speed

One of the important traffic flow characteristics is speed. There are two basic methods to measure speed in traffic engineering; Space Mean Speed (SMS) and Time Mean Speed (TMS). Space mean speed (SMS) for a traffic stream is calculated by taking two points on the roadway and determining the time taken by each vehicle to travel between those two points. The distance between the two points is then divided by the means of time taken by vehicles in the stream.

$$SMS = \frac{d}{(\frac{\sum t}{n})}$$

Where,

d= Distance between the two specified points.

n= number of vehicles whose speed is determined.

t= time taken by each vehicle to travel between those two points

Time Means Speed (TMS) is determined by measuring the speed of individual vehicle in traffic stream and then dividing the sum of speeds of all the vehicles by number of vehicles whose speed is determined.

$$TMS = \frac{\Sigma(\frac{d}{ti})}{n}$$

Where,

d= Distance travel by vehicle.

n= number of vehicles whose speed is determined.

t= time taken by the vehicle to cover distance ‘d’.

## 2.3 Synthesis of the Past Research

### 2.3.1 Use of Pneumatic tubes for speed data

O C Puan et al., (2019) studied the use of a traffic counting device based on the pneumatic tube for automatically collecting data under heterogeneous traffic. In the study, MetroCount@5600 is used which is pneumatic tube base equipment and is generally known as automatic traffic count (ATC) in the field. For validation of data collected using MetroCount@5600 video recording technique is used. For the sake of the reliability of the results obtained, the data is collected at four different locations. For each of the sites considered in the study, a video recording camera is installed alongside MetroCount@5600. The traffic data from the video recording is decoded manually using a tally sheet into five different classes. These classes include motorcycles, cars and vans, buses, medium trucks with two or three axles, and a large trucks with three or more axles. The data obtained from MetroCount@5600 is classified into the same five classes of vehicles.

After analysis of the data obtained from these two methods, it is found that there is no significant difference in traffic composition and volume obtained using the two methods. It is found that automatic traffic count (ATC) like MetroCount@5600 can be used in place of a video recording camera for the classified count of traffic. It is noted that there is the chance of higher error if the pneumatic tubes used are soft. This is due to a bumping issue which can result in more than one pulse per pass. In addition, it is found that if the number of maneuvers is higher at a particular point, then there are higher chances of error because the ATC cannot record two or more vehicles passing over it at a time.

### 2.3.2 Methods for estimating Passenger Car Unit

P Raj et al., (2019) reviewed the methods which were used for calculating Passenger Car Units (PCU). In developing countries like India, various methods are in use for the determination of Passenger Car Units (PCU) for different types of road facilities and different vehicle compositions. But the methods are not completely adopted for heterogeneous traffic due to the presence of poor lane discipline, intraclass variability due to alteration of the vehicles, and a wide variety of vehicles in the traffic streams and their maneuverability. Keeping all these factors under consideration different methods are used for the estimation of PCU for different facility types under both homogeneous and heterogeneous traffic conditions and the advantages and disadvantages of each of the method is determined. The common methods discussed include the Multiple Linear Regression Method, Speed modeling, Headway method, Space Occupancy Method, and Simulation Method. For both homogeneous and heterogenous traffic the parameters used are almost always different for each type of facility. Studies carried out where there is homogeneous traffic present need only one factor for the determination of PCU. It is because there is no or very less variation between the behavior of the drivers and there is no abnormality in the traffic stream. On the other hand, many studies on heterogeneous traffic show the use of multiple factors for the determination of PCU. The factor is usually both static and dynamic characteristics. Due to the presence of more intraclass variability, weak lane discipline and a greater number of vehicle types heterogeneous traffic are more complex to analyze. Due to this reason, the parameters required for the estimation of PCU under heterogeneous condition is more complex to measure or determine compare to that of homogeneous traffic.

M Sharma et al., (2019) studied **the** literature of the work done on the estimation of Passenger Car Units (PCU). In his work different methodologies are discussed for the calculation of PCU and determine the advantages and shortcomings of each of the methods. Many researchers worked on the static value of PCU while other take dynamic characteristics into account. This study also examines how the passenger car unit (PCU) varies with different parameters like traffic volume, composition, road geometrics, etc. It is found that PCU factors recommended in the literature vary with the region where it is estimated. Inconsistency is also found in how the PCU factors vary with different parameters in the study. It is also discussed how the PCU factor varies with different parameters in urban areas.

A. Mehar et al., (2014) estimated Passenger Car Units (PCU) for different types of vehicles present on inter-city multilane highways for different Levels of Service (LOS) in India. Micro-simulation software PTV VISSIM is used to generate speed data and traffic flow for conditions that are not possible to obtain in the field. Parameters are first calibrated in PTV VISSIM to obtain heterogeneous traffic behavior of the traffic stream and then speed-volume relation is obtained for Passenger cars and one of the other four categories of vehicles. The percentage of vehicles of the category whose PCU is to be determined is also varied to find out how PCU varies with the percentage of the vehicle under consideration. For each type of vehicle, the process is repeated, and the PCU factor is suggested for these vehicle types at different traffic volumes, and traffic compositions for 4-lane and 6-lane divided highways.

Two points are selected for the research work. Both points are on intercity highways. One of the points is present on a four-lane highway and the other on a six-lane highway. A section of length 100 meters is selected on a straight portion of the road under consideration such that it is not influenced by any intersection or access point. Traffic data is collected for 6 hours in total. A 2-hour traffic count is done in the morning from 9:00 am to 11:00 am, 2 hours from 1:00 pm to 3:00 pm, and 2 hours from 6:00 pm to 8:00 pm using the video recording technique of a clear weekday. The traffic data is classified into five different categories. These include Passenger Car, three-wheeler (3W), motorized two-wheeler, big utility car, and heavy vehicle. The traffic count is done for 5-minute intervals for data collection purposes. The wiedemann-99 model has 10 parameters, ranging from $CC_0$–$CC_9$ to define different driving behavior such as free driving, following, approaching, and breaking. $CC_0$ signifies the stopping distance (m) among the vehicles while minimum time headway(s) is given by $CC_1$ which is the minimum headway the vehicles are desired to maintain at a higher volume level. $CC_0$ and $CC_1$ are the two parameters used in the calculation of mean safety distance among the vehicles for the whole traffic stream.

J Zhou (2019) discussed how Passenger Car Unit (PCU) varies using the Highway capacity manual (HCM-6) and in the field in Nebraska. In the highway capacity manual to accounting for trucks in a traffic stream, PCU factor is used. The equal density method is used for the estimation of the PCU factor in HCM-6. It is found that the HCM-6 PCU values are not suitable to be used in the western U.S because it has a traffic composition where more than 25 percent of vehicles are trucks. It is also assumed in HCM-6 that the desired speed for Passenger Car and trucks in the same on level terrain which it not true because in the western US many heavy trucks are overseen using speed limiters so their speed is expected to be considerably less than the speed limit on the roads. Thirdly, the PCU calculated in HCM-6 is based on a three-lane per direction freeway, while predominantly there are freeways with two-lane in each direction in the western US. This increase in lane number can have a significant effect on the PCU values for the western US. Lastly, the trucks present on the roads of the western US are quite different in dimension compared to those used in simulations for the calculation of PCU values in HCM-6. it was found in the research that PCU values recommended in HCM-6 are not appropriate to be used for traffic studies conducted in western parts of the United States of America (USA). It is because HCM-6 underrate the effects of trucks on four-lane level freeway segment that have different free flow speed distribution, different truck dimensions, and a high percentage of trucks predominately two-lane per direction.

N Webster (1999) used the FRESIM model to calculate PCU value for trucks on freeways. The effect of eight different parameters is part of the study. It includes the number of lanes per direction, percentage of trucks in the traffic stream, traffic flow rate, highway grade, length of grade, the free-flow operating speed of traffic, and percentage of a truck in the traffic stream. The object of the study includes the determination of how the PCU value of trucks is influenced by traffic stream and vehicle characteristics. The secondary objective of the study is to give PCU values for trucks to be used in HCM methodology in design projects. After the data is analyzed, it is found that PCU value increase as traffic flow speed, grade, length of grade, and free flow speed increase. It is also found that PCU value decreases with an increase in truck percentage and number of lanes. The PCU values calculated in the research are compared with those calculated in HCM. It is found that the PCU values obtained are almost the same on the level and slightly steep grade but, are lower for steep grades. It is found that PCU value also varies with the length of grade. It is also noted that in some cases as the percentage of trucks increases the value of PCU decreases. It usually happens on sections where traffic volume is on the higher side.

J Zhou et al., (2018) studied the determination of passenger car units (PCU) on level freeway segments which experience different average speeds and high truck percentages. It is determined that the PCU factors determined in HCM-2010 are not appropriate to be used in traffic studies conducted in western parts of the United States primarily because there is a higher percentage of the truck it the region. It is also assumed that passenger cars and trucks travel at the same free flow speed which is against what is experienced in the field. But, many heavy vehicles in the western United States is equipped with speed limiters to cut fuel cost, and therefore they travel slower than the speed limit.  Higher truck percentage interaction and speed difference can result in moving bottlenecks when trucks move in a group at low speeds. J Zhou develops new PCE values based on the 2010 HCM equal-density approach using calibrated CORSIM and VISSIM simulation models. It is revealed that the PCE factor in the HCM 2016 and HCM 2010 undervalue the effect of heavy trucks on level terrain freeways that experience higher truck percentages, and where vehicles of different type have great differences in average free-flow speeds.

A.Hazoor (2016) estimated Passenger Car Units(PCU) for Capacity Analysis using a simulation technique in Quetta, Pakistan. Simulations on PTV VISSIM are run to generate vehicle speeds and traffic flow under various conditions. In VISSIM a network model is created to depict real field conditions and different VISSIM parameters are adjusted so the model shows real mix traffic conditions. It is further validated with the field data obtained from the data collected. VISSIM can work with different constrains such as vehicle composition, traffic signal, and lane configuration. Car-following model called Wiedemann 74 & Wiedemann 99 developed by Wiedemann is used in

VISSIM. The basic theory behind Wiedemann's models is that driver can be in any of the following four modes: free driving, following, braking and approaching.  In the study, Hazoor used Wiedemann 99 car following model for calibration. The model has ten basic parameters ranging from $CC_0$ to $CC_9$. In this study, Hazoor only $CC_0$ (stopping distance) and $CC_1$ (time headway) was adjusted which can affect individual driving behavior. It is found in the study that PCU value is not absolute and it changes with different factors such as vehicle composition and volume.

M. Adnan et al., (2013) take twelve different points in the metropolitan city of Karachi to determine if the PCU used in Pakistan is correct. Four different methods are used to determine PCU factors. The traffic in the city is heterogeneous and it is found that at almost all locations more than 10 different classes or vehicles are present. The PCU value obtained is then compared with those which are currently in use and with PCU values obtained from different methods. Adnan found that method that includes the use of projected area i.e., the Chandra Method along with the vehicle speed estimate PCU values better than those which uses only one of the static or dynamic characteristic. It is also found that there is a significant different among the values of PCE obtained from different methods. The study suggested PCU value be used in both urban environments and on inter-city highways.

# CHAPTER 3: DATA COLLECTION

Data collection is an important step in any research work. Since the main objective of the research is to calculate Passenger Car Units (PCU) for freeways and highways of Pakistan, the data collected should be such that it is representative and the location should be selected such that vehicles of all types use those sections. The next question is what method should be used for determining the inputs needed for the calculation of the Passenger Car Unit on these sections. The main input required for the calculation of PCU factors includes Speed, Headway, Vehicle dimensions, and Vehicle Class.

The method used for data collection is Automatic Traffic count (ATC) using MetroCount@5600. This has for several years been a popular method of vehicle counting. One or more rubber tubes are stretched across the road and connected at one end to a data logger. The other end of the tube is sealed.

Unlike developed countries, there is heterogeneous traffic present on the highways and freeways of Pakistan. The main reason behind this heterogeneous traffic is locally manufactured vehicles e.g., Rickshaws and Pickups. The vehicles which are imported to the country remain in their shapes for a few years and are then modified by the owner for different reasons mainly for lesser fuel consumption and increased fridge capacity. The Vehicles classes are defined below:

1. Motorcycles
2. Passenger Car
3. HiAce
4. Bus
5. 2-axle Truck
6. 3-axle Truck
7. 4-axle Truck
8. 5-axle Truck

9. 6-axle Truck
10. Others (Animal Driver Cart etc.)

### 3.1 Convenience of MetroCount®5600

The MetroCount@5600 Roadside Unit is controlled via a standard RS-232 serial communication port, using MC Survey for desktop and laptop PCs, or MC SetLite for Pocket PCs. Traffic volume at a site dictates how long it will take to fill your Roadside Unit's memory. Higher flow rates result in shorter logging periods. The Roadside Unit can be installed in a variety of ways, with either one or two sensors. However, the most common approach is to use a Classifier Sensor Layout, which requires two sensors in parallel, approximately one meter apart.

### 3.2 Site Selection for Installation

Resultant data quality from a given site can be affected by a number of site characteristics. Below is a list of points to consider when selecting a survey site. Whilst some situations are unavoidable, it is important to be aware of the side- effects to data quality.

- Select sites where most traffic is traveling at a constant speed across the tubes. If possible, avoid sites where vehicles are accelerating or decelerating due to bends, steep inclines, traffic signals, or intersections.
- Try to avoid sites where vehicles stop over the tubes.
- Ensure that traffic will cross perpendicular to the tubes. Avoid sites where vehicles will turn across the tubes.
- Minimize single-tube hits by avoiding excessive swerving or lane changing.
- Ensure there is a suitable securing point for the Roadside Unit, such as a post or tree.

### 3.3 Calibration of MetroCount®5600

Pneumatic tube Count (MetroCount®5600) works on the principle of sending a pulse to the data logger as a vehicle’s tire passes over it. Pneumatic tube provides a selection of 22 schemes of vehicle classification criteria and none of them is directly applicable to the Pakistani vehicle classification system. To date, there is no validation study of this method for vehicle classification in Pakistan. Figure 3-1 shows the control unit of MetroCount@5600 along with pneumatic tubes.


**Figure 3-1:** Metro Count installed on roadside

Since the heterogeneous traffic in Pakistan is not covered in any of the 22 schemes built-in in the Metro Count 5600 it is decided to make one that can classify the traffic count in accordance with the prevailing traffic in Pakistan. For this purpose, the tubes are installed on the road carriageway according to the specifications and it is monitored for one hour. During this one hour, the Metro Count 5600 is calibrated for different types of vehicles passing the pneumatic tube connected to it. For example, when a HiAce passes the pneumatic tube the variation in plus, spacing in the axle, and number of axles determines the vehicle class and this is done for a number of this class of vehicles. The MetroCount@5600 is calibrated so that if this kind of vehicle passes the tubes it will identify it as a HiAce. For each type of vehicle, this process is carried out and finally, the Metro Count is calibrated for the prevailing traffic on the location where the Classified Traffic count is needed.

### 3.4 Installation of MetroCount@5600

There are different techniques for the installation of these tubes for different lane numbers and directional traffic according to the requirement and ease. For a two-lane road without median separation one MetroCount@5600 unit is installed which provides the Classified traffic Count for each direction of the two-lane road.

For a four-lane road with a median separation, the units are installed for each side of the traffic separately. To count the vehicles separately for each lane the configuration is done in the same way as for a two-lane highway. Here the count provided by a Metro count unit is unidirectional.

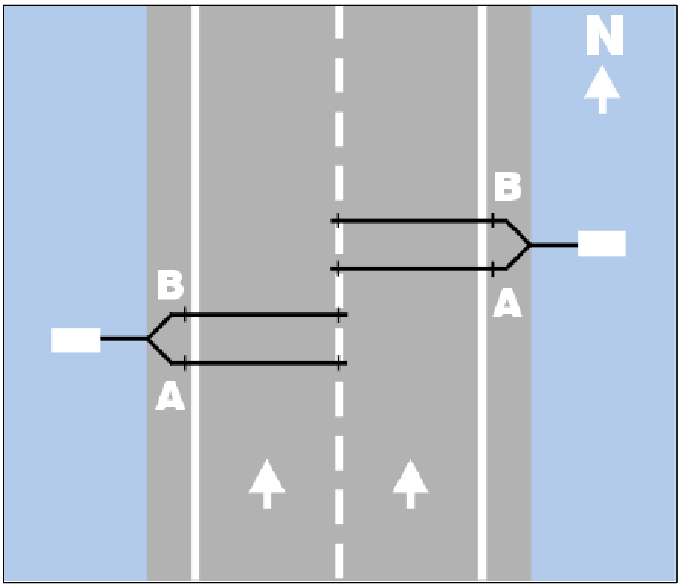



**Figure 3-2:** Prefer Method for traffic count on Median separated Carriageway

For freeways or highways with the number of lanes more than four, classified traffic counts are done for truck lanes separately while for the fast lanes the count is done combinedly.

## 3.5 Data Extraction

The Metro Count Unit is removed after the required number of days. It is then connected to a PC or a laptop to extract the data. The data is extracted using MTE software. The software has the option to export the data into a Microsoft excel spreadsheet. Further, analysis of the data is done in MS excel in this project. There are options in the MTE software to analyze the Traffic Count data collected. Table 3-1 shows the sample output data of MetroCount@5600.

**Table 3-1:**Sample output data of MetroCount@5600

| Day | DATE | TIME | VEHICLE TYPE | SPEED (Km/h) |
|---|---|---|---|---|
| Tuesday | 2/25/2020 | 7:13:01 AM | 2-Axle Truck | 66.18 |
| Tuesday | 2/25/2020 | 7:14:08 AM | 3-Axle Truck | 47.03 |
| Tuesday | 2/25/2020 | 7:14:48 AM | Motorcycle | 37.52 |
| Tuesday | 2/25/2020 | 7:15:25 AM | Car | 82.83 |
| Tuesday | 2/25/2020 | 7:15:49 AM | 4-Axle Truck | 60.33 |
| Tuesday | 2/25/2020 | 7:16:44 AM | 5-Axle Truck | 53.12 |
| Tuesday | 2/25/2020 | 7:16:48 AM | Others | 42.75 |
| Tuesday | 2/25/2020 | 7:16:57 AM | Others | 40.12 |
| Tuesday | 2/25/2020 | 7:17:23 AM | 3-Axle Truck | 41.47 |
| Tuesday | 2/25/2020 | 7:17:45 AM | Motorcycle | 56.69 |
| Tuesday | 2/25/2020 | 7:17:50 AM | 2-Axle Truck | 47.22 |
| Tuesday | 2/25/2020 | 7:17:57 AM | Car | 75.45 |
| Tuesday | 2/25/2020 | 7:18:22 AM | Car | 63.96 |
| Tuesday | 2/25/2020 | 7:18:38 AM | Car | 52.77 |
| Tuesday | 2/25/2020 | 7:19:41 AM | 4-Axle Truck | 45.90 |
| Tuesday | 2/25/2020 | 7:21:12 AM | Car | 45.44 |
| Tuesday | 2/25/2020 | 7:21:19 AM | 2-Axle Truck | 54.18 |
| Tuesday | 2/25/2020 | 7:21:21 AM | Motorcycle | 49.73 |
| Tuesday | 2/25/2020 | 7:21:53 AM | Car | 92.29 |
| Tuesday | 2/25/2020 | 7:22:12 AM | Motorcycle | 54.18 |
| Tuesday | 2/25/2020 | 7:23:25 AM | Motorcycle | 71.70 |
| Tuesday | 2/25/2020 | 7:23:54 AM | Car | 61.12 |

## 3.6 Data Collection Points

The Data collection points are selected in such a way that it is representative of the highways and freeways in Pakistan. These points are selected so that majority of characteristics of different roads of Pakistan are covered in the count. These locations should also be close to Islamabad so that, the equipment can be checked regularly for any interruption in the operations. The batteries of the equipment are checked regularly so that there is no break in the traffic count at the locations. Following are the locations at which the Traffic Count equipment is installed in Punjab and Khyber Pakhtunkhwa.

### 3.6.1 Data Collection Point-01 (N-5 near Mullah Mansoor)

The Data Collection Point 01 (DCP-01) is selected on National Highway-5 (N-5) also known as Grand Trunk Road (G.T Road). The total length of N-5 is approximately 1819 km which starts at Karachi passing thought the plains of Sindh and Punjab and terminating at Torkham at the Pak-Afgan Border. It is the longest of all the roads in the country. N-5 carries 80% of commercial traffic of the country which makes up only 4.6% of the total road network of the country.

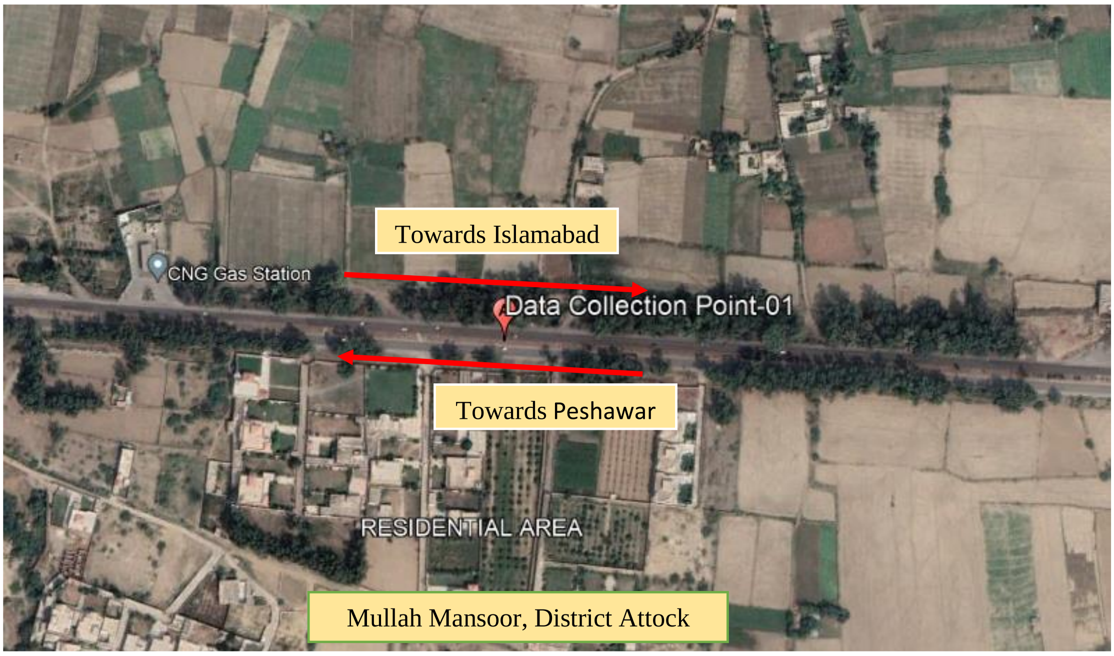



**Figure 3-3:** Data Collection Point-01 on N-5

Figure 3-3 shows the google imagery of DCP-01. The MetroCount@5600 Unit is installed near Mullah Mansoor, Attock on a straight portion of the road. The point falls at latitude 33.890907° and longitude 72.309579° near Total Foji Petrol Pump. Here the total number of lanes is four and there is a 5.5-meter median with a plantation present in the center.

### 3.6.2 Data Collection Point-02 (N-45 near Raskai Interchange of M-1)

Data Collection Point 02 (DCP-02) is selected on National Highway-45 (N-45). The total length of N-45 is approximately 309 km which emerges from N-5 at Nowshera which is a four-lane road. It passes through the plains of District Mardan where it is still a four-lane road. Entering the hilly terrain of Malakand the number of lanes reduced to two. It then crosses into Dir Lower and Dir Upper and finally, it enters District Chitral. Heavy Vehicles are present in high numbers on this road. The MetroCount Unit is installed on N-45 near the Raskai Interchange of M-1. The point falls at latitude 34.085346° and longitude 72.007499° next to FWO Institute of Technical Education.

Here the total number of lanes are four separated by a narrow median. Figure 3-4 shows the google imagery of DCP-02.

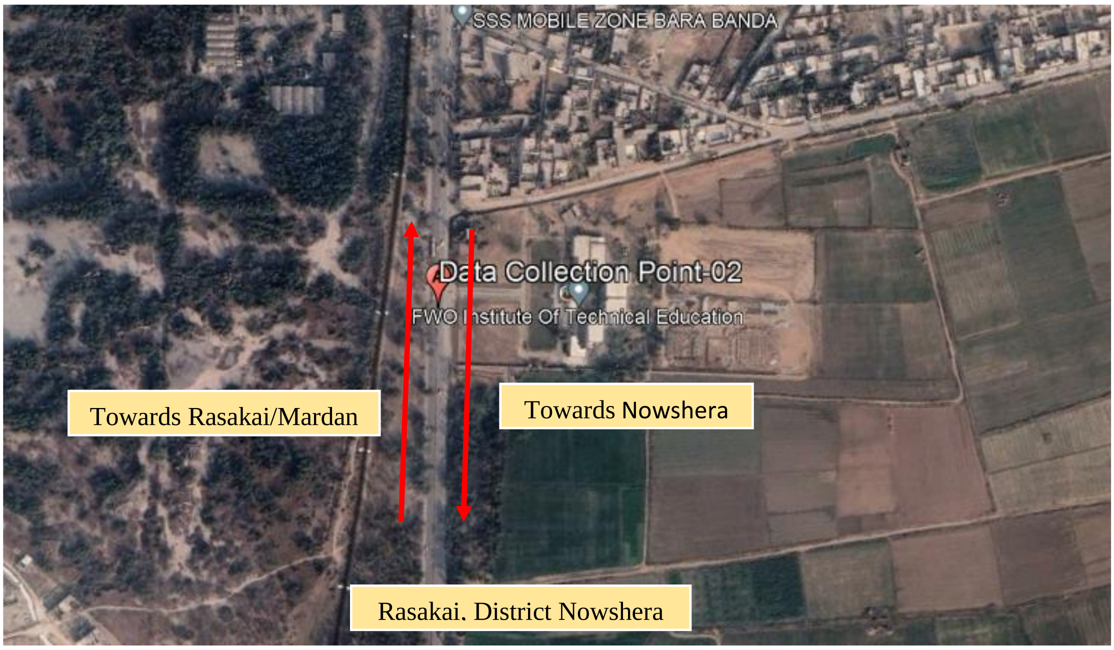



**Figure 3-4:** Data Collection Point-02 on N-45

### 3.6.3 Data Collection Point-03 (M-1 near AWT-Sangjani Paswal Interchange)

Data Collection Point 03 (DCP-03) is selected on Motorway-1 (M-1). The total length of M-1 is approximately 155 km which starts from Islamabad and terminates at Peshawar after passing through District Attock, Swabi, Nowshera, Mardan, and Charsadda. The Motorway was completed for 13 billion rupees and was opened for traffic in 2007. This motorway provides an alternative to N-5 between Islamabad and Peshawar. The majority of vehicles on M-1 are Passenger vehicles while the adequate number of Heavy Vehicles are also present. The MetroCount Unit is installed on M-1 near the AWT-Sangjani Paswal Interchange of M-1. The point fall at latitude 33.648497° and longitude 72.830041°. Here the total number of lanes are six separated by a median of approximately 10 meters. Figure 3-5 shows the google imagery of DCP-03.

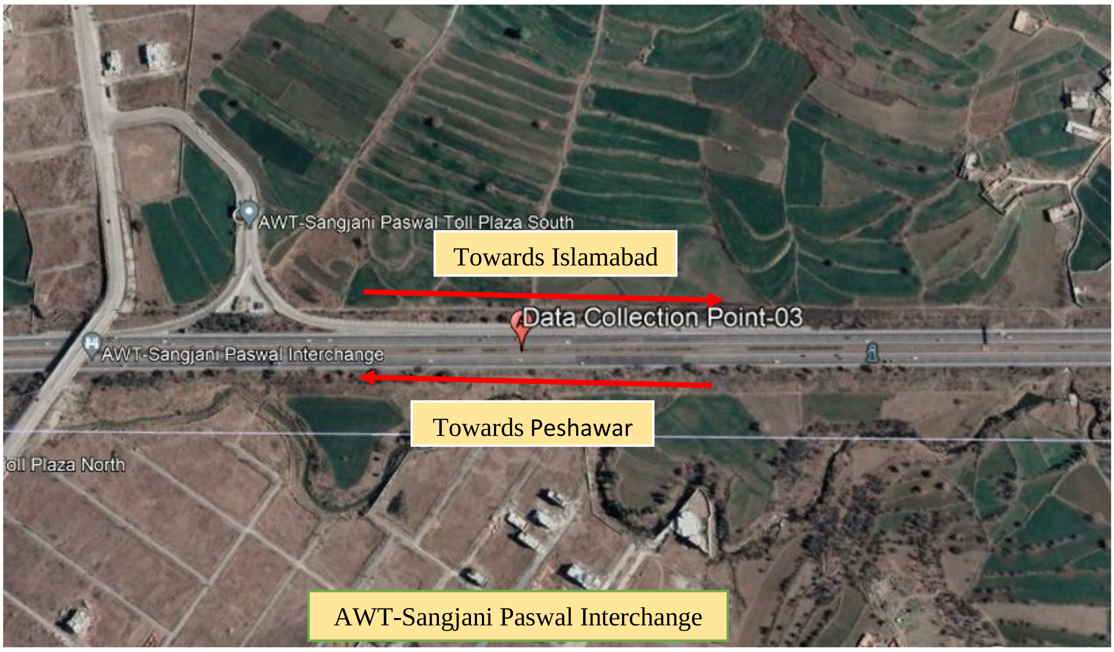



**Figure 3-5:** Data Collection Point-03 on M-1

### 3.6.4 Data Collection Point-04 (N-35 near Jahirkass Interchange)

The Data Collection Point 04 (DCP-04) is selected on National Highway-35 (N-35) also known as Karakoram Highway. Its construction work is started in 1962 and it was opened to the general public in 1978. The total length of N-35 is approximately 1300 km which starts from Hasanabdal and terminates at Xinjiang Uyghur Autonomous Region of the People Republic of China (PRC). The length of the highway which falls in Pakistani territory is 887km whereas 413 km of the road length falls in PRC territory. The MetroCount Unit is installed on N-35 near Jahirkass Interchange. The point falls at latitude 33.908874°and longitude 72.782884°. This is a two-lane two-way highway with carriageway width of 7.3 meters and the width of the shoulder varies from 0.5 to 1.5 meters from place to place. Figure 3-6 shows the google imagery of DCP-04.

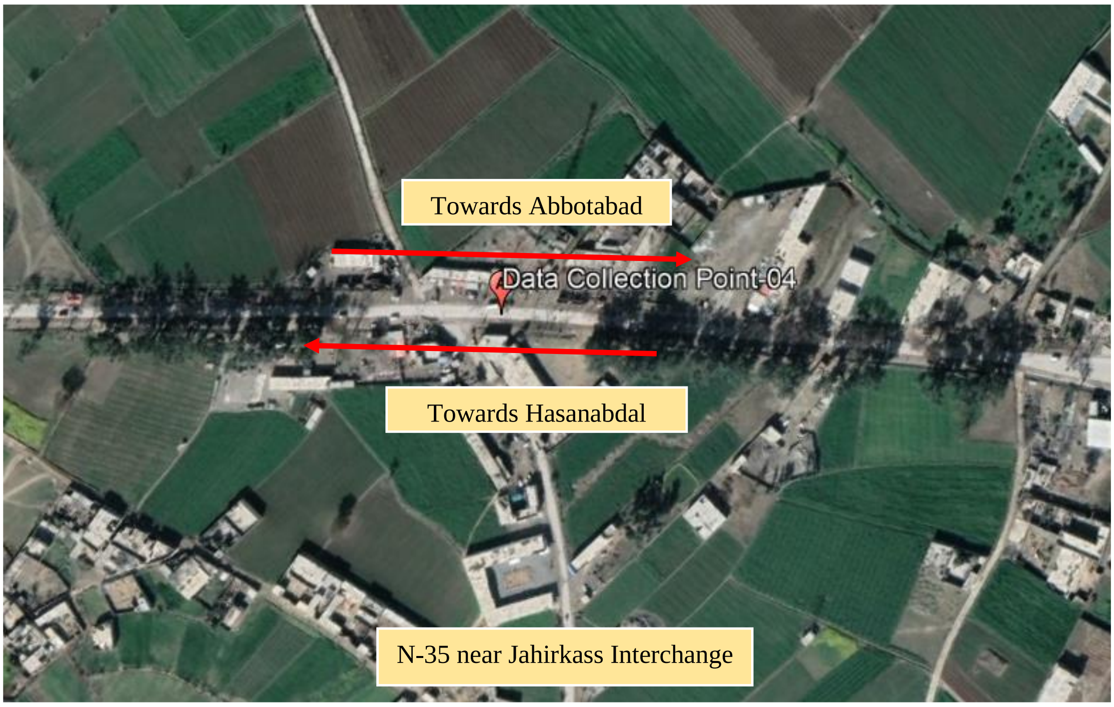



**Figure 3-6:** Data Collection Point-04 on N-35

## 3.7 Roadway Dimensions

The other input required in the analysis to calculate the Passenger Car Unit using PTV VISSIM are the dimensions of the roadway at the point where the data is been collected. This includes the width of each lane and the shoulders (both interior and exterior) and the width of the median where present. It also includes the recording of the general environment of that place and the traffic entering or leaving the road under study.

### 3.7.1 Road Features at Data Collection Point-01 (N-5 near Mullah Mansoor)

There are a total of 4 lanes present in both directions of the carriageway. Each lane of the carriageway has a width of 3.65 meters. The internal shoulders are approximately 0.6 meters on both sides of the median. The median is 5.5 meters wide and the height of the plantation is around 2 m. The outer shoulder is a Triple surface treated with an aggregate base course underneath. The width of the shoulder is 2 meters on both sides.

### 3.7.2 Road Features at Data Collection Point-02 (N-45)

There are a total of 4 lanes present in both directions of the carriageway. Each lane of the carriageway has a width of 3.65 meters. The internal shoulders are approximately 0.3 meters on both sides of the median. The median is 0.6 meters wide and there are small plants present in the median. Earthen shoulders are present on both sides of the carriageway varying from 0.5 to 1.5 m.

### 3.7.3 Road Features at Data Collection Point-03 (M-1)

There are a total of 6 lanes present in both directions of the carriageway. Each lane of the carriageway has a width of 3.65 meters. The internal shoulders are approximately 0.6 meters on both sides of the median. The median is 11 meters wide and plants of enough height are present which prevents the glare effect of vehicles moving in the opposite direction. A shoulder width of about 3 meters is present on both sides of the carriageway.

### 3.7.4 Road Features at Data Collection Point-04 (N-35)

There are a total of 2 lanes present in both directions of the carriageway. Each lane of the carriageway has a width of 3.65 meters. A shoulder width of 1 m is present on both sides of the carriageway.

## 3.8 Vehicle Dimensions

In different parts of the world, there are many different types of vehicle present. It varies not only from country to country and continent to continent but is different in developed, developing, and under-developed worlds as well. The dimensions of vehicles are needed not only in the calculation of the Passenger Car Unit (PCU) by the Chandra method and Modified Chandra method but it is also required to calculate PCU by density method in PTV VISSIM.

In Pakistan, the dimension and weight of heavy vehicles vary a lot from what it is in the outside world. When new or used vehicles are imported into Pakistan, then are used in their original condition for some years and then the dimensions and axle configuration of the vehicles are changed for different purposes. The length and width of the vehicles are increased for the purpose to carry more freight while the axle configuration is changed for the purposed to reduce fuel consumption.

Since the Data collection points (DCP) fall in the near vicinity of the twin cities, Rawalpindi and Islamabad so the dimension of the vehicle should also be determined here for better results. The vehicle dimensions are determined at the Sabzi Mandi of Islamabad present in Sector I-11. The length and width of the vehicles are determined using a measuring tape. The height of vehicles are also determined. To determine the dimensions of Hiace, Mini-bus, and large bus vehicles dimensions are determined at the Mandi Mor Public Transport Stands. The dimensions of the Passenger Car are determined from the website of the manufacturers.

Table 3-2 shows the data of average dimensions of the vehicle at Sabzi Mandi, Islamabad, and Mandi Mor Public transport Stands and data obtained from the website of the Car Manufacturer.

**Table 3-2:** Average dimensions of vehicle from site

| S/No | Class | Average of Length | Average of Width | Average of Area | NHA max Length | NHA max width | NHA Average Height |
|---|---|---|---|---|---|---|---|
| 1 | 2-wheeler | 1.90 | 0.75 | 1.42 | | | |
| 2 | Car | 4.30 | 1.70 | 7.32 | | | |
| 3 | HiAce | 4.69 | 1.75 | 8.18 | | | |
| 4 | Bus | 11.30 | 2.47 | 27.87 | | | |
| 5 | 2-axle | 7.26 | 2.22 | 16.14 | 12.00 | 2.55 | 4.0~4.5 |
| 6 | 3-axle | 10.00 | 2.27 | 22.67 | 12.00 | 2.55 | 4.0~4.5 |
| 7 | 4-axle | 15.50 | 2.40 | 37.20 | 12.00 | 2.55 | 4.0~4.5 |
| 8 | 5-axle | 17.20 | 2.30 | 39.56 | 17.40 | 2.55 | 4.0~4.5 |
| 9 | 6-axle | 17.23 | 2.62 | 45.09 | 17.40 | 2.55 | 4.0~4.5 |
| Note: All the units are in meters or square meters | | | | | | | |

# CHAPTER 4: METHODOLOGY

A research methodology stretches research validity and provides technically and logically sound findings. It also offers a complete plan that helps to keep scholars on track, making the process smooth, manageable, and effective. This chapter presents the research methodology adopted for the research work. This chapter describes the procedure used for the determination of the research area, converging on the research topic, selection of site, and analysis of the data collected. The chapter also explains the different methods used for the calculation of Passenger Car Units (PCU). These Methods include the Chandra method, Modified Chandra method, Headway method, and Equal Density method using PTV VISSIM software.

## 4.1 Defining Research Area

The main objective of this six-credit hour research activity is to work in a direction that can help to find solutions for present and future challenges to our society. Growing traffic on the roads of Pakistan is one of the main issues our country is facing. For the improvement of the current road network system or development of a new system traffic data analysis is a very important part of the design phase of the project. In developing countries like Pakistan where there is heterogenous traffic on road, there is a need for a way to convert this heterogeneous traffic into a uniform homogeneous traffic flow for analysis purposes. This can be done by converting the whole heterogeneous traffic consisting of different types of vehicles into a single type of vehicle. For this purpose, a Passenger car is selected since it is the usually an adequate percentage of the total traffic on the roads. The Passenger Car Unit (PCU) is last calculated for Pakistan by NTRC in the 1990s when there were completely different traffic flow dynamics and there was no freeway in the country. Now after three decades, it is needed to calculate the PCU factor again for different classes of roads and different flow conditions. The topic is discussed with the local development authority and research institutes like NTRC and they express the need for the calculation of Passenger Car Units for Pakistan. The sites for data collection are also discussed with the authorities and they give their approval for the research activities.

### 4.2 Data Preparation

The data which is collected for one week at Data collection points (DCP) shown in Chapter 3, is in raw form and it needs preparation and removing of outliers. The data also need to remove the overlapping of vehicles with the same timestamp. Due to some unknown reasons, there were some extended gaps in the data. These gaps are removed so that it does not affect the analysis of the data. Once the data is organized for each lane separately, the headway is found for each of the vehicles. Headway is a difference in time which one vehicle has from another while passing a point. So, it is found by subtracting the time stamp of the vehicle ahead from the vehicle whose headway is in question.

**Table 4-1:** Sample of Headway Calculation

| C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|
| **Day No.** | **Day** | **DATE** | **TIME** | **VEHICLE TYPE** | **SPEED** | **Head way** |
| 6 | Friday | 11/29/2019 | 12:00:50 AM | Others | 48.36 | |
| 6 | Friday | 11/29/2019 | 12:00:54 AM | Others | 46.60 | 4.00 |
| 6 | Friday | 11/29/2019 | 12:01:14 AM | Bus | 34.45 | 20.00 |
| 6 | Friday | 11/29/2019 | 12:01:14 AM | Bus | 34.45 | 0.00 |
| 6 | Friday | 11/29/2019 | 12:01:21 AM | 2-Axle Truck | 40.67 | 7.00 |
| 6 | Friday | 11/29/2019 | 12:01:59 AM | 4-Axle Truck | 39.05 | 38.00 |
| 6 | Friday | 11/29/2019 | 12:02:38 AM | Motorcycle | 39.89 | 39.00 |
| 6 | Friday | 11/29/2019 | 12:02:38 AM | Motorcycle | 39.89 | 0.00 |
| 6 | Friday | 11/29/2019 | 12:03:40 AM | 2-Axle Truck | 48.28 | 62.00 |
| 6 | Friday | 11/29/2019 | 12:04:16 AM | 2-Axle Truck | 44.09 | 36.00 |
| 6 | Friday | 11/29/2019 | 12:04:16 AM | 2-Axle Truck | 44.09 | 0.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | Friday | 11/29/2019 | 12:05:11 AM | Motorcycle | 44.09 | 55.00 |
| 6 | Friday | 11/29/2019 | 12:05:11 AM | Motorcycle | 44.09 | 0.00 |
| 6 | Friday | 11/29/2019 | 12:06:27 AM | 3-Axle Truck | 35.45 | 76.00 |

The headway in column 7 of Table 4-1 is calculated by subtracting the time of the preceding vehicle from the vehicle whose headway is calculated.

### 4.3 Procedure of Chandra Method

The PCU of a given vehicle category can be stated as the amount of interaction of that vehicle type to the traffic stream as compared to a Passenger Car. This interaction varies with both the volume & proportion composition of the traffic stream. It varies with the length and width of the vehicle's weight-to-horsepower ratio of the vehicle. Their interactions are reflected in the speed of a vehicle type therefore speed is considered as one of the basic parameters for the estimation of PCU factors.

It is clear that if the speed of a vehicle is higher it will result in a lesser interruption to the traffic stream as compared to the vehicle which is moving with a crawling speed which results in a ripple effect and the traffic flow is affected by it. Other dynamic characteristics include acceleration and braking characteristics. On the other hand, there are static characteristics that are mostly related to the physique of the vehicle under study. It includes the length, height, width, number of axles, and configuration of axles. Both of the characteristics have an eminent effect on the overall vehicle behavior in a traffic stream. The equation below is used to calculate Passenger Car Units for a given type of vehicle.

$$\mathrm{PCUi} = \left(\frac{\mathrm{Vc}}{\mathrm{Vi}}\right) / \left(\frac{\mathrm{Ac}}{\mathrm{Ai}}\right)$$

Where,

Vc = Speed of passenger car (km/h).

Vi = Speed of vehicle type i (km/h).

Ac = Projected rectangular area of car ($m^2$).

Ai = Projected rectangular area of vehicle type i on the road ($m^2$).

For instance, we have to find the PCU for “Vehicle A” whose area is 10 $m^2$ moving at a speed of 50 km/h and the average area of a Passenger Car in the traffic stream is 5 $m^2$ traveling at an average speed of 75 km/h. So, the speed ratio is 1.5, and the area ratio is 0.5. The PCU for “Vehicle A” comes out to be 1.5/0.5=3.

## 4.4 Using Modified Chandra Method for Calculation of PCU factors

The factors considered in this method are mean speed, mean time headway, and mean rectangular projected area of vehicle types. This method estimates the PCU value of subject vehicle types by taking the product of speed factor, headway factor, and area factor. The factors calculation and development of the PCU equation are discussed in detail in the following paragraphs.

### 4.4.1 Speed factor (Fv)

The speed factor is a ratio of the mean speed of a standard car (Vc) to the mean speed of the subject vehicle type (Vi).

$$Fv = \frac{Vc}{Vi}$$

where:

Fv = speed factor of subject vehicle type,

Vc = mean speed of standard car,

Vi = mean speed of subject vehicle type.

### 4.4.2 Headway factor (Ft)

The headway factor based on the mean time headway of different vehicle types is calculated by dividing the mean lower time headway of the subject vehicle type (Ti) by the mean lower time headway of the standard car (Tc).

$$Ft = \frac{Ti}{Tc}$$

where:

Ft = Headway factor of subject vehicle type,

Tc = mean lower time headway of standard car,

Ti = mean lower time headway of subject vehicle type.

### 4.4.3 Area factor (Fa)

PCU of a vehicle type depends on vehicular dimensions. PCU is inversely proportional to the area of the vehicle. The area factor is the ratio of the rectangular projected area of the standard car (Ac) to the area of the subject vehicle type (Ai).

$$Fa = \frac{Ai}{Ac}$$

Fa = Headway factor of subject vehicle type.

Ac = rectangular projected area of a standard car.

Ai = rectangular projected area of subject vehicle type.

### 4.4.4 PCU of subject vehicle type

PCU value of the subject vehicle is calculated by the product of the speed factor, headway factor, and area factor of the corresponding subject vehicle.

$$PCUi = Fv * Ft * Fa$$

where:

PCUi = PCU value of subject vehicle type,

Fv = Speed factor of subject vehicle type,

Ft = Headway factor of subject vehicle type,

Fa = Area factor of subject vehicle type.

### 4.5 Headway Method

Headways have been used in some of the most popular methods of PCU estimation to account for the primary effect of heavy vehicles in the traffic stream that they take more space than a single passenger car. The equation is given for the estimation of PCU by the headway method.

$$PCU = [\left(\frac{hm}{hc}\right) - c]/t$$

Where

hm = time headway of mixed vehicle

hc = time headway of passenger cars

c = Proportion of cars in the traffic stream

t =Proportion of commercial vehicles in traffic stream.

This method is best suited in a condition where there is a level grade and a low level of service. Different research shows that this method works best when all the vehicles in the traffic stream are divided into two categories i.e., Commercial and Non-commercial vehicles.

## 4.6 PTV VISSIM

PTV VISSIM a microsimulation Software is a useful tool that helps engineers for evaluating large-scale, different complex projects before investing capital and cost in them. This software has the unique capabilities to analyze different traffic conditions and give the most optimum results. The software uses real-time simulations for this purpose.

### 4.6.1 Step-01: Model Creation

The first step in PTV VISSIM is developing the model in the software. The model in this case is very simple since it is a straight road portion for all the four-location selected for the study. The model is created by using links and connectors. Figure 4-1 shows the model created for calculating density for different volumes and other characteristics. It is clear **in** Figure 4-2 that the inner shoulder of 0.3 m and outer shoulder of 1.5 m is provided using the same links as for the carriageway lanes to use real condition in the simulation.

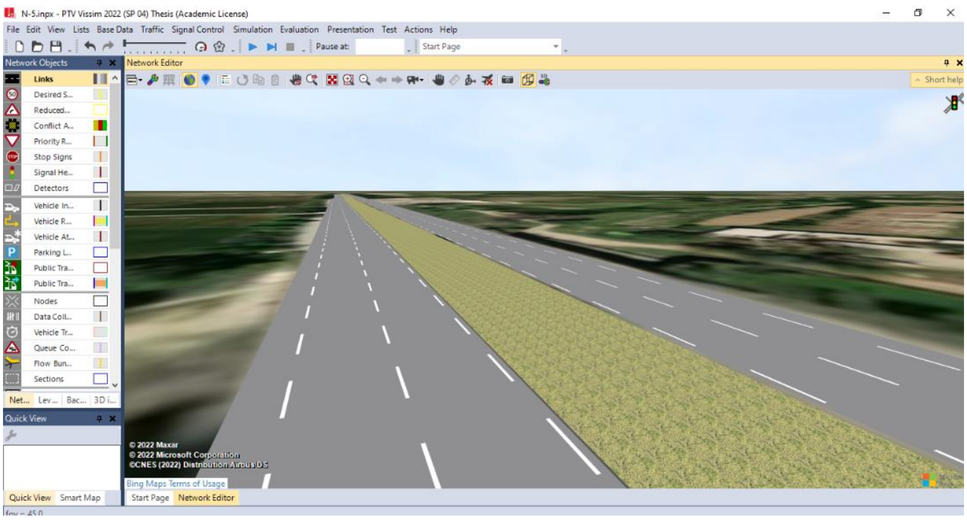



**Figure 4-1:** N-5 section Modelled in PTV VISSIM

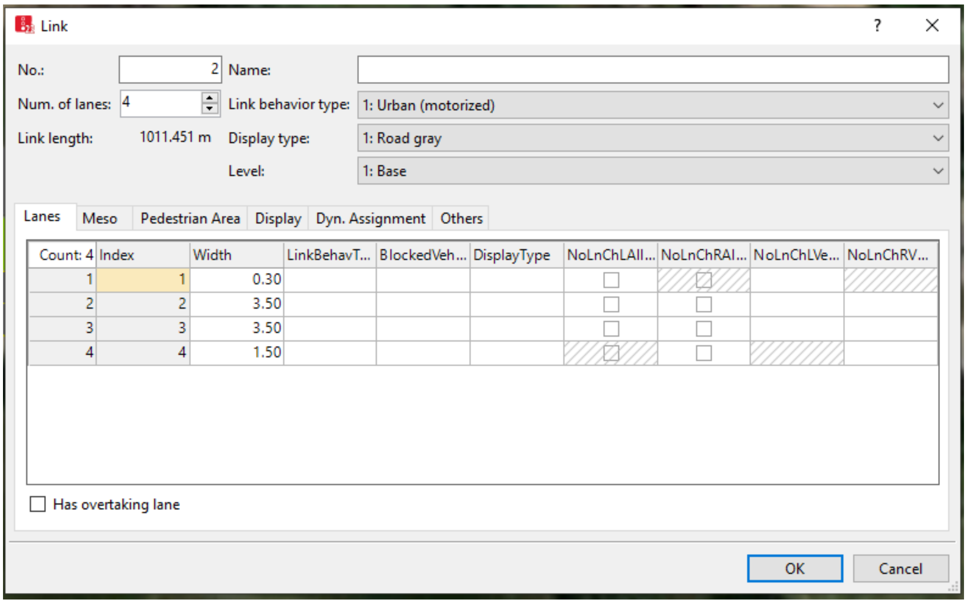


**Figure 4-2:** Lane configuration for unidirectional Roadway (N-5)

### 4.6.2 Step-02: 2D/3D Models/ 2D/3D Models Segments

Now that the roadway is defined, the next step is to define the vehicles which have the same static and dynamic characteristics as that in real conditions. For this purpose, different vehicle types are built-in PTV VISSIM. The PTV VISSIM is software primarily developed for the road condition of developed countries so, it needs calibration not only in model creation but also in vehicle type/class definition, its dimension, and other characteristics. The survey conducted for the determination of vehicle dimensions is for the purpose to take those dimensions in the software. There are some vehicles in the country which is not present in the default setting of the software and so it is added, keeping in view the dimensions of the vehicle in the field. For example, a 5-axle truck is not present in the default setting of the software. It is added into the software and the dimension is modified accordingly for better results. This addition is done in 2D/3D Models/ 2D/3D Models Segments Sheet as shown in Figure 4-3.

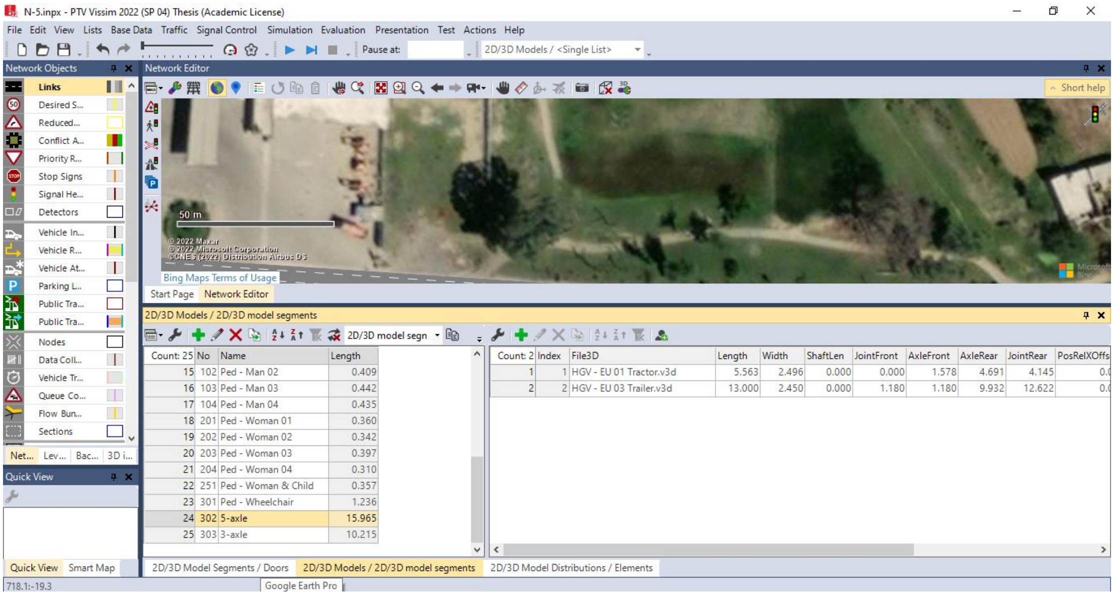


**Figure 4-3:** 2D/3D Models/ 2D/3D Models Segments

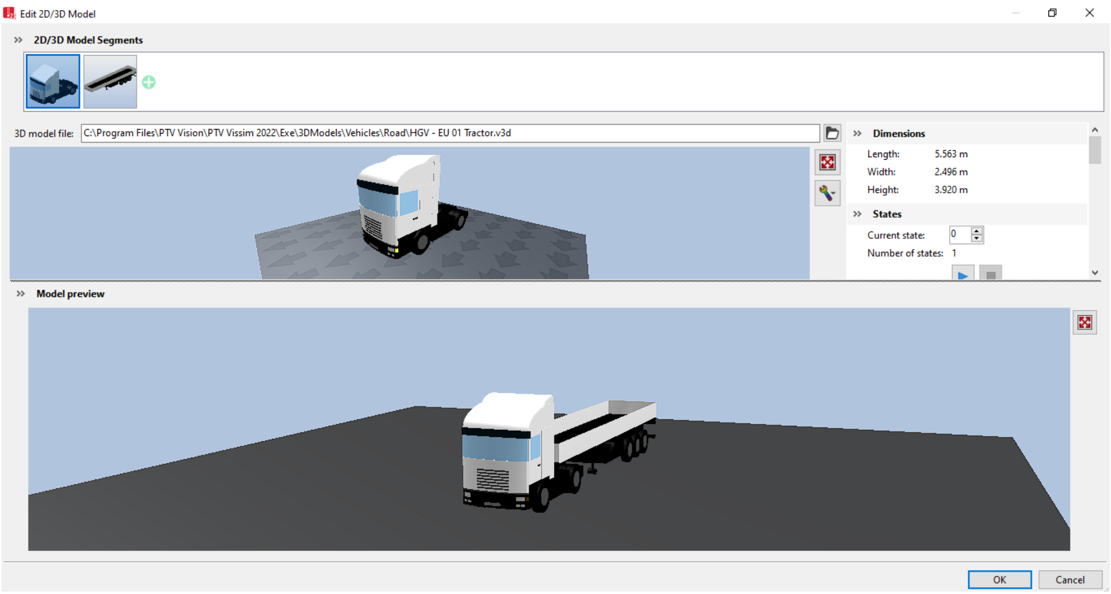


**Figure 4-4:** 5-axle Truck Model in Edit 2D/3D Model window

### 4.6.3 Step-03: Vehicle Type/ Vehicle Class:

The next step is to define the type of vehicles that is present on the roads. There are different types of vehicles on the road, with each type of vehicle having many different variants and dimensions. Therefore, for each type of vehicle average dimensions are used with the restriction of their availability in PTV VISSIM. There are nine (09) major types of vehicle types in the data collected at these four points. This includes Motorcycle, Passenger Car, HiAce, Bus, 2-axle, 3-axle, 4-axle, 5-axle, and 6-axle Trucks. Those vehicles which are classified in the “Others” category are negligible in number and they are not considered in the study. Figure 4-5 shows a different type of vehicles present at Data Collection Point 1. The category is also specified for each type of vehicle.

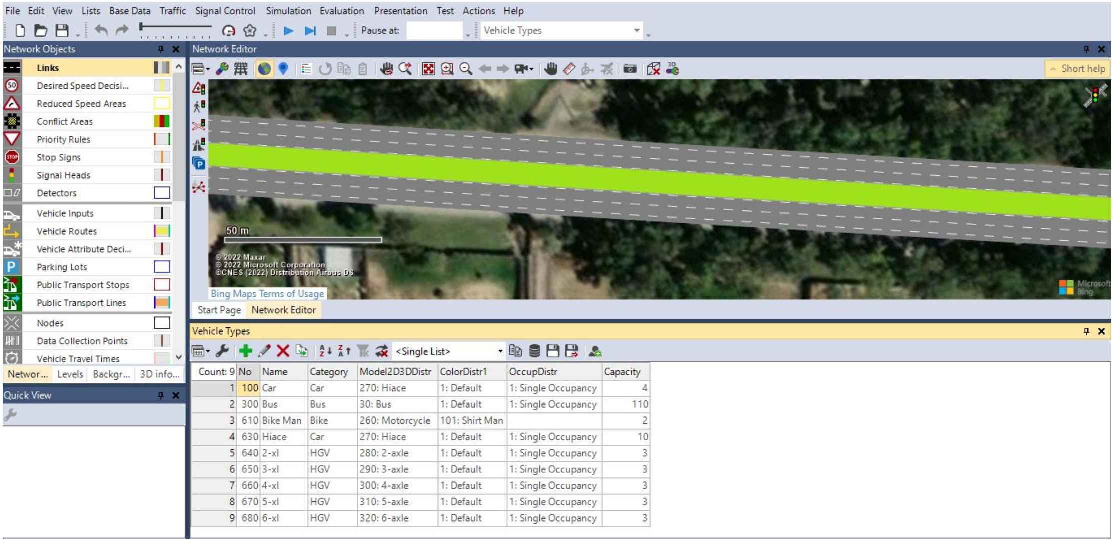



**Figure 4-5:** Vehicle Types at N-5

### 4.6.4 Step-04: Vehicle Composition/Relative flow

Once the vehicle types are selected, PTV VISSIM asks for the composition of the traffic flow. It determines the number or percentage of each vehicle type on the road section. In the present research thesis, the vehicle composition is in percentage at each of the Data collection points. Along with the vehicle composition, there is desired speed distribution, which is defined for each vehicle type. The speed distribution is selected using the average speed of each vehicle type at the data collection point. Figure 4-6 shows the Vehicle composition/Relative flow for N-5 North bound.

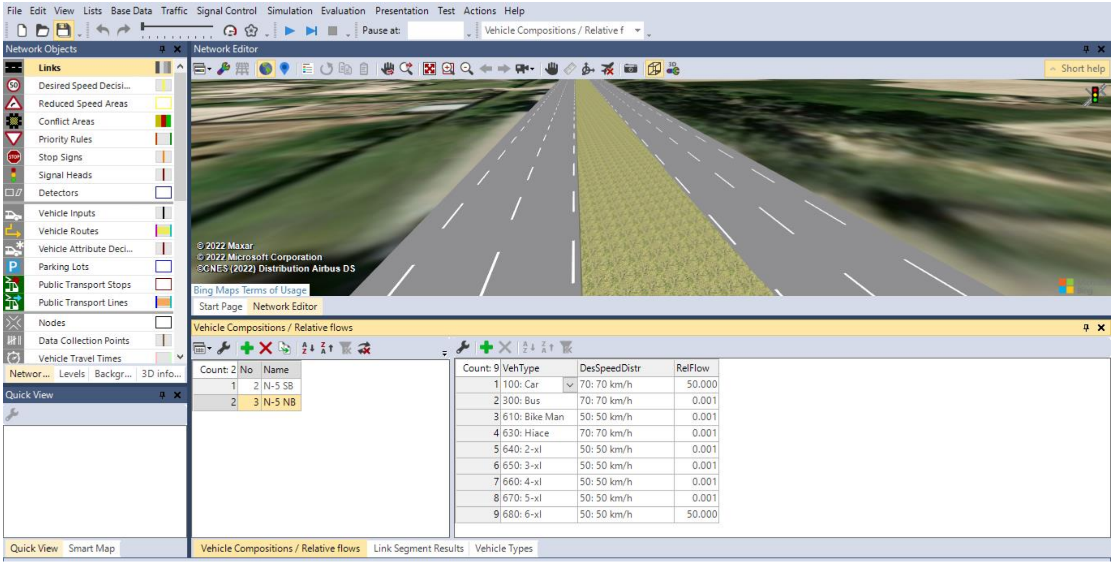


**Figure 4-6:**Vehicle composition/Relative flow for N-5 (North bound)

### 4.6.5 Link Result

With the vehicle composition/ relative flow all the required data to find the required results is almost complete. Since Equal Density Method is used to determine the passenger Car Unit (PCU) for each type of vehicle, so we need to find the density for each type of vehicle in the traffic stream along with the variation in traffic volume. For this purpose, we need to evaluate each of the two links in opposite directions. Along with the Density, Delay and speed variation is also determined using Link results. Figure 4-7 show the density and delay determined for each of the vehicle type in both directions.

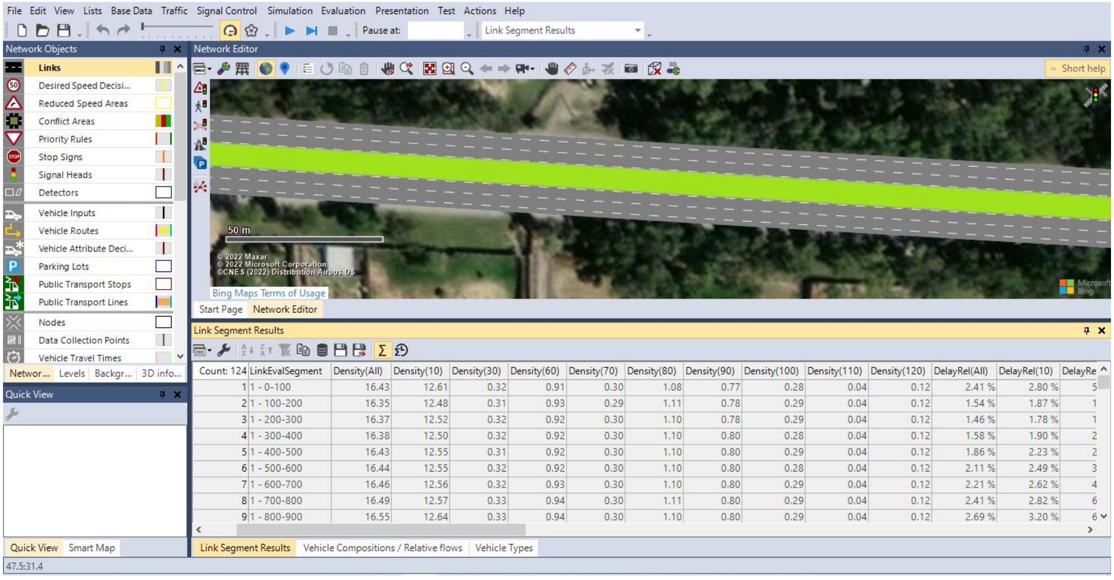



**Figure 4-7:** Density and Delay determined for both Links

### 4.6.6 Equal-Density Methodology

One of the equal impendence methods is the equal density method which is the method uses vehicle density to calculate Passenger Car Unit (PCU). Figure 4-8 shows the key parameters and process to calculate PCU. The Objective is to identify the density of the subject traffic flow which gives the same density as the Base and mixed flow. For the three different density volume data, three curves are developed. Following are the types of flow with descriptions to calculate PCU.

1. **Base Flow:** Traffic flow which is comprised of passenger cars only.
2. **Subject Flow:** It is the mixed traffic flow in which a specific number of passenger cars are replaced with the vehicle type whose PCU factor is to be determined.
3. **Mixed Flow:** It is the traffic flow in which passenger car and a specific percentage of each vehicle type are present.

Based on the previous research conducted, all the curves in Figure 4-8 are assumed to be quadratic.

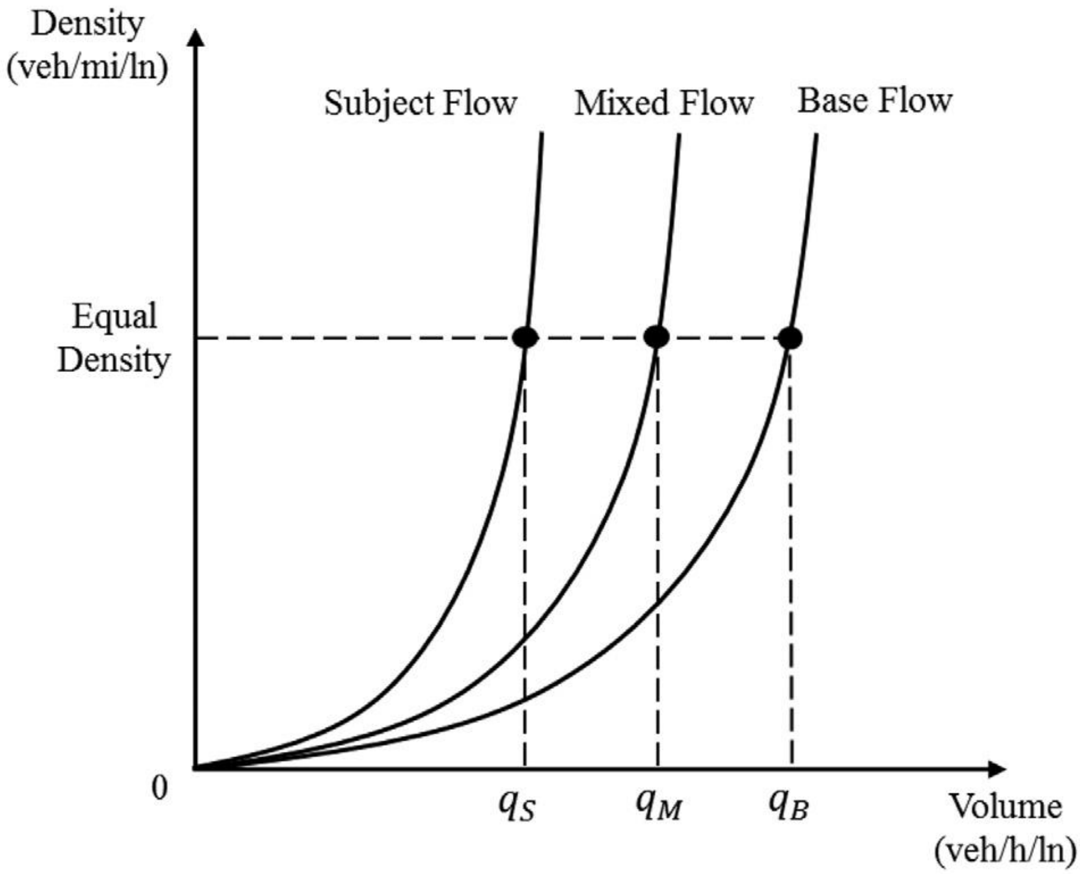



**Figure 4-8:** Volume Density curve for PCU estimation using EDM

$$Di = a1i * Vi + a2i * Vi^2$$

Where,

i = indicator for traffic flow (i = 1, base flow; i = 2, subject flow; i = 3, mixed flow)

Di = density estimated by hourly volume and average speed for traffic flow i (veh/mi/ln)

Vi = hourly volume estimated for traffic flow i (veh/h/ln)

a1i, a2i = estimated coefficients

In this research, the vehicle types used are those which are common on the freeways and highways of Pakistan. The dimensions used for different types of vehicles are measured at different areas and their average dimensions are used in the research. The average lengths and speed distributions of each vehicle are based on the data collected from the site. The percentage of passenger cars that are replaced is 10% for each iteration.

The requirement for large volumes of data to create the density–volume curves mean the equal-density approach is based on simulation outcomes. All of the traffic flows described above are simulated and the density values output is obtained. The coefficients of the above equation are then estimated using the density and volume data from the simulation data. Once each of the three density–volume curves is formed, the vehicle's equal density PCE may be calculated at a given volume and given vehicle percentage, as shown in the equation below.

$$\text{PCE}_{qs,\,pt} = \frac{1}{\Delta P}\left(\frac{qb}{qs} - \frac{qb}{qm}\right) + 1$$

PCEqs , pv = equal-density-based PCE for particular vehicle type for given traffic flow volume qs and that vehicle percentage pv.

Δp = percentage of subject vehicles.

qb = base (e.g., passenger car only) flow volume that results in the same density as the given traffic flow (veh/h/ln).

qm = mixed (e.g., pv percent trucks and (1 - pv) percent cars) flow volume that results in same density as the given traffic flow (veh/h/ln).

qs = subject (e.g., (pv+ 5) percent trucks and (1- pv - 5) percent cars) traffic flow volume (veh/h/ln).

# CHAPTER 5: DATA ANALYSIS

The data is collected using the method explained in Chapter 03. This data collected is in the raw form and after processing the data, all the unwanted outliers are removed from the data. Once the data is prepared, it needs to be analyzed. Analysis of this data provides, a detailed look into the data collected. It enables to presentation of the data from different perspectives. The data analyzed can also be presented by using different charts, graphs, and tables. This chapter analyzes the data collected at all four points of the research project.

## 5.1 Analysis of DCP-01 (N-5)

The data collection point 01 (DCP-01) is selected on National Highway-5 (N-5) also known as Grand Trunk Road (G.T Road). The total length of N-5 is approximately 1819 km which starts at Karachi passing through the plains of Sindh and Punjab and terminating at Torkham at Pak-Afgan Border. It is the longest of all the roads in the country. N-5 carries 80% of commercial traffic of the country which makes up only 4.6% of the total road network of the country.

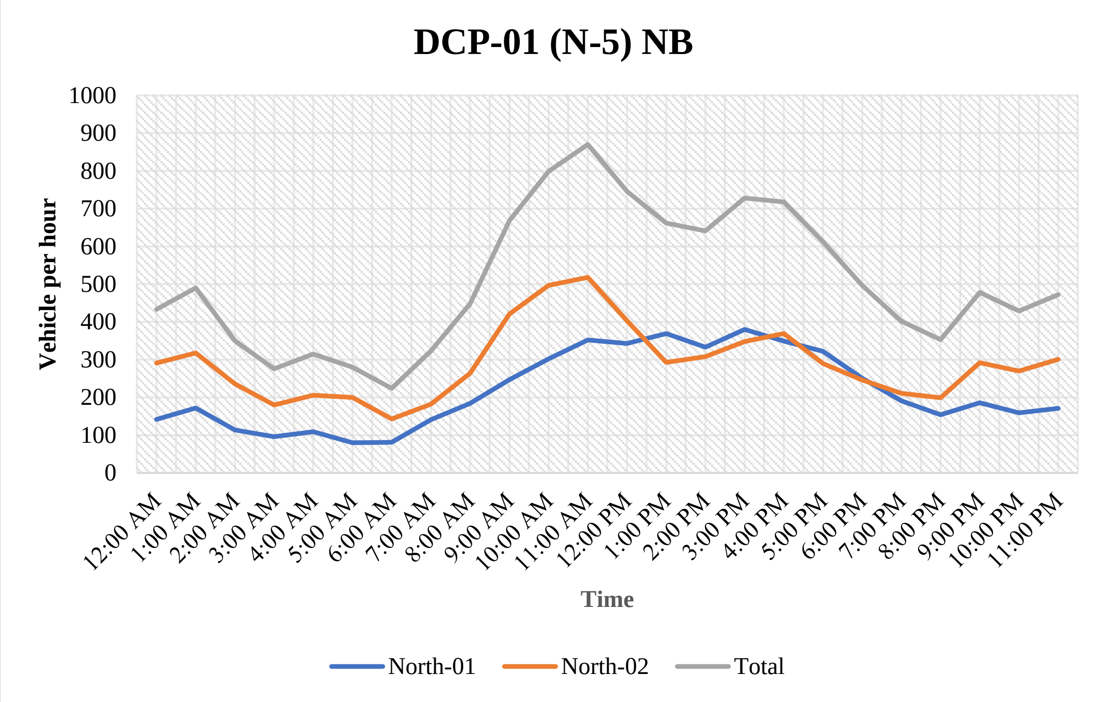



**Figure 5-1:** Hourly Traffic on North bound of N-5 (NB)

Figure 5-1 shows the hourly traffic recorded on the N-5 (traveling from Islamabad to Peshawar). The peak hour of the traffic flow is 10 AM to 11 AM of the day when there is almost 800 vehicle per hour on the northbound. It is also evident that the least traffic is present from 1 AM to 4 AM. It can be seen that there is almost equal distribution of vehicles on both the lanes in the northbound direction.

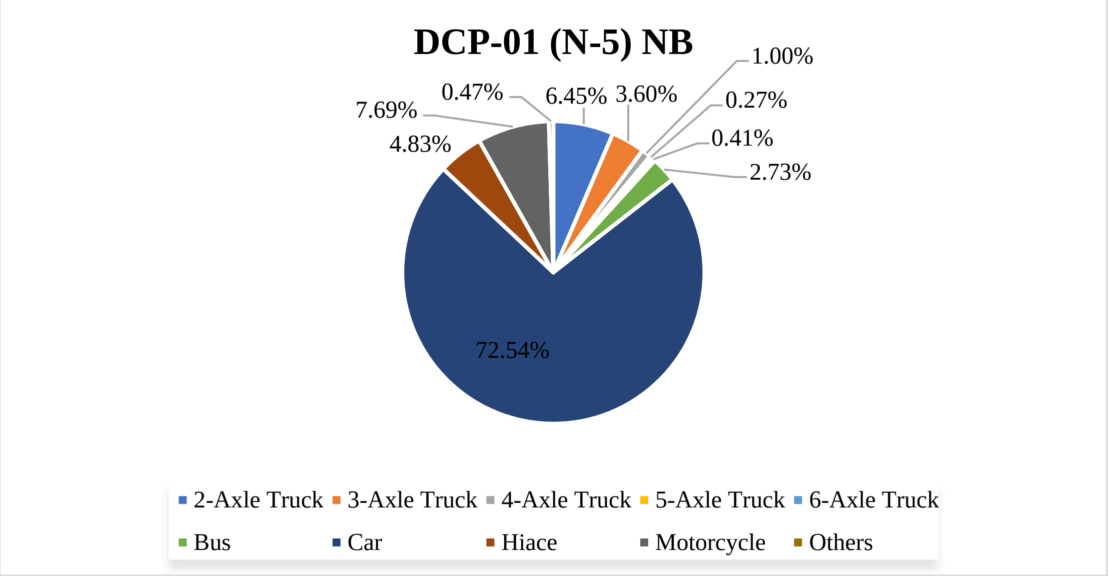



**Figure 5-2:** Distribution based on Vehicle Type N-5 (NB)

Figure 5-2 shows the distribution of traffic flow based on vehicle type on a pie chart. The traffic flow comprised almost three-quarter of Passenger Cars, followed by motorcycles which make up 7.69% of traffic. 2-axle trucks are also present in adequate numbers on the road. 5-axle and 6-axle trucks make the least of the traffic composition.

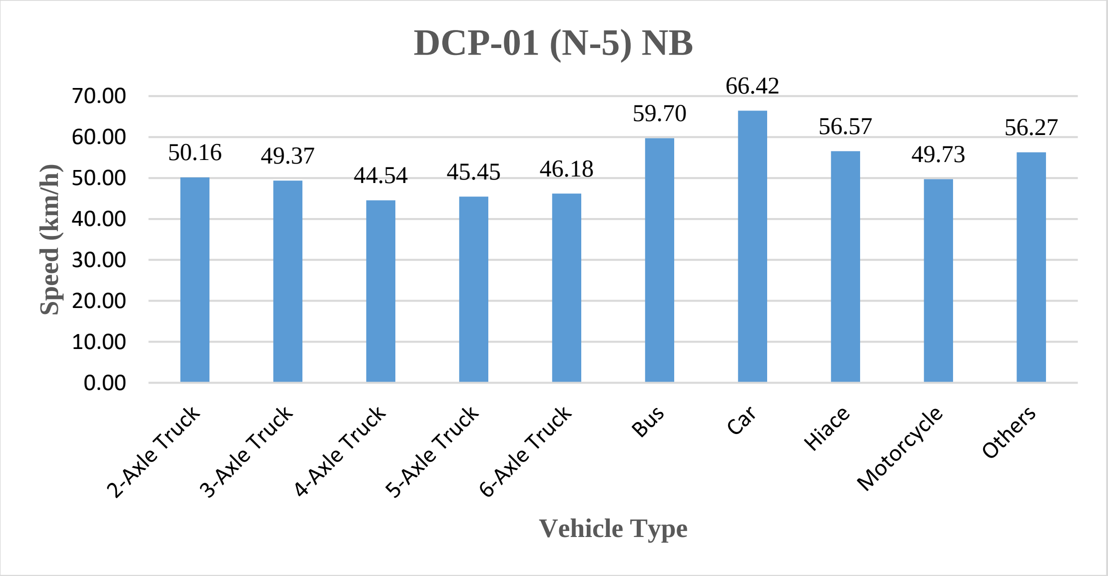



**Figure 5-3:** Average speed of different Vehicle types N-5 (NB)

Figure 5-3 shows the average speed of different vehicle types on the northbound N-5. The highest average speed is that of a passenger car followed by HiAce and Bus. Motorcycles follow at an average speed of 50 kilometers per hour. This data is analyzed for one complete day. The speed is on the upper end at times when the traffic volume is low and it is lower as the volume increases during peak hours. It is also noted that for the same volume of traffic-heavy vehicles have higher speeds during night times as compared to when it is daylight.

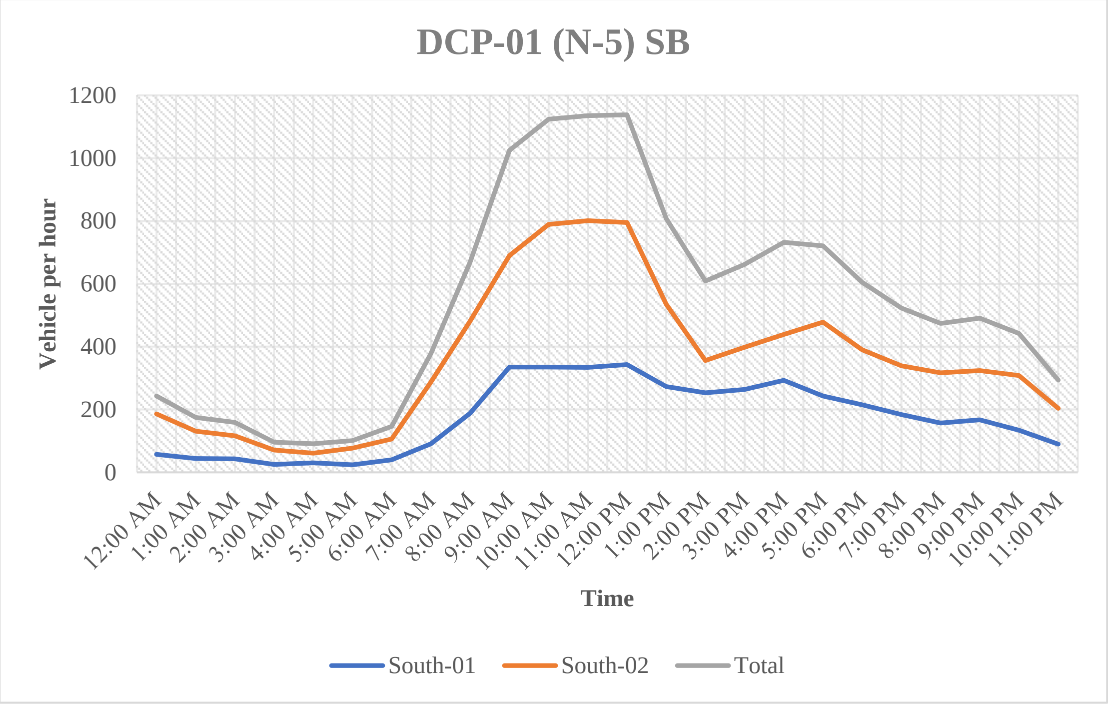



**Figure 5-4:** Hourly Traffic on South Bound of N-5 (SB)

Figure 5-4 shows the hourly traffic recorded on the N-5 (traveling from Peshawar to Islamabad). The peak hour of the traffic flow is 12 PM to 01 PM of the day when there is almost 1150 vehicle per hour on the southbound. It is also evident that the least traffic is present from 03 AM to 06 AM. It can be seen that there is higher traffic flow on the outer lane compared to the inner fast lane.

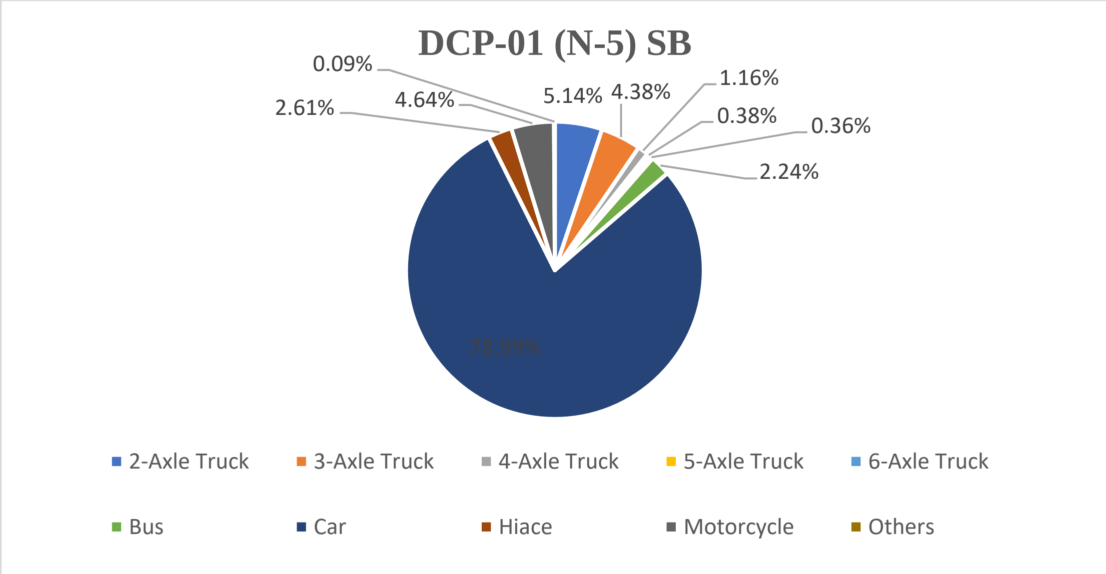



**Figure 5-5:** Distribution based on Vehicle Type N-5 (SB)

Figure 5-5 shows the distribution of traffic flow based on vehicle type on a pie chart. The traffic flow comprised almost 79 percent of Passenger Cars, followed by 2-axle trucks which make up 5.14% of traffic. Motorcycles are also present in adequate numbers on the road. 5-axle and 6-axle trucks make the least of the traffic composition.

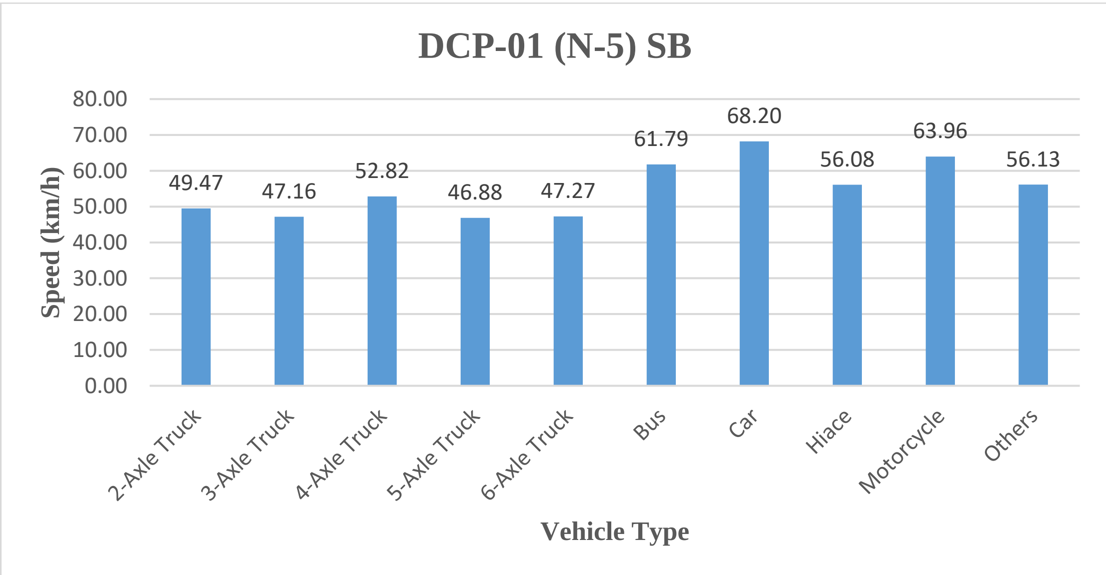



**Figure 5-6:** Average speed of different Vehicle types N-5 (SB)

Figure 5-6 shows the average speed of different vehicle types on the southbound of N-5. The highest average speed is that of a passenger car followed by HiAce and Bus. Motorcycles follow at an average speed of 68 kilometers per hour. This data is analyzed for one complete day. The speed is on the upper end at times when the traffic volume is low and it is lower as the volume increases during peak hours. It is also noted that for the same volume of traffic-heavy vehicles have higher speeds during night times as compared to when it is daylight, showing aggressive behavior of truck drivers at night.

## 5.2 Analysis of DCP-02 (N-45)

The data collection point 02 (DCP-02) is selected on National Highway-45 (N-45). The total length of N-45 is approximately 309 km which emerges from N-5 at Nowshera which is a four-lane road. It passes through the plains of District Mardan where it is still a four-lane road. Entering the hilly terrain of Malakand the number of lanes reduced to two. It then crosses into Dir Lower and Dir Upper and finally, it enters District Chitral. Heavy Vehicles are present in high numbers on this road.

Figure 5-7 shows the hourly traffic recorded on the N-45 (traveling from Nowshera to Mardan). The peak hour of the traffic flow is 11 AM to 12 PM of the day when there is almost 1300 vehicle per hour on the northbound. It is also evident that the least traffic is present from 02 AM to 05 AM. It can be seen that there is an almost equal amount of traffic flow on both the traffic lanes in the north direction.

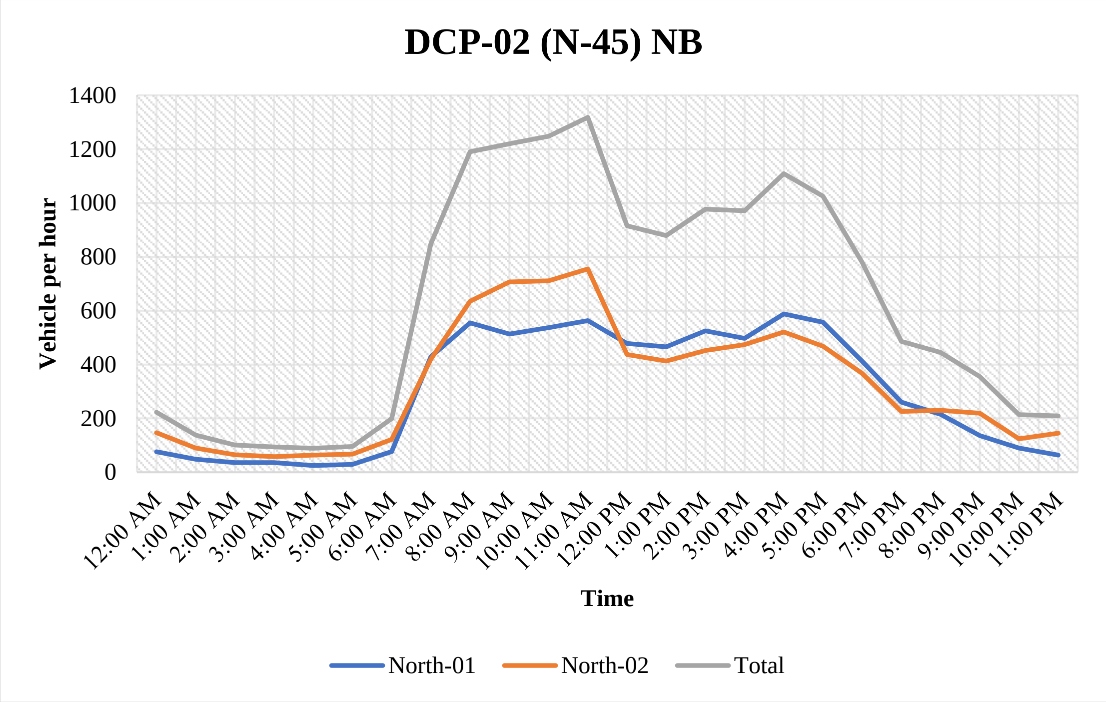



**Figure 5-7:** Hourly Traffic on South Bound of N-45 (NB)

Figure 5-8 shows the distribution of traffic flow based on vehicle type on a pie chart. The traffic flow comprised almost 76 percent of Passenger Cars, followed by motorcycle which makes up 15 percent of traffic. 2-axle trucks are also present in adequate numbers on the road. 5-axle and 6-axle trucks make the least of the traffic composition.

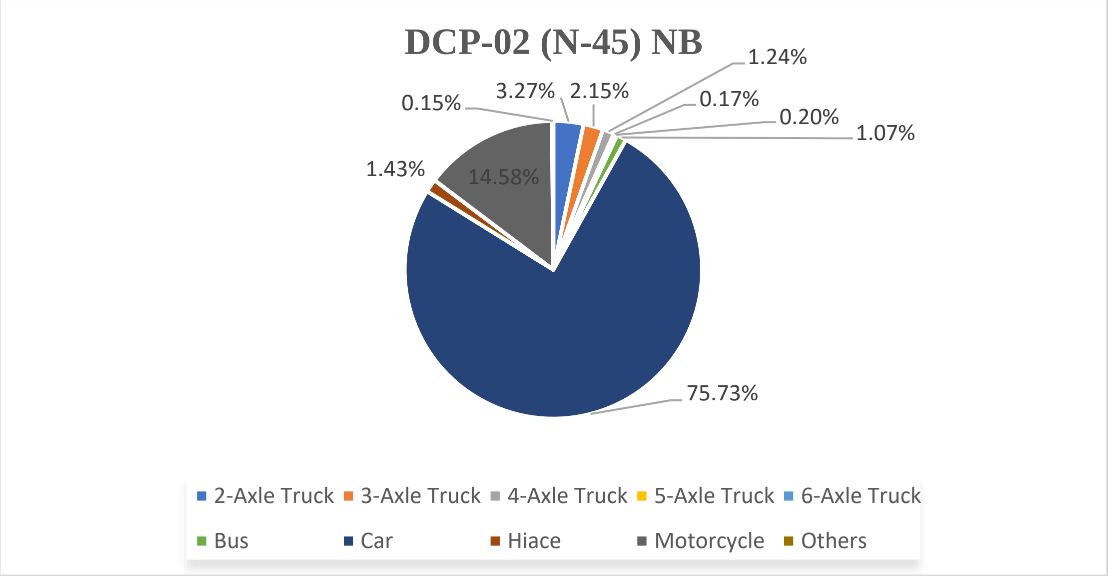



**Figure 5-8:** Distribution based on Vehicle Type N-45 (NB)

Figure 5-9 shows the average speed of different vehicle types on the northbound N-45. The highest average speed is that of a HiAce and Passenger Car followed by Buses. Motorcycles follow at an average speed of 37 kilometers per hour. This data is analyzed for one complete day. The speed is on the upper end at times when the traffic volume is low and it is lower as the volume increases during peak hours. It is also noted that for the same volume of traffic-heavy vehicles have higher speeds during night times as compared to when it is daylight, showing aggressive behavior of truck drivers at night.

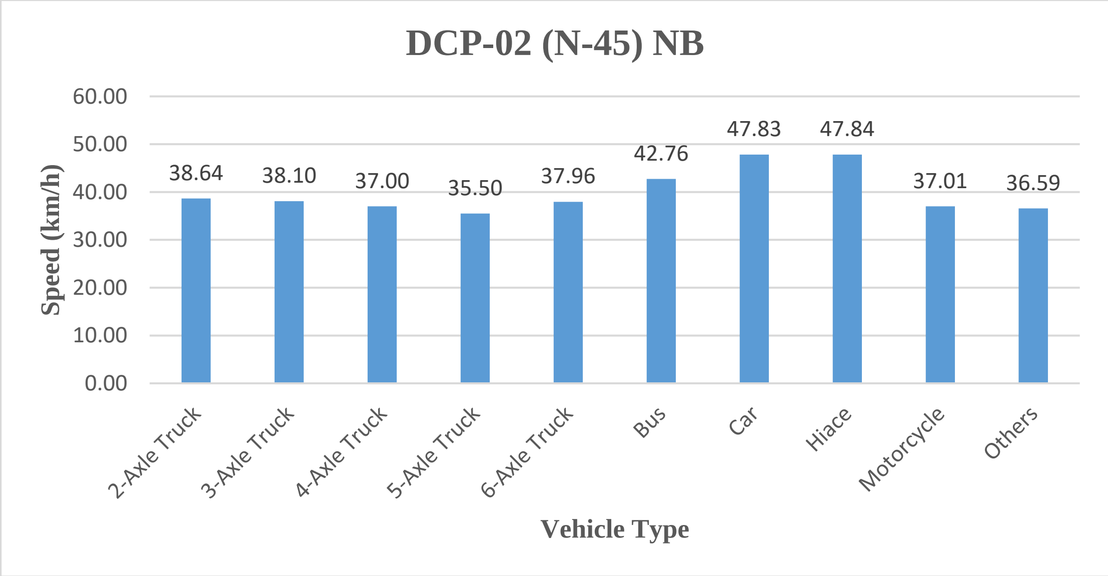



**Figure 5-9:**Average Speed of different Vehicle Types N-45 (NB)

Figure 5-10 shows the hourly traffic recorded on the N-45 (traveling from Mardan to Nowshera). The peak hour of the traffic flow is 11 AM to 12 PM of the day when there is almost 1300 vehicle per hour on the southbound. It is also evident that the least traffic is present from 02 AM to 05 AM. It can be seen that there is an almost equal amount of traffic flow on both the traffic lanes in the north direction.

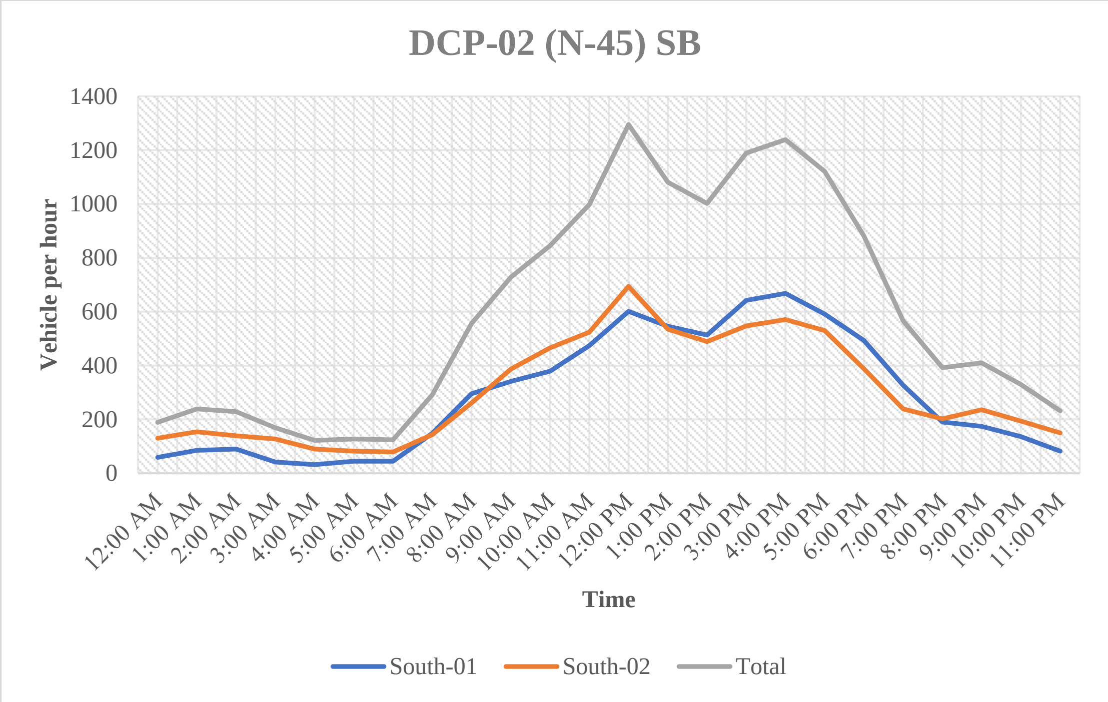



**Figure 5-10:**Hourly Traffic on South Bound of N-45 (NB)

Figure 5-11 shows the distribution of traffic flow based on vehicle type on a pie chart. The traffic flow comprised almost 76 percent of Passenger Cars, followed by motorcycle which makes up 13 percent of traffic. 2-axle trucks are also present in adequate numbers on the road. 5-axle and 6-axle trucks make the least of the traffic composition.

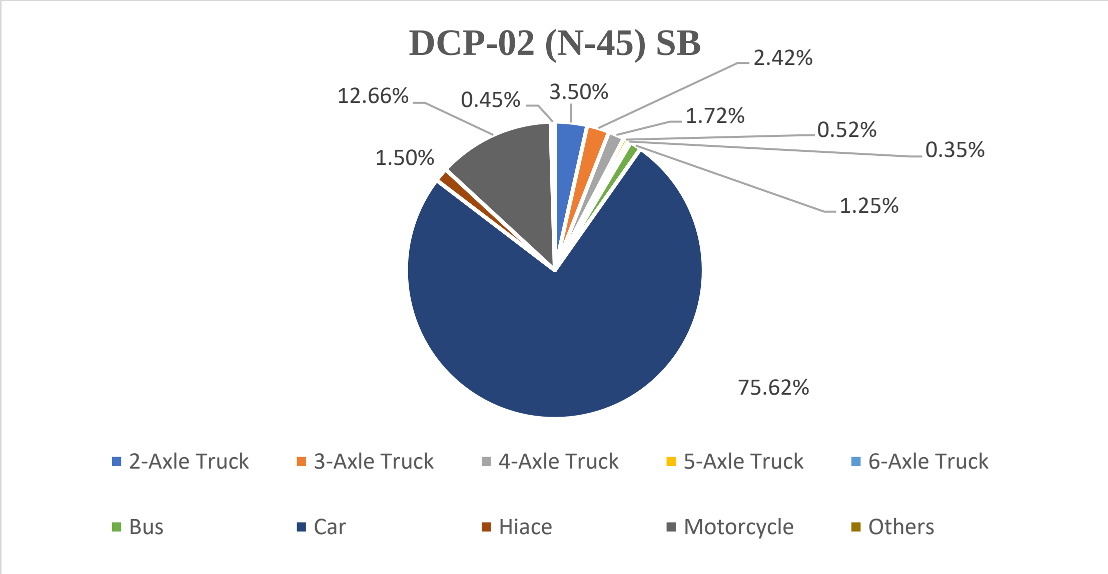



**Figure 5-11:** Distribution based on Vehicle Type N-45 (SB)

Figure 5-12 shows the average speed of different vehicle types on the southbound of N-45. The highest average speed is that of a HiAce and Passenger Car followed by Buses. Motorcycles follow at an average speed of 38 kilometers per hour. This data is analyzed for one complete day. The speed is on the upper end at times when the traffic volume is low and it is lower as the volume increases during peak hours. It is also noted that for the same volume of heavy vehicles have higher speeds during night times as compared to when it is daylight, showing aggressive behavior of truck driver at night.

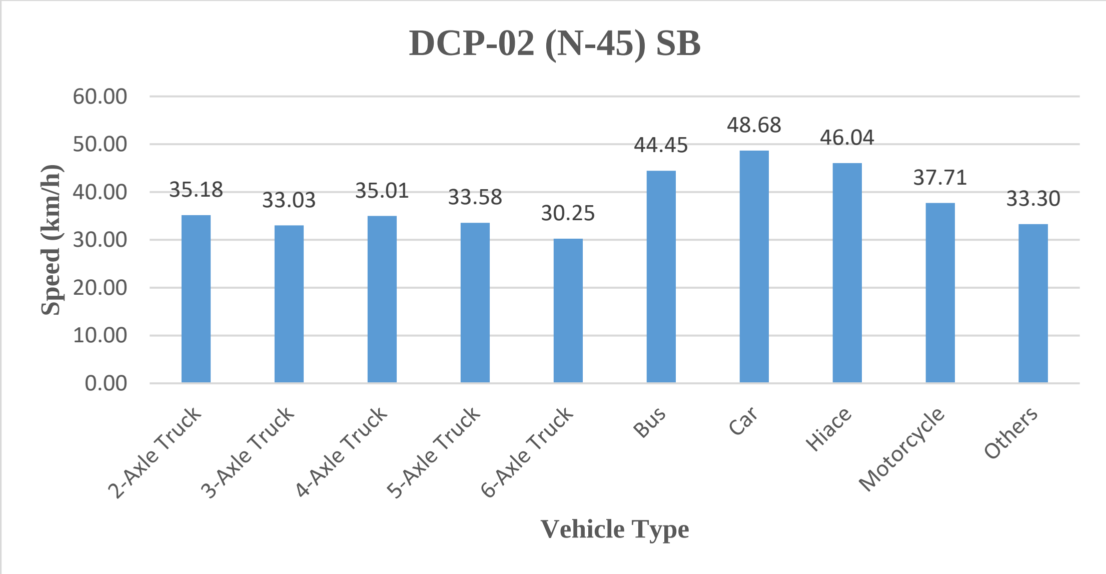



**Figure 5-12:** Average Speed of different Vehicle Types N-45 (SB)

### 5.3 Analysis of DCP-03 (M-1)

The data collection point 03 (DCP-03) is selected on Motorway-1 (M-1). The total length of M-1 is approximately 155 km which starts from Islamabad and terminates at Peshawar after passing through District Attock, Swabi, Nowshera, Mardan and Charsadda. The Motorway was completed at 13 billion rupees and was opened for traffic in 2007. This motorway provides an alternative to N-5 between Islamabad and Peshawar. The majority of vehicles on M-1 are Passenger vehicles while an adequate number of Heavy Vehicles are also present.

Figure 5-13 shows the hourly traffic recorded on the M-1 (traveling from Islamabad to Peshawar). The peak hour of the traffic flow is 06 PM to 07 PM of the day when there is 1160 vehicle per hour on the northbound. It is also evident that the least traffic is present from 03 AM to 05 AM. It can be seen that there is an almost equal amount of traffic flow on both the traffic lanes in north direction. The graph “North-1” represents the veh/hour for the fast (inner) lane while “North-2” represents the sum for the other two lanes.

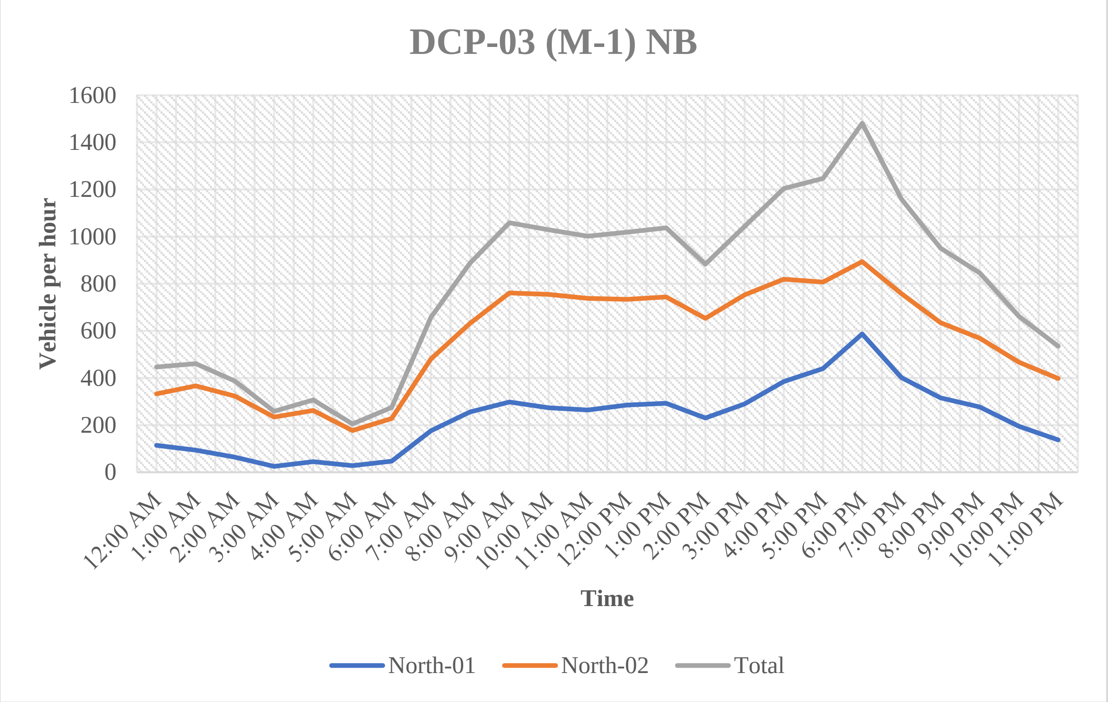



**Figure 5-13:**Hourly Traffic on North Bound of M-1 (NB)

Figure 5-14 shows the distribution of traffic flow based on vehicle type on a pie chart. The traffic flow comprised almost 71 percent of Passenger Cars, followed by HiAce which makes up 21 percent of traffic. 2,3 and 4-axle trucks are also present in adequate numbers on the road. 5-axle and 6-axle trucks make the least of the traffic composition. The lower presence of heavy vehicles on M-1 is because of N-5 which is an alternate route between Islamabad and Peshawar with a lower toll tax. Other reasons include the presence of a load controlling regime and lesser facilities for vehicle repair.

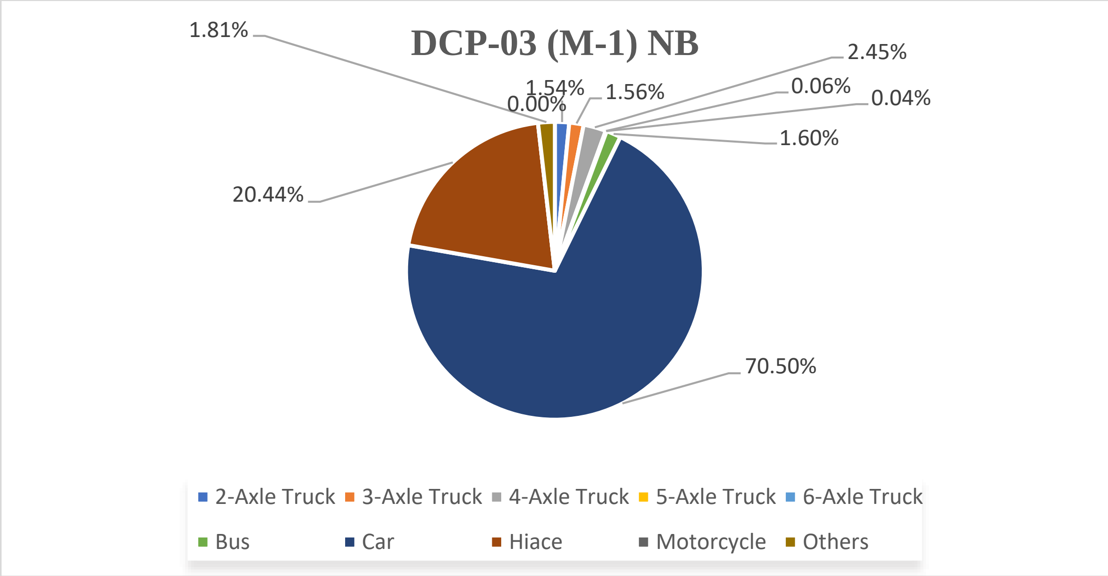



**Figure 5-14:** Distribution based on Vehicle Type M-1 (NB)

Figure 5-15 shows the average speed of different vehicle types on the northbound of M-1. The highest average speed is that of a HiAce followed by Passenger Cars. 2-axle and Bus follow at an average speed of 80~85 kilometers per hour. This data is analyzed for one complete day. The speed is on the upper end at times when the traffic volume is low and it is lower as the volume increases during peak hours. It is also noted that for the same volume of heavy vehicles have higher speeds during night times as compared to when it is daylight, showing aggressive behavior of truck drivers at night.

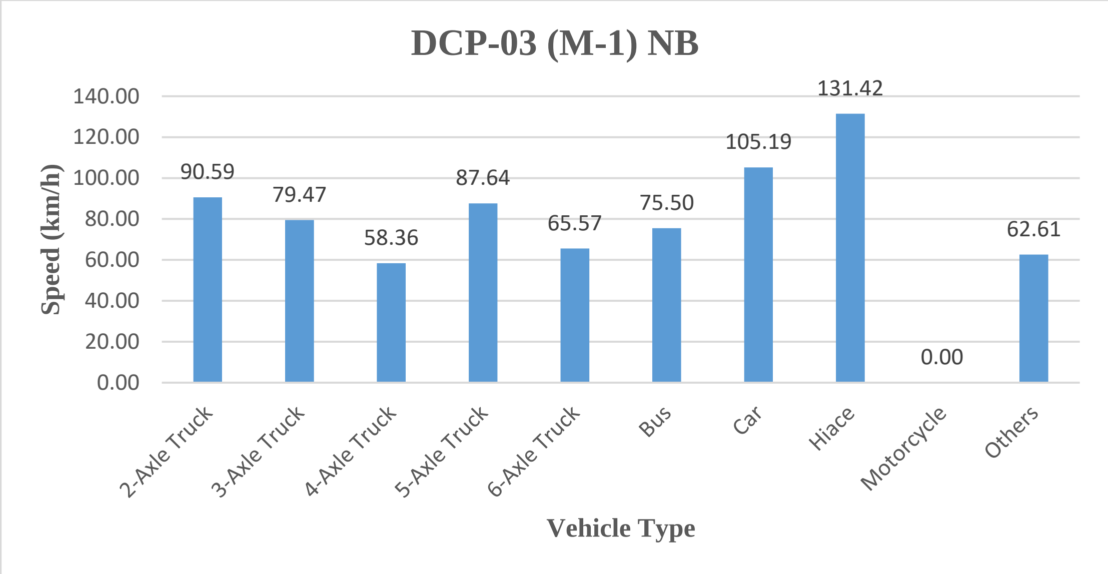



**Figure 5-15:** Average Speed of different Vehicle Types M-1 (NB)

Figure 5-16 shows the hourly traffic recorded on the M-1 (traveling from Peshawar to Islamabad). There are two peak hours of the traffic flow. One is the morning peak hour, 09 AM to 10 AM and the second peak hour is the evening peak hour, 05 AM to 06 AM. At morning peak hour volume is 1500 vehicles per day and at evening peak hour it is 1528 vehicles per hour. It is also evident that the least traffic is present during 02 AM to 04 AM. It can be seen that there is an almost equal amount of traffic flow on both the traffic lanes in the north direction. The graph “South-1” represents the veh/hour for the fast (inner) lane while “South-2” represents the sum for the other two lanes.

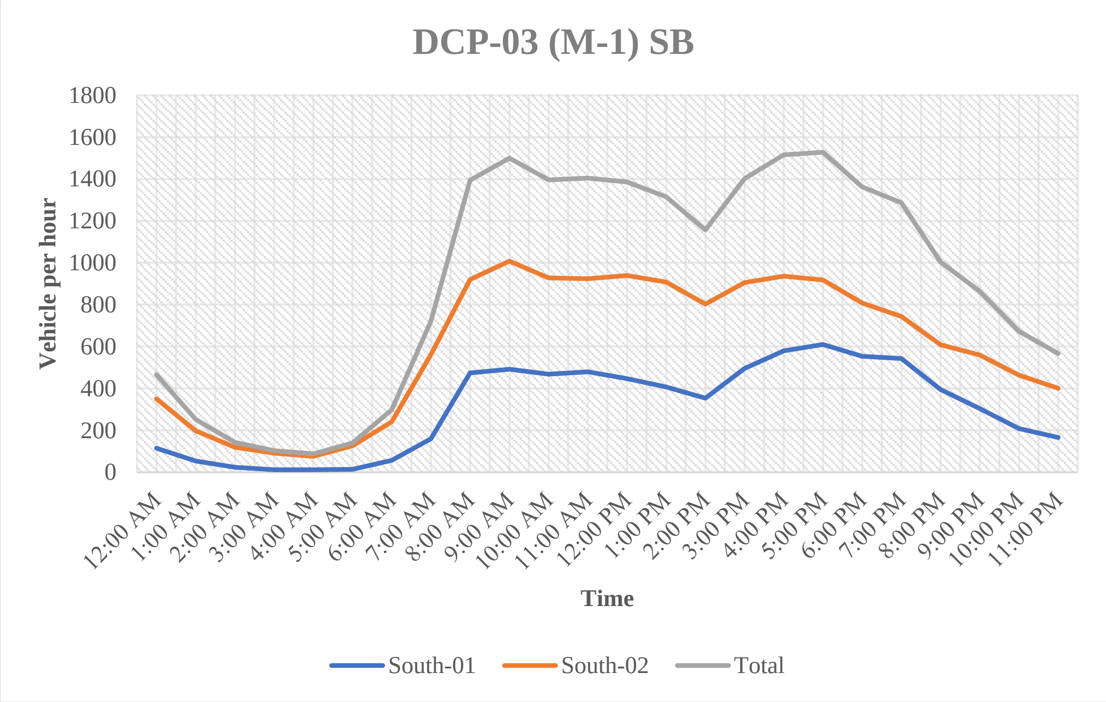



**Figure 5-16:** Hourly Traffic on South Bound of M-1 (SB)

Figure 5-17 shows the distribution of traffic flow based on vehicle type on a pie chart. The traffic flow comprised almost 84 percent of Passenger Cars, followed by HiAce which makes up 8 percent of traffic. 2 and 3-axle trucks are also present in adequate numbers on the road. 5-axle and 6-axle trucks make the least of the traffic composition. The lower presence of heavy vehicles on M-1 is because of N-5 which is an alternate route between Islamabad and Peshawar with a lower toll tax. Other reasons include the presence of a load controlling regime and lesser facilities for vehicle repair.

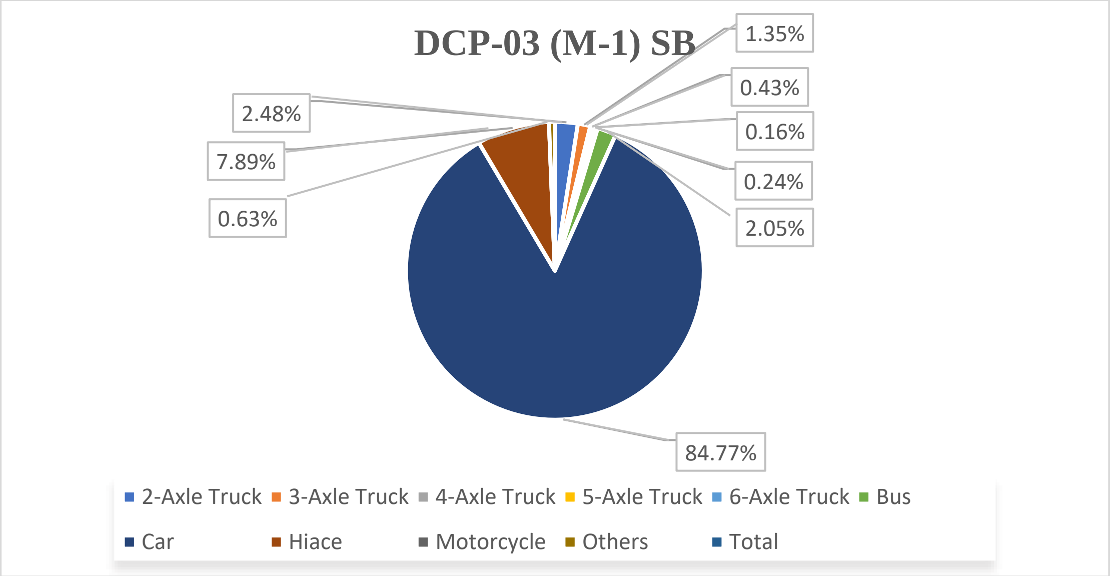



**Figure 5-17:** Distribution based on Vehicle Type M-1 (SB)

Figure 5-18 shows the average speed of different vehicle types on the northbound of M-1. It is clear that the highest average speed is that of Passenger Cars and HiAce. The bus follows at an average speed of 90 kilometers per hour. This data is analyzed for 24 hours. The speed is on the upper end at times when the traffic volume is low and it is lower as the volume increases during peak hours. It is also noted that for same volume of heavy vehicles have higher speeds during night times as compared to when it is daylight, showing aggressive behavior of truck drivers at night.

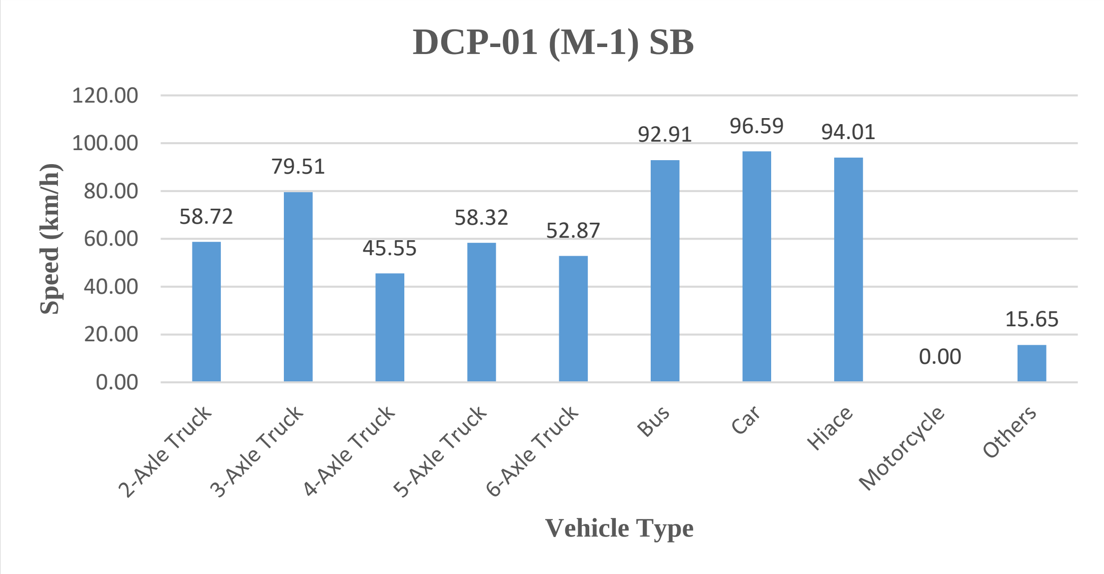



**Figure 5-18:** Average Speed of different Vehicle Types M-1 (SB)

### 5.4 Analysis of DCP-04 (N-35)

The data collection point 04 (DCP-04) is selected on National Highway-35 (N-35) also known as Karakoram Highway. Its construction work is started in 1962 and it was opened to the general public in 1978. The total length of N-35 is approximately 1300 km which starts from Hasanabdal and terminates at Xinjiang Uyghur Autonomous Region of People Republic of China (PRC). The length of the highway which falls in Pakistani territory is 887km whereas 413 km of the road length falls in PRC territory. The MetroCount Unit is installed on N-35 near Jahirkass Interchange. The point falls at latitude 33.908874°and longitude 72.782884°. This is a two-lane two-way highway with a carriageway width of 7.3 meters and the width of the shoulder that varies from 0.5 to 1.5 meters from place to place.

Figure 5-19 shows the hourly traffic recorded on the N-35. There is one peak hour present in the data which is from 05 PM to 06 PM. It is also evident that the least traffic is present from 01 AM to 04 AM. It can be seen that there is an almost equal amount of traffic flow on both traffic lanes. The graph "North" represents the veh/hour for vehicles moving in northbound direction while “South” represents the veh/hour for vehicles moving in the northbound direction.

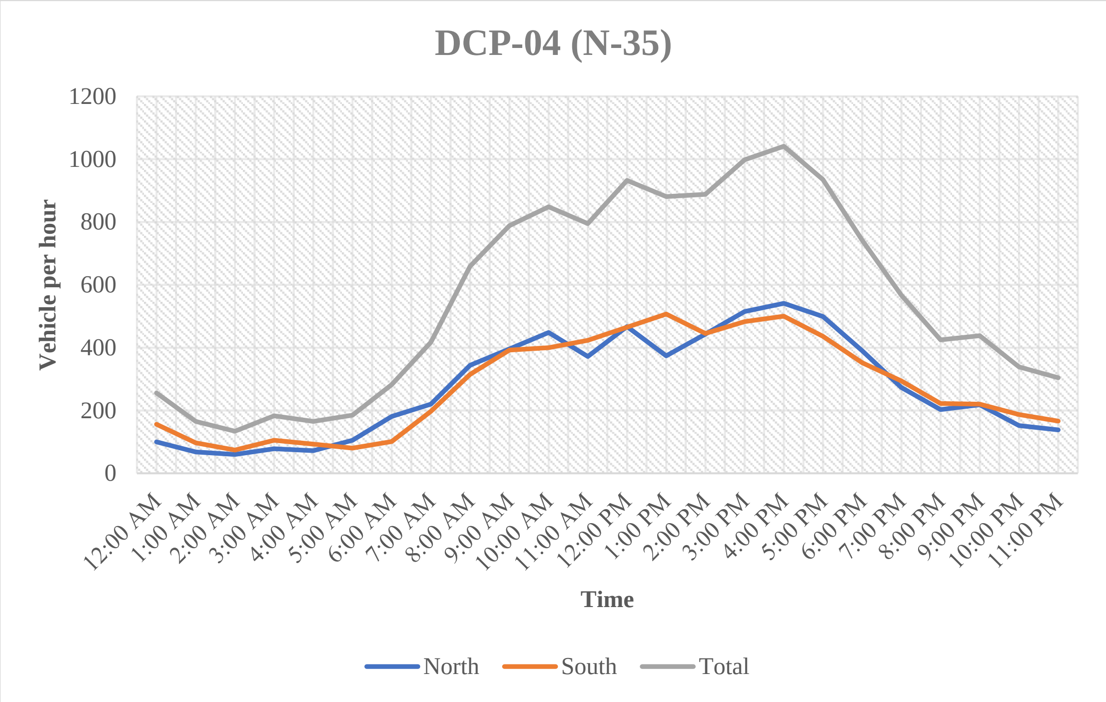



**Figure 5-19:**Hourly Traffic on N-35

Figure 5-20 shows the distribution of traffic flow based on vehicle type on a pie chart. The traffic flow comprised almost 52 percent of Passenger Cars, 29 percent of Motorcycles, 8.7 percent of 2-axle trucks, and 3 percent of HiAce. Unlike the previous three locations, this highway is two lane single carriageway road. The total percentage of heavy vehicles is around 14 percent. This highway is currently used for Transit trade purposes.

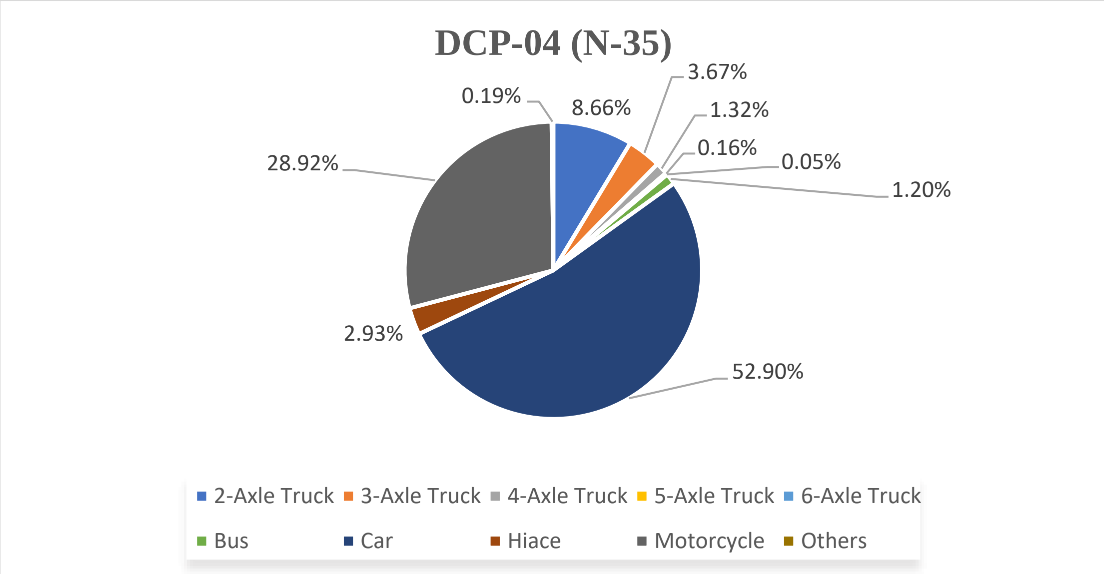



**Figure 5-20:** Distribution based on Vehicle Type N-35

Figure 5-21 shows the average speed of different vehicle types on the N-35. The highest average speed is that of Passenger Car and Bus. HiAce and motorcycles follow. This data is analyzed for 24 hours. The speed is on the upper end at times when the traffic volume is low and it is lower as the volume increases during peak hours. It is also noted that for the same volume of heavy vehicles have higher speeds during night times as compared to when it is daylight, showing aggressive behavior of truck drivers at night. By comparing the speed distribution of this location with the previous location it is clear that there is a significant difference between the speed, which is because of the different geometry of the road. N-35 is a two-lane single-carriageway road while all three roads are median-separated roads due to which driver drives at lower speed N-35.

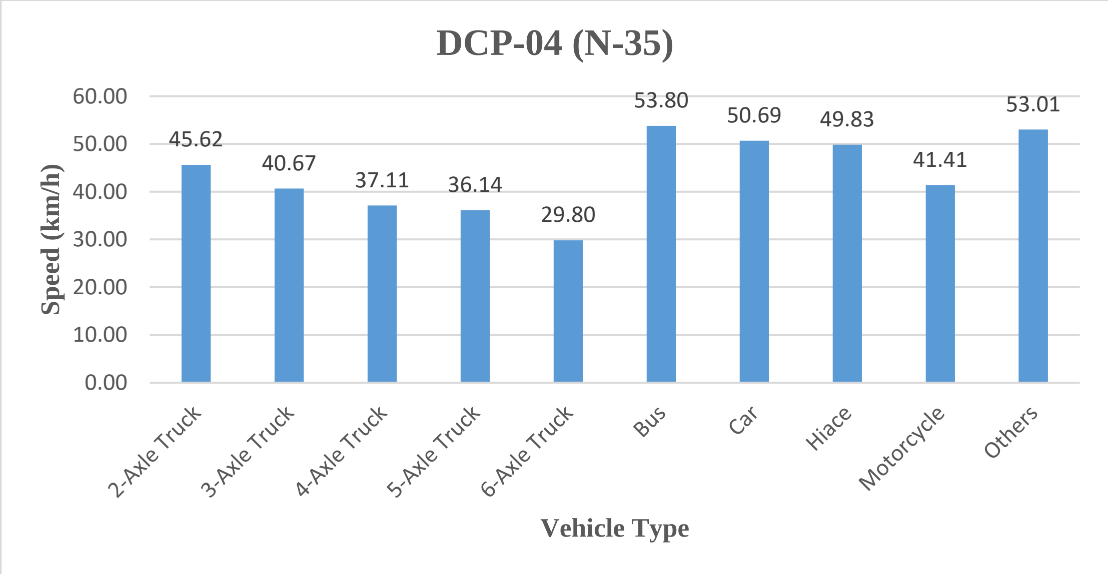



**Figure 5-21:** Average Speed of different Vehicle Types

# CHAPTER 6: RESULTS

Different methods are used in the literature to calculate Passenger Car Units (PCUs) for different types of vehicles. The methods include the Headway method, Speed methods (Chandra method & Modified Chandra method), and Simulation techniques. Headway and Speed methods are used to calculate PCEs for highways only while the Simulation technique is used for PCE calculation on different classes of roads. The Simulation Technique uses the Equal Density Method for PCU Estimation.

## 1.1 Speed Method (Chandra's Method)

The speed Method (Chandra Method) uses Speed and Projected area for the calculation of Passenger Car Equivalent (PCE). This method of estimating PCE is very common in use for Intra-city traffic. It uses the speed of the particular vehicle type and the projected area of that vehicle. Chandra Method is used to calculate PCE for Data Collection Point (DCP) at Mullah Mansoor. The vehicle's dimension is measured at different areas in Rawalpindi, Islamabad, and Peshawar. The speed of the vehicles is determined for each vehicle class by taking the average of the particular vehicle type for a three-hour traffic speed data on different days. Table 6-1 and Figure 6-1 show the PCU factor calculated for Northbound on N-5 while Table 6-2 and Figure 6-2 show PCU factors calculated for Southbound on N-5 using Chandra's Method.

**Table 6-1:**PCU Calculation using Chandra's Method for North-bound

| S/No | Vehicle Type | Average of Length | Average of Width | Average of Area | Ratio of (Ai/Ac) | Average speed ratio (Vc/Vi) | PCU Chandra Method |
|---|---|---|---|---|---|---|---|
| 1 | 2-axle | 7.26 | 2.22 | 16.14 | 2.21 | 1.19 | 2.63 |
| 2 | 3-axle | 10.00 | 2.27 | 22.67 | 3.10 | 1.18 | 3.65 |
| 3 | 4-axle | 15.50 | 2.20 | 34.10 | 4.66 | 1.22 | 5.71 |
| 4 | 5-axle | 17.20 | 2.30 | 39.56 | 5.41 | 1.28 | 6.90 |
| 5 | 6-axle | 17.23 | 2.62 | 45.09 | 6.16 | 1.12 | 6.89 |

| S/No | Vehicle Type | Average of Length | Average of Width | Average of Area | Ratio of (Ai/Ac) | Average speed ratio (Vc/Vi) | PCU Chandra Method |
|---|---|---|---|---|---|---|---|
| 6 | Bus | 11.30 | 2.47 | 27.87 | 3.81 | 0.99 | 3.78 |
| 8 | Car | 4.30 | 1.70 | 7.32 | 1.00 | 1.00 | 1.00 |
| 9 | HiAce | 4.69 | 1.75 | 8.18 | 1.12 | 1.02 | 1.15 |
| 7 | Motorcycle | 1.90 | 0.75 | 1.42 | 0.19 | 1.18 | 0.23 |

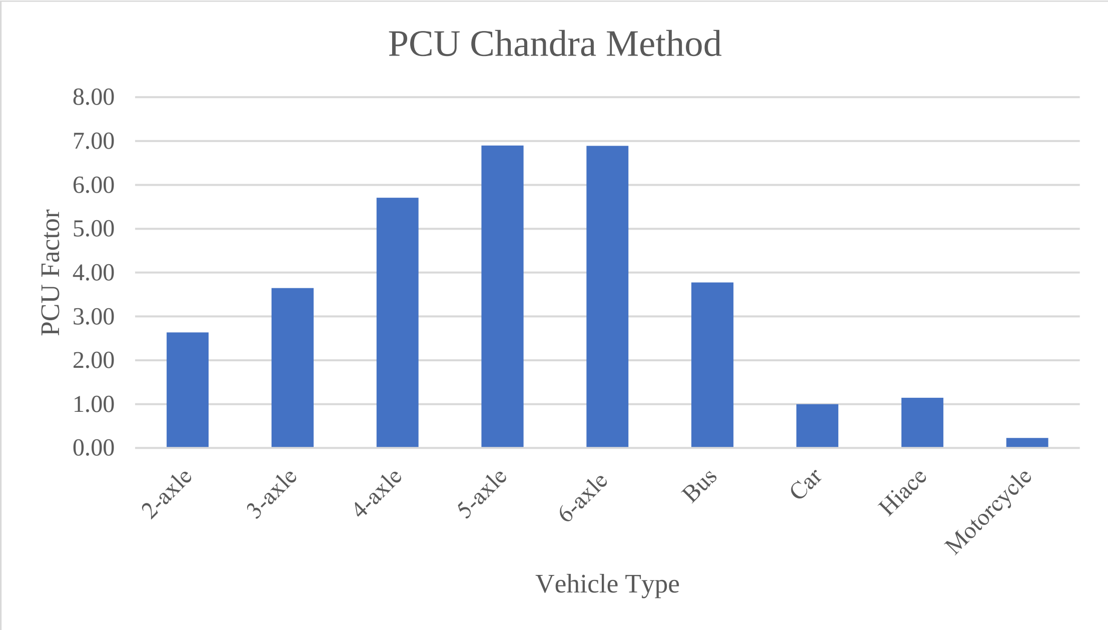



**Figure 6-1:** PCU Calculation using Chandra's Method for North-bound

**Table 6-2:** PCU Calculation using Chandra's Method for South-bound

| S/No | Vehicle Type | Average of Length | Average of Width | Average of Area | Ratio of Ai/Ac | Average speed ratio (Vc/Vi) | PCU Chandra Method |
|---|---|---|---|---|---|---|---|
| 1 | 2-axle | 7.26 | 2.22 | 16.14 | 2.21 | 1.16 | 2.56 |
| 2 | 3-axle | 10.00 | 2.27 | 22.67 | 3.10 | 1.35 | 4.17 |
| 3 | 4-axle | 15.50 | 2.20 | 34.10 | 4.66 | 1.16 | 5.42 |
| 4 | 5-axle | 17.20 | 2.30 | 39.56 | 5.41 | 1.41 | 7.65 |
| 5 | 6-axle | 17.23 | 2.62 | 45.09 | 6.16 | 1.28 | 7.90 |
| 6 | Bus | 11.30 | 2.47 | 27.87 | 3.81 | 0.81 | 3.10 |

| S/No | Vehicle Type | Average of Length | Average of Width | Average of Area | Ratio of Ai/Ac | Average speed ratio (Vc/Vi) | PCU Chandra Method |
|---|---|---|---|---|---|---|---|
| 8 | Car | 4.30 | 1.70 | 7.32 | 1.00 | 1.00 | 1.00 |
| 9 | Hiace | 4.69 | 1.75 | 8.18 | 1.12 | 1.02 | 1.14 |
| 7 | Motorcycle | 1.90 | 0.75 | 1.42 | 0.19 | 1.16 | 0.23 |

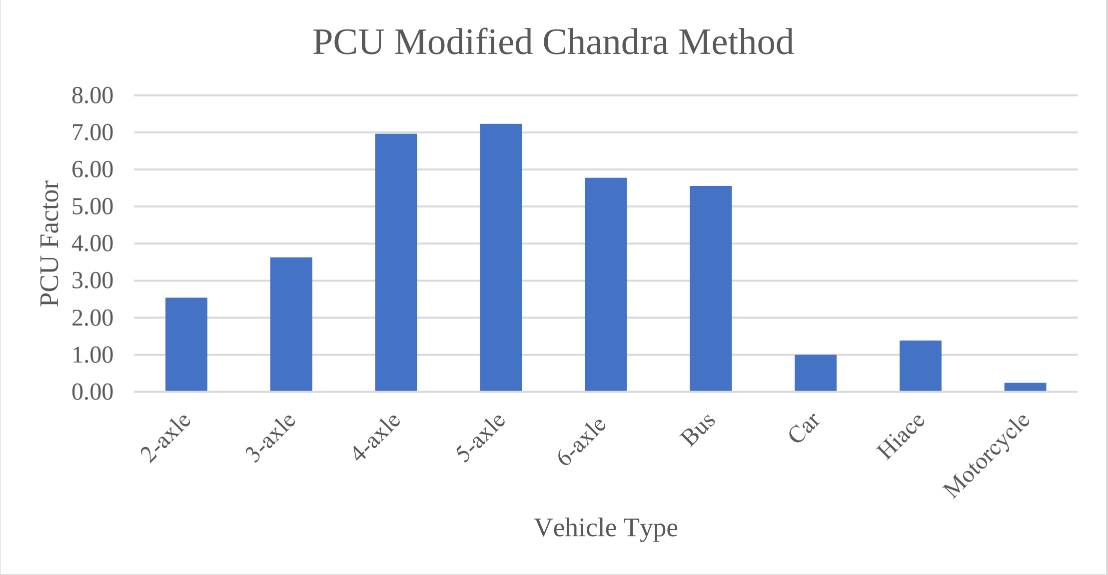



**Figure 6-2:** PCU Calculation using Chandra's Method for South-bound

Chandra's Method is used widely in developing countries. The results in the above illustrations validate that this method works well in heterogeneous traffic. PCU calculated for different vehicles shows a gradual increase as its Projected area and speed ratio increase. This method gives a slightly higher value for 3-axle trucks and above.

## 1.2 Speed Method (Modified Chandra's Method)

The speed Method (Modified Chandra's Method) uses Speed, headway, and Projected area for the calculation of Passenger Car Equivalent (PCE). It uses the speed of the particular vehicle type, its headway, and the projected area of that vehicle. Modified Chandra's Method is used to calculate PCE for Data Collection Point (DCP) at Mullah Mansoor. The vehicle's dimension is measured in different areas in Rawalpindi, Islamabad, and Peshawar. The speed of the vehicles is determined for each vehicle class by taking the average of the particular vehicle type for a three-hour traffic speed data on different days. The headway for each type of vehicle is calculated in the same way as the average speed. Table 6-3 and Figure 6-3 show the PCU factor calculated for Northbound on N-5 while Table 6-4 and Figure 6-4 show PCU factors calculated for Southbound on N-5 using Modified Chandra’s Method.

**Table 6-3:** PCU Calculation using Modified Chandra's Method for North-bound

| S/No | Vehicle Type | Average of Length | Average of Width | Average of Area | Ratio of (Ai/Ac) | Average speed ratio (Vc/Vi) | Average Headway ratio (hi/hc) | PCU Modified Chandra Method |
|---|---|---|---|---|---|---|---|---|
| 1 | 2-axle | 7.26 | 2.22 | 16.14 | 2.21 | 1.19 | 0.96 | 2.54 |
| 2 | 3-axle | 10.00 | 2.27 | 22.67 | 3.10 | 1.18 | 1.00 | 3.63 |
| 3 | 4-axle | 15.50 | 2.20 | 34.10 | 4.66 | 1.22 | 1.22 | 6.96 |
| 4 | 5-axle | 17.20 | 2.30 | 39.56 | 5.41 | 1.28 | 1.05 | 7.23 |
| 5 | 6-axle | 17.23 | 2.62 | 45.09 | 6.16 | 1.12 | 0.84 | 5.77 |
| 6 | Bus | 11.30 | 2.47 | 27.87 | 3.81 | 0.99 | 1.47 | 5.55 |
| 8 | Car | 4.30 | 1.70 | 7.32 | 1.00 | 1.00 | 1.00 | 1.00 |
| 9 | HiAce | 4.69 | 1.75 | 8.18 | 1.12 | 1.02 | 1.21 | 1.38 |
| 7 | Motorcycle | 1.90 | 0.75 | 1.42 | 0.19 | 1.18 | 1.06 | 0.24 |

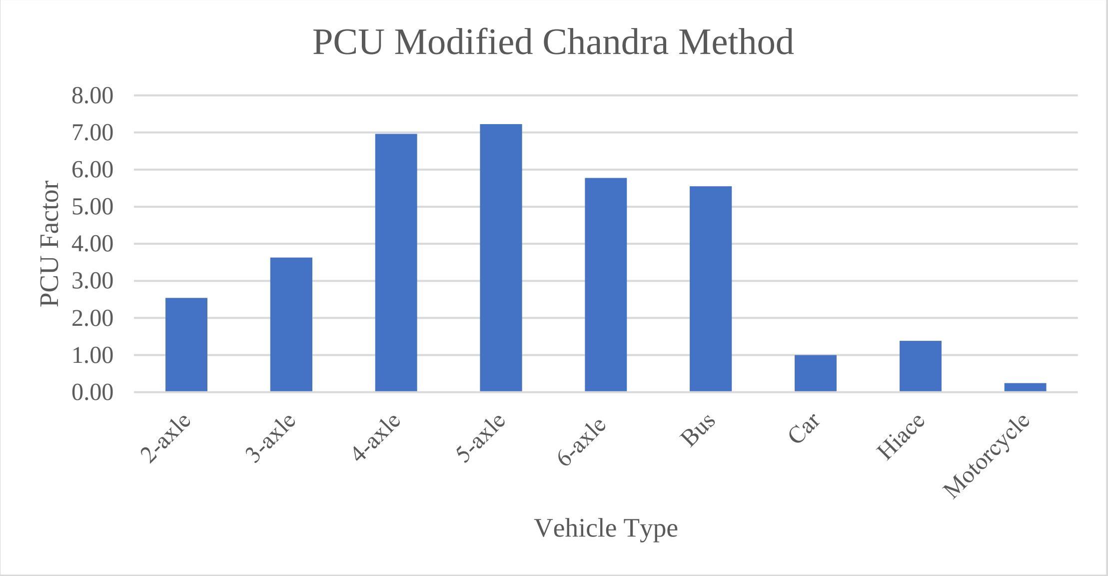



**Figure 6-3:** PCU Calculation using Modified Chandra's Method for North-bound

**Table 6-4:** PCU Calculation using Chandra's Method for South-bound

| S/No | Vehicle Type | Average of Length | Average of Width | Average of Area | Ratio of Ai/Ac | Average speed ratio (Vc/Vi) | Average Headway ratio (hi/hc) | PCU Modified Chandra Method |
|---|---|---|---|---|---|---|---|---|
| 1 | 2-axle | 7.26 | 2.22 | 16.14 | 2.21 | 1.16 | 0.95 | 2.44 |
| 2 | 3-axle | 10.00 | 2.27 | 22.67 | 3.10 | 1.35 | 1.10 | 4.59 |
| 3 | 4-axle | 15.50 | 2.20 | 34.10 | 4.66 | 1.16 | 0.80 | 4.36 |
| 4 | 5-axle | 17.20 | 2.30 | 39.56 | 5.41 | 1.41 | 0.69 | 5.28 |
| 5 | 6-axle | 17.23 | 2.62 | 45.09 | 6.16 | 1.28 | 0.95 | 7.50 |
| 6 | Bus | 11.30 | 2.47 | 27.87 | 3.81 | 0.81 | 0.67 | 2.07 |
| 8 | Car | 4.30 | 1.70 | 7.32 | 1.00 | 1.00 | 1.00 | 1.00 |
| 9 | Hiace | 4.69 | 1.75 | 8.18 | 1.12 | 1.02 | 0.70 | 0.79 |
| 7 | Motorcycle | 1.90 | 0.75 | 1.42 | 0.19 | 1.16 | 0.99 | 0.22 |

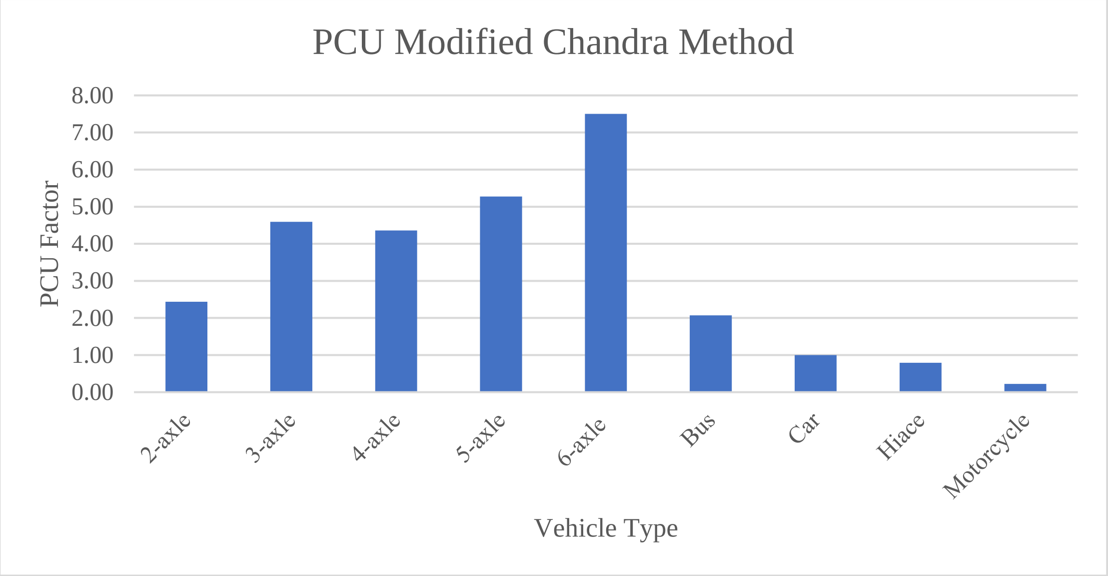



**Figure 6-4:** PCU Calculation using Chandra's Method for South-bound

Modified Chandra's Method is used widely in developing countries. The results in the above illustrations validate that this method works well in heterogeneous traffic. PCU calculated for different vehicles shows a gradual increase as its Projected area and speed ratio increase. This method gives a slightly higher value for 5 and 6-axle trucks.

### 1.3 Simulation Method (Equal Density Method)

Different Simulation techniques and software are in use to imitate the real field traffic flow condition. PTV VISSIM is a powerful microsimulation software and a useful tool that is used in this research work. The software is used to determine density at different flow conditions and different volumes for all four Data Collection Points (DCPs). Once, the density for the mixed flow (In situ flow volume) condition is determined, the Equal Density Method (EDM) is used to calculate Passenger Car Unit. One of the equal impendence methods is the equal density method which uses vehicle density to calculate Passenger Car Unit (PCU). It is the same method used to calculate the equivalent truck factor in Highway Capacity Manual 2010. It identifies the density for the Subject traffic flow which gives the same density as the Base and Mixed flow. The following sub-heads gives the results of equal density method for the four DCP.

### 1.3.1 EDM-Results for N-5

There is a total of the 4-lanes present in both directions of the carriageway. Each lane of the carriageway has a width of 3.65 meters. The internal shoulders are approximately 0.6 meters on both sides of the median while the outer shoulder is approximately 2 meters. The median is 5.5 meters wide. The traffic flow comprised almost three-quarter of Passenger Cars, followed by motorcycles which make up 7.69% of traffic. 2-axle trucks are also present in adequate numbers on the road. 5-axle and 6-axle trucks make the least of the traffic composition.

The estimated Passenger Car Unit determined for N-5 is given in Table 6-5. It can be seen that the values of PCU are a bit on the higher end of the PCU factor estimated by the National Transportation and Research Centre (NTRC). It is due to the variation in traffic flow characteristics over the last two decades. Table 6-5 shows the same Passenger Car Unit factor for N-5 in a graphical illustration.

**Table 6-5:** Estimated PCU factors for Different Vehicle types on N-5

| S/No. | Vehicle Type | Estimated PCU Factor |
|---|---|---|
| 1 | Bike | 0.48611612 |
| 2 | HiAce | 1.51827605 |
| 3 | Bus | 2.568231842 |
| 4 | 2-axle Truck | 1.779078774 |
| 5 | 3-axle Truck | 3.100027632 |
| 6 | 4-axle Truck | 3.636447734 |
| 7 | 5-axle Truck | 4.177552727 |
| 8 | 6-axle Truck | 4.723404255 |

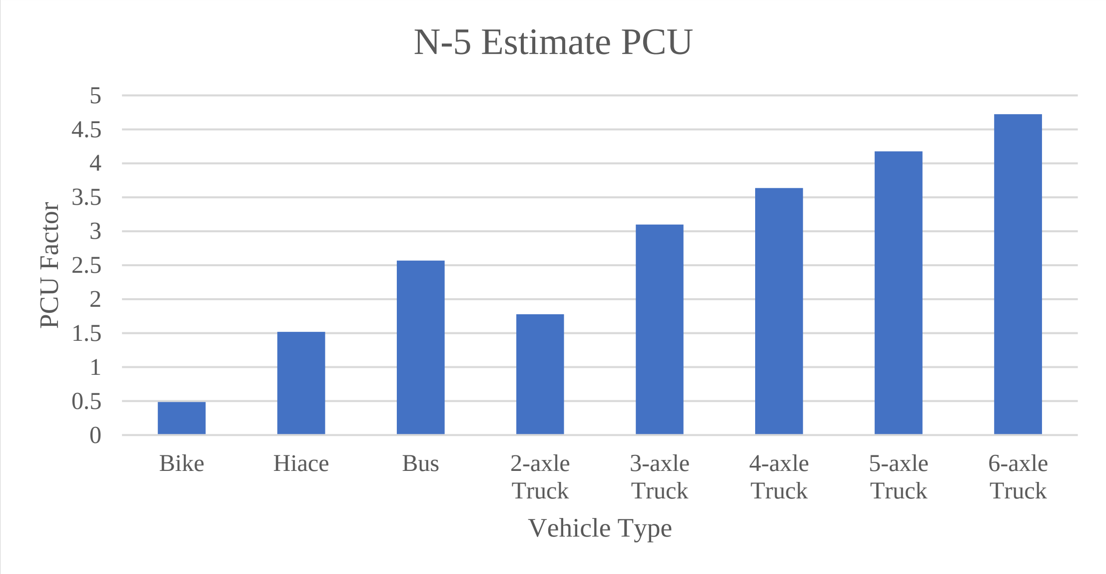



**Figure 6-5:** Estimated PCU factors for Different Vehicle types on N-5

This study shows the PCU factor for Bike is 0.486, for HiAce it is 1.518, for Bus it is 2.568, for 2-axle the value is 1.779, for 3-axle value is 3.100, for 4-axle its value is 3.636, 5-axle value is 4.177 and 6-axle 4.723.

**Table 6-6:** Base, Mixed, and subject flow for 2-axle truck on N-5

| Volume | Base flow (Car only) | Mixed flow (In Situ) | Subject flow |
|---|---|---|---|
| 20 | 0.227703318 | 0.249701545 | 0.251857502 |
| 150 | 2.029052091 | 2.200679591 | 2.250824325 |
| 400 | 5.513639591 | 6.066957955 | 6.229096638 |
| 750 | 10.28162277 | 11.475039 | 11.86780426 |
| 800 | 10.94195459 | 12.22822132 | 12.65116643 |
| 850 | 11.60831295 | 12.9960775 | 13.47404172 |
| 900 | 12.30920155 | 13.79786568 | 14.29520647 |
| 950 | 12.91824341 | 14.55250927 | 15.0479576 |
| 1000 | 13.69590909 | 15.45542095 | 15.99391856 |
| 1050 | 14.44395595 | 16.30665259 | 16.89610906 |
| 1100 | 15.28456895 | 17.31226855 | 17.93547598 |
| 1150 | 15.96848177 | 18.12104309 | 18.76973573 |
| 1200 | 16.71488173 | 19.05047336 | 19.75906778 |
| 1250 | 17.47578073 | 19.93911114 | 20.72662139 |

| Volume | Base flow (Car only) | Mixed flow (In Situ) | Subject flow |
|---|---|---|---|
| 1500 | 20.75730132 | 24.07624305 | 25.05137964 |
| 2000 | 27.51019182 | 32.90407068 | 34.29536838 |
| 2500 | 34.22188755 | 42.23457645 | 43.7321338 |
| 3000 | 41.84441318 | 53.22437814 | 54.73480332 |

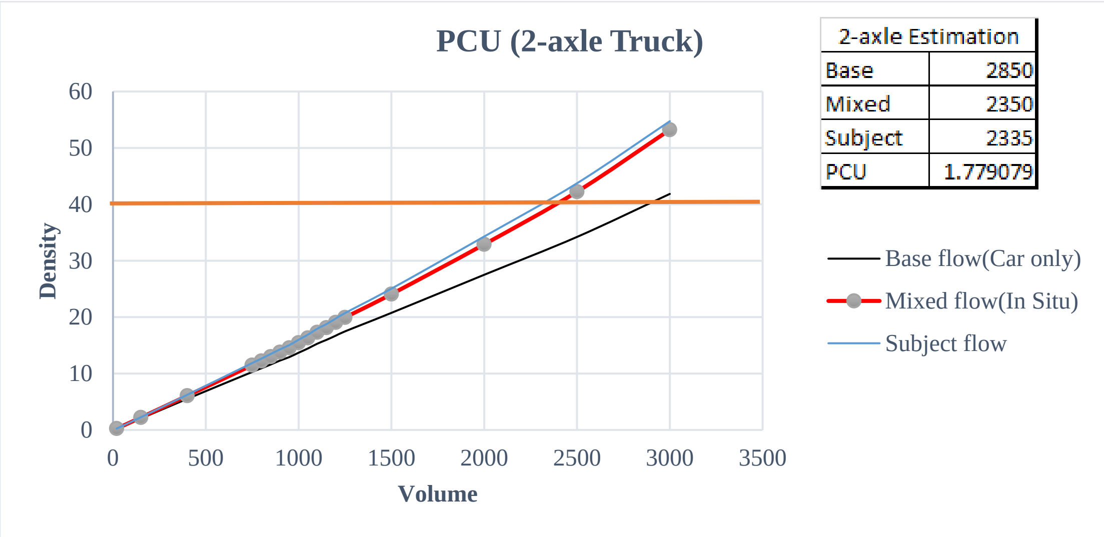



**Figure 6-6:** Base, Mixed and subject flow for 2-axle truck on N-5

Table 6-6 shows the density estimated using PTV VISSIM for different types of flows and different volumes. The data of the table is plotted on a graph in Figure 6-6. It is clear from the figure that the Volume density curve is curvilinear. A density of 40 vehicles per hour per lane is taken to find the volume of base, mixed and subject flow. For base flow, the volume is 2850 vehicles per hour. For mixed flow, the value is 2350 vehicle per hour while for subject flow it is 2335 vehicle per hour. The Passenger Car Unit (PCU) come out to be 1.779.

The above data in Table 6-6: Base, Mixed, and subject flow for 2-axle truck on N-5 and Figure 6-6 is for 2-axle trucks only as a sample. **Appendix A** & **Appendix B** contains the detail for each vehicle types separately.

### 1.3.2 EDM-Results for M-1

There are a total of 6 lanes present in both directions of the carriageway. Each lane of the carriageway has a width of 3.65 meters. The internal shoulders are approximately 0.6 meters on both sides of the median. The median is 11 meters wide and a plantation of enough height is present which prevents the glare effect of vehicles moving in the opposite direction. A shoulder width of around 3 meters is present on both sides of the carriageway. The traffic flow comprised almost 71 percent of Passenger Cars, followed by HiAce which makes up 21 percent of traffic. 2,3 and 4-axle trucks are also present in adequate numbers on the road. 5-axle and 6-axle trucks make the least of the traffic composition.

The estimated Passenger Car Unit determined for M-1 is given in Figure 6-7. It can be seen that the values of PCU are a bit on the higher end of the PCU factor estimated by the National Transportation and Research Centre (NTRC). It is due to the variation in traffic flow characteristics over the last two decades. Figure 6-7 shows the same Passenger Car Unit factor for M-1 in a graphical illustration.

**Table 6-7:**Estimated PCU factors for Different Vehicle types on M-1

| S/No. | Vehicle Type | Estimated PCU Factor |
|---|---|---|
| 1 | Bike | - |
| 2 | Hiace | 1.38049405 |
| 3 | Bus | 2.407423351 |
| 4 | 2-axle Truck | 1.763485872 |
| 5 | 3-axle Truck | 2.797197428 |
| 6 | 4-axle Truck | 3.849327007 |
| 7 | 5-axle Truck | 4.382453069 |
| 8 | 6-axle Truck | 4.920371275 |

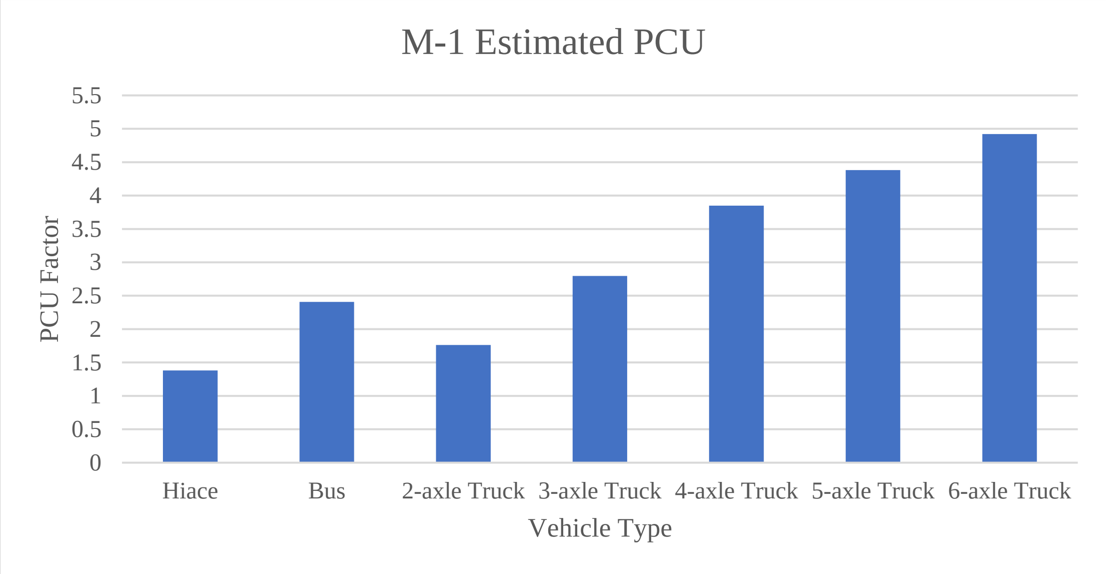



**Figure 6-7:** Estimated PCU factors for Different Vehicle types on M-1

This study shows the PCU factor for HiAce is 1.38, for Bus it is 2.407, for 2-axle the value is 1.763, for 3-axle its value is 2.797, for 4-axle its value is 3.849, 5-axle value is 4.382and 6-axle 4.920.

**Table 6-8:** Base, Mixed, and subject flow for 2-axle truck on M-1

| Volume | Base flow (Car only) | Mixed flow (In Situ) | Subject flow |
|---|---|---|---|
| 20 | 0.142070273 | 0.142664545 | 0.144804514 |
| 150 | 1.373335182 | 1.438426 | 1.46000239 |
| 400 | 4.017738864 | 4.1676155 | 4.230129733 |
| 750 | 7.680943773 | 7.9493535 | 8.068593803 |
| 800 | 8.194113227 | 8.507129273 | 8.634736212 |
| 850 | 8.714137136 | 9.0494525 | 9.185194288 |
| 900 | 9.224658091 | 9.549723364 | 9.692969214 |
| 1000 | 10.28879745 | 10.53833286 | 10.69640786 |
| 1100 | 11.43761782 | 11.83915368 | 12.01674099 |
| 1200 | 12.48487318 | 13.0147215 | 13.20994232 |
| 1300 | 13.62605795 | 14.25201268 | 14.46579287 |
| 1500 | 15.87427959 | 16.62433959 | 16.87370468 |
| 1800 | 19.02155645 | 20.11735414 | 20.41911445 |
| 2000 | 21.21176755 | 22.51207977 | 22.84976097 |

| Volume | Base flow (Car only) | Mixed flow (In Situ) | Subject flow |
|---|---|---|---|
| 2200 | 23.34614059 | 24.74839873 | 25.11962471 |
| 2500 | 26.31671655 | 28.36114814 | 28.78656536 |
| 2800 | 29.78946373 | 32.41411277 | 32.90032446 |
| 3000 | 32.26897464 | 35.24480641 | 35.77347851 |
| 3500 | 37.97905964 | 42.54590227 | 43.18409081 |
| 4000 | 43.68814314 | 50.45829018 | 51.21516453 |
| 5000 | 55.45828982 | 66.26383214 | 67.25778962 |
| 6000 | 68.09594186 | 86.93332618 | 88.23732607 |

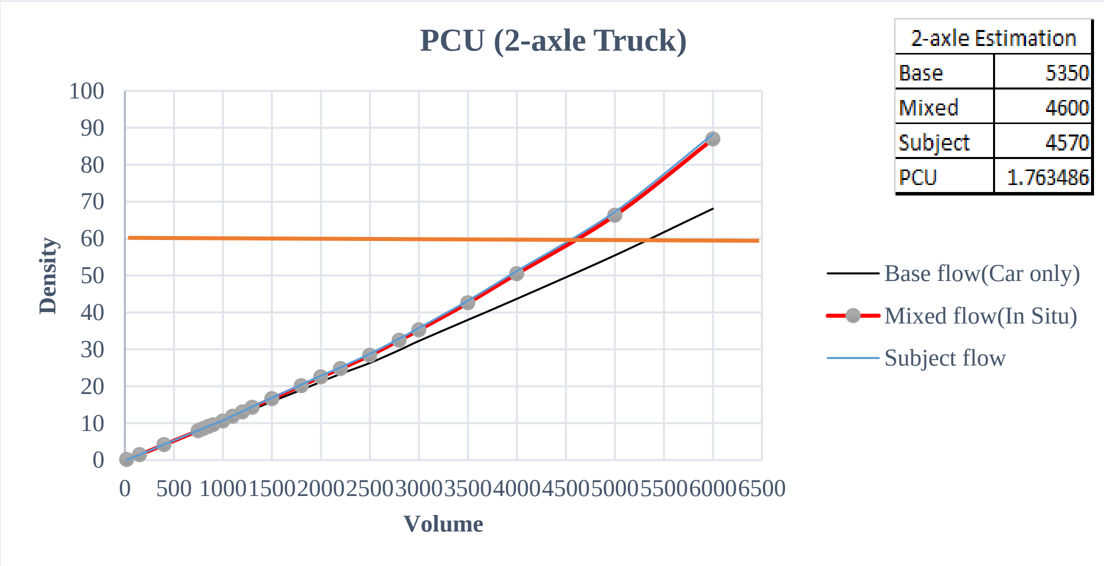



**Figure 6-8:** Base, Mixed, and subject flow for 2-axle truck on M-1

Figure 6-8 shows the density estimated using PTV VISSIM for different types of flows and different volumes. The data of the table is plotted on a graph in Figure 6-8. It is clear from the figure that the Volume density curve is curvilinear. The density of 60 vehicle per hour per lane is taken to find the volume of base, mixed and subject flow. For base flow the volume is 5350 vehicle per hour. For mixed flow the value is 4600 vehicle per hour while for subject flow it is 4570 vehicle per hour. The Passenger Car Unit (PCU) come out to be 1.763.

The above data in Table 6-8 and Figure 6-8 is for 2-axle trucks only as a sample. **Appendix A** & **Appendix B** contains the detail for each vehicle types separately.

### 1.3.3 EDM-Results for N-35

There are a total of 2 lanes present in both directions of the carriageway. Each lane of the carriageway has a width of 3.65 meters. A shoulder width of 1 m is present on both sides of the carriageway. The traffic flow comprised almost 52 percent of Passenger Cars, 29 percent of Motorcycles, 8.7 percent of 2-axle trucks, and 3 percent of HiAce. Unlike the previous three locations this highway is two lane single carriageway road. The total percentage of heavy vehicles is around 14 percent.

The estimated Passenger Car Unit determined for N-35 is given in Table 6-9 and Figure 6-9. It can be seen that the values of PCU are a bit on the higher end of the PCU factor estimated by the National Transportation and Research Centre (NTRC). It is due to the variation in traffic flow characteristics over the last two decades.

**Table 6-9:** Estimated PCU factors for Different Vehicle types on N-35

| S/No. | Vehicle Type | Estimated PCU Factor |
|---|---|---|
| 1 | Bike | 0.70876109 |
| 2 | HiAce | 1.586485694 |
| 3 | Bus | 2.775748351 |
| 4 | 2-axle Truck | 1.881750905 |
| 5 | 3-axle Truck | 3.076513153 |
| 6 | 4-axle Truck | 3.987240217 |
| 7 | 5-axle Truck | 4.293659705 |
| 8 | 6-axle Truck | 4.910824604 |

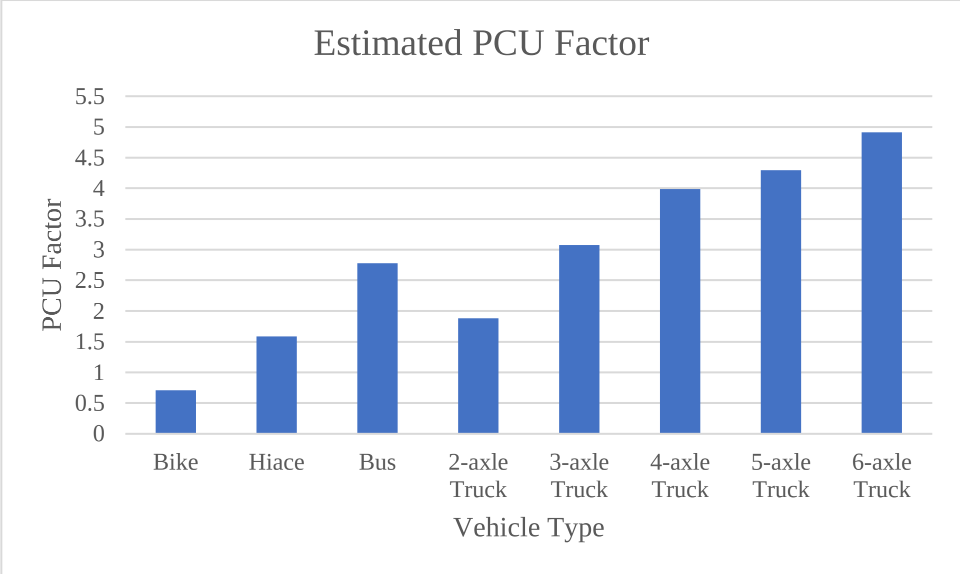



**Figure 6-9:** Estimated PCU factors for Different Vehicle types on N-35

This study shows the PCU factor for Bike is 0.708, for Hiace it is 1.568, for Bus it is 2.775, for 2-axle the value is 1.881, for 3-axle its value is 3.076, for 4-axle it value is 3.987, 5-axle value is 4.293 and 6-axle 4.910.

**Table 6-10:** Base, Mixed, and subject flow for 2-axle truck on N-35

| Volume | Base flow (Car only) | Mixed flow (In Situ) | Subject flow |
|---|---|---|---|
| 40 | 0.227159714 | 0.2576685 | 0.261791196 |
| 300 | 2.0334775 | 2.389127286 | 2.427353322 |
| 800 | 5.546810643 | 6.8076295 | 6.916551572 |
| 1500 | 10.38418771 | 13.29068643 | 13.50333741 |
| 1600 | 11.05735843 | 14.1962595 | 14.42339965 |
| 1700 | 11.74167879 | 15.094236 | 15.33574378 |
| 1800 | 12.45578971 | 16.09975457 | 16.35735064 |
| 2000 | 13.88123579 | 18.05040807 | 18.3392146 |
| 2200 | 15.51552164 | 20.31705736 | 20.64213027 |
| 2400 | 16.96530886 | 22.39611679 | 22.75445465 |
| 2600 | 18.45963679 | 24.50197829 | 24.89400994 |
| 3000 | 21.13951507 | 28.42984714 | 28.8847247 |
| 3600 | 25.526429 | 35.32467907 | 35.88987394 |

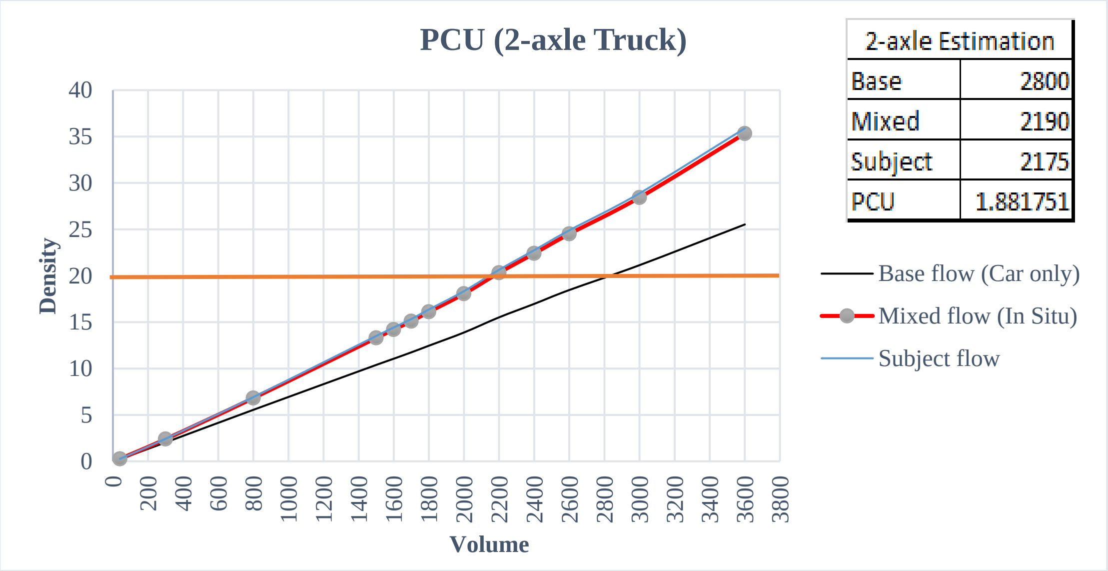



**Figure 6-10:** Base, Mixed and subject flow for 2-axle truck on N-35

Table 6-10 shows the density estimated using PTV VISSIM for different types of flows and different volumes. The data of the table is plotted on a graph in Figure 6-10. It is clear that from the figure that the Volume density curve is curvilinear. The density of 20 vehicle per hour per lane is taken to find the volume of base, mixed and subject flow. For base flow, the volume is 2800 vehicle per hour. For mixed flow the value is 2190 vehicle per hour while for subject flow it is 2175 vehicle per hour. The Passenger Car Unit (PCU) come out to be 1.881.

The above data in Table 6-10 and Figure 6-10 is for 2-axle trucks only as a sample. **Appendix A** & **Appendix B** contains the detail for each vehicle types separately.

### 1.3.4 EDM-Results for N-45

There are a total of 4 lanes present in both directions of the carriageway. Each lane of the carriageway has a width of 3.65 meters. The internal shoulders are approximately 0.3 meters on both sides of the median. The median is 0.6 meters wide and there are small plants present in the median. Earthen shoulders are present on both sides of the carriageway varying from 0.5 to 1.5 m. The traffic flow comprised almost 76 percent of Passenger Cars, followed by motorcycle which makes up 15 percent of traffic. 2-axle trucks are also present in adequate numbers on the road. 5-axle and 6-axle trucks make the least of the traffic composition.

**Table 6-11:** Estimated PCU factors for Different Vehicle types on N-45

| ` | Vehicle Type | Estimated PCU Factor |
|---|---|---|
| 1 | Bike | 0.484313018 |
| 2 | Hiace | 1.520094563 |
| 3 | Bus | 2.573734409 |
| 4 | 2-axle Truck | 1.781812383 |
| 5 | 3-axle Truck | 3.10739615 |
| 6 | 4-axle Truck | 3.645698427 |
| 7 | 5-axle Truck | 4.188702035 |
| 8 | 6-axle Truck | 4.736468832 |

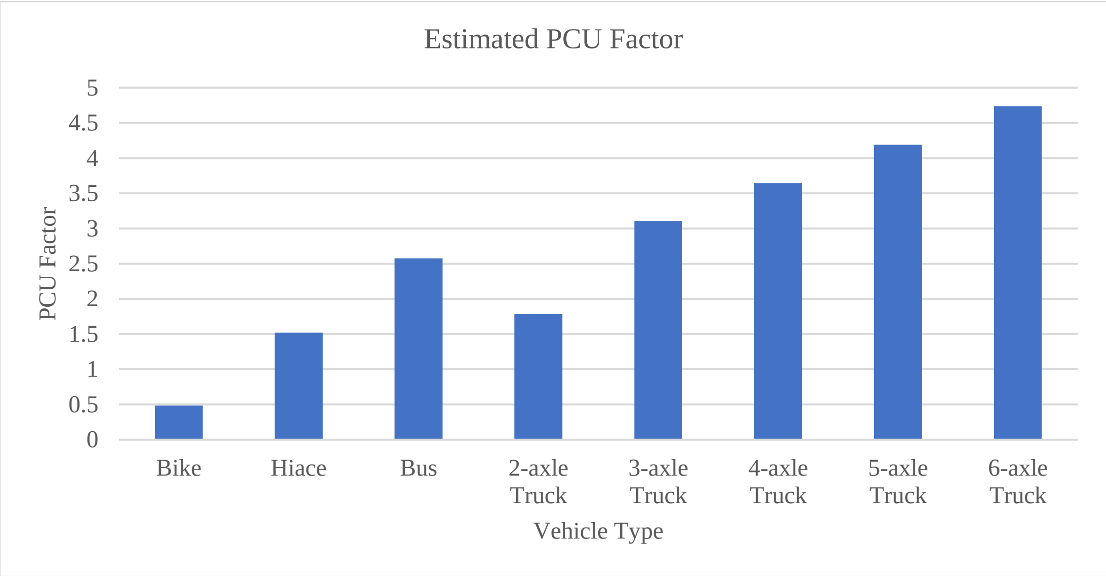



**Figure 6-11:** Estimated PCU factors for Different Vehicle types on N-45

This study shows the PCU factor for Bike is 0.484, for Hiace it is 1.520, for Bus it is 2.573, for 2-axle the value is 1.782, for 3-axle its value is 3.107, for 4-axle its value is 3.645, 5-axle value is 4.188 and 6-axle 4.736.

**Table 6-12:** Base, Mixed, and subject flow for 2-axle truck on N-45

| Volume | Base flow (Car only) | Mixed flow (In Situ) | Subject flow |
|---|---|---|---|
| 20 | 0.227703318 | 0.249701545 | 0.250644502 |
| 150 | 2.029052091 | 2.200679591 | 2.249611325 |
| 400 | 5.513639591 | 6.066957955 | 6.227883638 |
| 750 | 10.28162277 | 11.475039 | 11.86659126 |
| 800 | 10.94195459 | 12.22822132 | 12.64995343 |
| 850 | 11.60831295 | 12.9960775 | 13.47282872 |
| 900 | 12.30920155 | 13.79786568 | 14.29399347 |
| 950 | 12.91824341 | 14.55250927 | 15.0467446 |
| 1000 | 13.69590909 | 15.45542095 | 15.99270556 |
| 1050 | 14.44395595 | 16.30665259 | 16.89489606 |
| 1100 | 15.28456895 | 17.31226855 | 17.93426298 |
| 1150 | 15.96848177 | 18.12104309 | 18.76852273 |
| 1200 | 16.71488173 | 19.05047336 | 19.75785478 |
| 1250 | 17.47578073 | 19.93911114 | 20.72540839 |
| 1500 | 20.75730132 | 24.07624305 | 25.05016664 |
| 2000 | 27.51019182 | 32.90407068 | 34.29415538 |
| 2500 | 34.22188755 | 42.23457645 | 43.7309208 |
| 3000 | 41.84441318 | 53.22437814 | 54.73359032 |

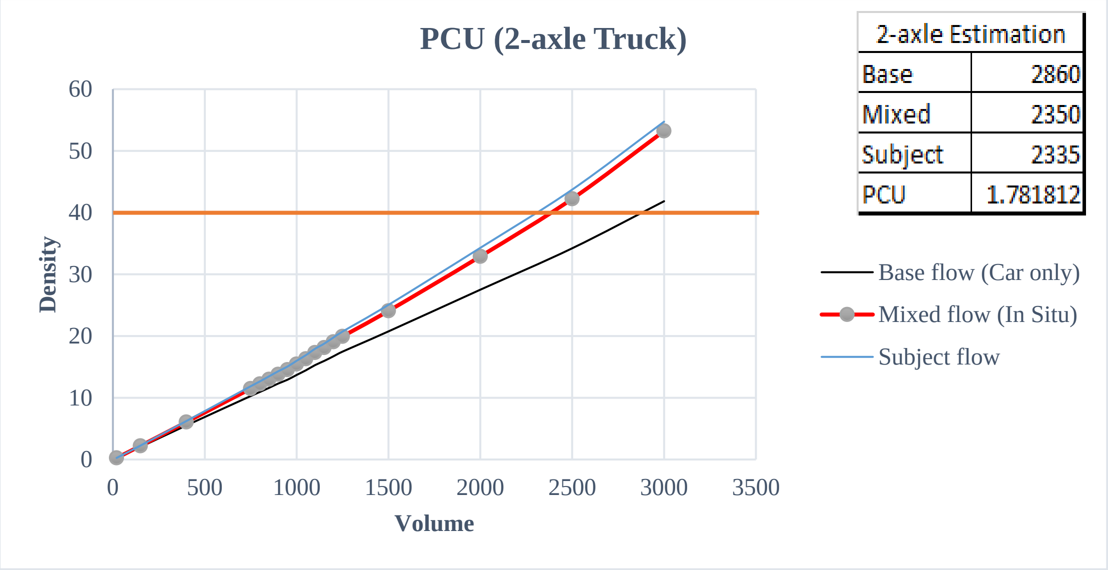



**Figure 6-12:** Base, Mixed, and subject flow for 2-axle truck on N-45

Table 6-12 shows the density estimated using PTV VISSIM for different types of flows and different volumes. The data of the table is plotted on the graph in Figure 6-12. It is clear from the figure that the Volume density curve is curvilinear. A density of 40 vehicle per hour per lane is taken to find the volume of base, mixed and subject flow. For base flow, the volume is 2860 vehicle per hour. For mixed flow, the value is 2350 vehicle per hour while for subject flow it is 2335 vehicle per hour. The Passenger Car Unit (PCU) come out to be 1.781.

The above data in Table 6-12 and Figure 6-12 is for 2-axle trucks only as a sample. **Appendix A** & **Appendix B** contains the detail for each vehicle types separately.

# CHAPTER 7: CONCLUSIONS & RECOMMENDATIONS

## 7.1 Conclusions

### 7.1.1 PCU calculation using Speed Methods

The methods used for PCU calculation in this research work give good results for the heterogeneous traffic condition of Pakistan. Both the speed methods give results that fall close together. The results for motorcycles, HiAce, and buses fall closer to the factors used in the design projects in Pakistan. On the other hand, the speed method gives higher values for heavy vehicles. The results of Chandra's method are better than the modified Chandra's method. This is against what one can expect because the modified Chandra method uses headway in addition to projected area and speed.

### 7.1.2 PCU calculation using Simulation Techniques

PTV VISSIM is widely used for the analysis and design of complicated traffic problems. The research utilizes PTV VISSIM to run a simulation that gives results. These results are later used in the Equal Density Method (EDM) to calculate Passenger Car Units. This is the same method used in Highway Capacity Manual (HCM) 2010 to calculate truck factors. This method is used to calculate PCU factors for both highways and freeways for different road geometric conditions and different volume levels. This method gives comfortable results. The results are given in Table 7-1 &Figure 7-1 below.

**Table 7-1:** Passenger Car Unit for four DCPs

| Vehicle Type | N-5 | N-45 | M-1 | N-35 | NTRC 92 |
|---|---|---|---|---|---|
| Bike | 0.49 | 0.48 | - | 0.71 | 0.25 |
| HiAce | 1.52 | 1.52 | 1.38 | 1.59 | 1.50 |
| Bus | 2.57 | 2.57 | 2.41 | 2.78 | 2.50 |

| Vehicle Type | N-5 | N-45 | M-1 | N-35 | NTRC 92 |
|---|---|---|---|---|---|
| 2-axle Truck | 1.78 | 1.78 | 1.76 | 1.88 | 1.50 |
| 3-axle Truck | 3.10 | 3.11 | 2.80 | 3.08 | 2.50 |
| 4-axle Truck | 3.64 | 3.65 | 3.85 | 3.99 | 3.50 |
| 5-axle Truck | 4.18 | 4.19 | 4.38 | 4.29 | 4.00 |
| 6-axle Truck | 4.72 | 4.74 | 4.92 | 4.91 | 4.00 |

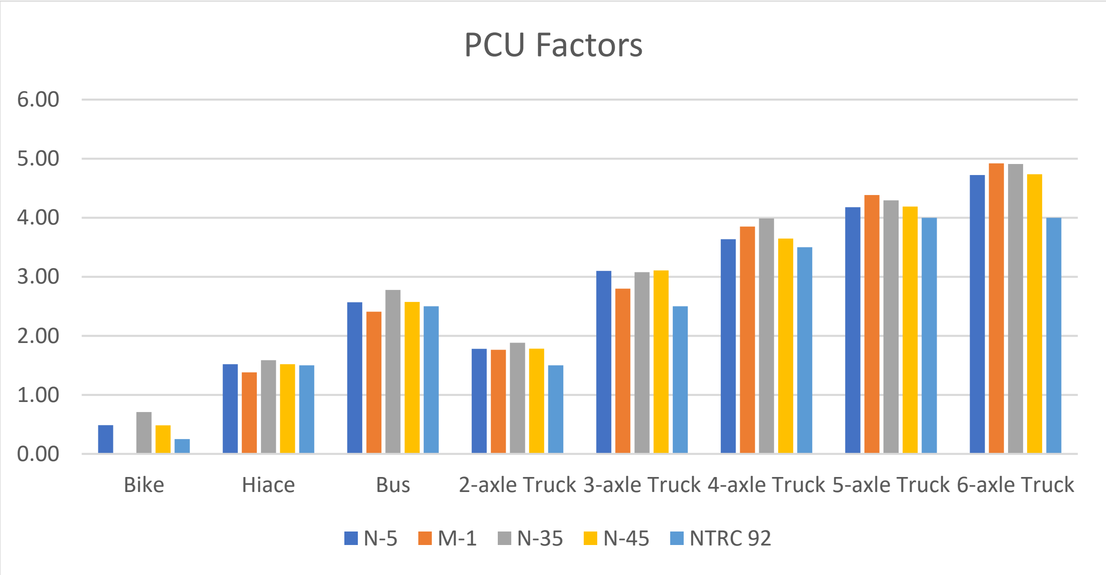



**Figure 7-1:** Passenger Car Unit for four DCPs

It can be seen that there is no abnormality in the results obtained from the Equal Density Method (EDM). The PCU for heavy vehicles increases gradually from 2-axle to 6-axle.

The Passenger Car Unit varies with different factors. Some of the factors include road class, speed, volume, and traffic composition. It is found that for high-volume traffic conditions, the same number of trucks has a greater influence on travel time in comparison with low-volume situations. Therefore, as the traffic volume increases the PCU of the truck increases. PCU of trucks increases with the increase in its percentage in the traffic stream if the volume remains constant. This is because the increase in heavy vehicle's proportion increases the congestion level in the traffic stream. It is found that if the traffic volume and its composition remain the same the PCU factor increase as the road width increase. The reason for this may be that the vehicles in the traffic stream maneuver more freely resulting in high PCU value. PCU decreases as the speed increases for the high percentage of trucks, while it increases with the increase in speed for the low percentage of trucks.

### 7.1.3 MetroCount@5600

The classified vehicle count data is collected using an automatic traffic tally device, i.e., the MetroCount@5600, which is considered more reliable compared to other video recording and decoding techniques. It was found that the area where there is the high number of overtaking maneuvers is not good for the use of MetroCount@5600 since it reduces the accuracy of classified counts. It is because there may be overtaking maneuvers at the location where the system is set up and the system can detect some other class of vehicle at the time of overtaking. An automatic pneumatic-tube-based traffic count device is chosen technique for classified traffic count, particularly for an extensive period of traffic monitoring exercises.

## 7.2 Recommendation

Some of the other factors which influence Passenger Car Unit (PCU) include road class, Level of Service (LOS), geometric factors (Carriageway width, Gradient, Horizontal curvature), and pavement condition. The research work is focused on the estimation of PCU for long route inter-city traffic on highways and freeways of the country. All the design firms in Pakistan use the PCU factor recommended by National Transportation Research Centre (NTRC). The factor is more than two decades old and a comprehensive study is needed in this regard. It is recommended to calculate separate PCU factors for intra-city traffic since their characteristic are completely different from those in inter-city traffic streams.

It is recommended to use different methods for PCU calculation which are common throughout the world. These methods include:

- Headway Method.
- Homogeneous co-efficient Method.
- Walker's method
- Multiple linear regression method
- Simultaneous equations method
- Huber Method

The current research study focuses primarily on the northern part of Pakistan. It is recommended to separately calculate the PCU factor for the Province of Sindh and Baluchistan which may give different results.

| **N-5 (near Mullah Mansoor):** Base flow, Mixed flow and Subject flow | | | | | | |
|---|---|---|---|---|---|---|
| **Volume** | **Density (Base flow)** | **Density (Mixed flow)** | **Density (Motorcycle Subject flow)** | **Density (HiAce Subject flow)** | **Density (Bus Subject flow)** | **Density (2-axle Subject flow)** |
| 20 | 0.228 | 0.250 | 0.244 | 0.256 | 0.256 | 0.252 |
| 150 | 2.029 | 2.201 | 2.167 | 2.256 | 2.260 | 2.251 |
| 400 | 5.514 | 6.067 | 5.970 | 6.219 | 6.233 | 6.229 |
| 750 | 10.282 | 11.475 | 11.290 | 11.762 | 11.797 | 11.868 |
| 800 | 10.942 | 12.228 | 12.036 | 12.534 | 12.574 | 12.651 |
| 850 | 11.608 | 12.996 | 12.792 | 13.321 | 13.365 | 13.474 |
| 900 | 12.309 | 13.798 | 13.583 | 14.143 | 14.179 | 14.295 |
| 950 | 12.918 | 14.553 | 14.318 | 14.916 | 14.956 | 15.048 |
| 1000 | 13.696 | 15.455 | 15.206 | 15.842 | 15.879 | 15.994 |
| 1050 | 14.444 | 16.307 | 16.044 | 16.714 | 16.756 | 16.896 |
| 1100 | 15.285 | 17.312 | 17.029 | 17.745 | 17.794 | 17.935 |
| 1150 | 15.968 | 18.121 | 17.818 | 18.574 | 18.630 | 18.770 |
| 1200 | 16.715 | 19.050 | 18.731 | 19.527 | 19.583 | 19.759 |
| 1250 | 17.476 | 19.939 | 19.616 | 20.438 | 20.502 | 20.727 |
| 1500 | 20.757 | 24.076 | 23.705 | 24.678 | 24.790 | 25.051 |
| 2000 | 27.510 | 32.904 | 32.419 | 33.727 | 33.935 | 34.295 |
| 2500 | 34.222 | 42.235 | 41.603 | 43.290 | 43.594 | 43.732 |
| 3000 | 41.844 | 53.224 | 52.477 | 54.555 | 55.021 | 54.735 |

| **N-5 (near Mullah Mansoor):** Base flow, Mixed flow and Subject flow | | | | | |
|---|---|---|---|---|---|
| **Volume** | **Density (Base flow)** | **Density (3-axle Subject flow)** | **Density (4-axle Subject flow)** | **Density (5-axle Subject flow)** | **Density (6-axle Subject flow)** |
| 20 | 0.228 | 0.255 | 0.255 | 0.255 | 0.255 |
| 150 | 2.029 | 2.278 | 2.278 | 2.278 | 2.278 |
| 400 | 5.514 | 6.305 | 6.305 | 6.306 | 6.306 |
| 750 | 10.282 | 12.012 | 12.017 | 12.025 | 12.026 |
| 800 | 10.942 | 12.805 | 12.809 | 12.814 | 12.817 |
| 850 | 11.608 | 13.638 | 13.644 | 13.649 | 13.649 |
| 900 | 12.309 | 14.470 | 14.480 | 14.480 | 13.651 |
| 950 | 12.918 | 15.231 | 15.239 | 15.238 | 14.482 |
| 1000 | 13.696 | 16.189 | 16.198 | 16.198 | 16.201 |
| 1050 | 14.444 | 17.102 | 17.113 | 17.120 | 17.126 |
| 1100 | 15.285 | 18.154 | 18.163 | 18.174 | 18.179 |
| 1150 | 15.968 | 18.999 | 19.012 | 19.032 | 19.034 |
| 1200 | 16.715 | 20.001 | 20.001 | 20.026 | 20.032 |
| 1250 | 17.476 | 20.980 | 21.001 | 21.019 | 21.023 |
| 1500 | 20.757 | 25.358 | 25.373 | 25.395 | 25.401 |
| 2000 | 27.510 | 34.718 | 34.759 | 34.803 | 34.801 |
| 2500 | 34.222 | 44.271 | 44.347 | 44.411 | 44.433 |
| 3000 | 41.844 | 55.426 | 55.509 | 55.614 | 55.689 |

| **M-1 (Near AWT interchange):** Base flow, Mixed flow and Subject flow | | | | | | |
|---|---|---|---|---|---|---|
| **Volume** | **Density (Base flow)** | **Density (Mixed flow)** | **Density (HiAce Subject flow)** | **Density (Bus Subject flow)** | **Density (2-axle Subject flow)** | **Density (3-axle Subject flow)** |
| 20 | 0.142 | 0.143 | 0.144 | 0.146 | 0.145 | 0.146 |
| 150 | 1.373 | 1.438 | 1.453 | 1.467 | 1.460 | 1.474 |
| 400 | 4.018 | 4.168 | 4.209 | 4.251 | 4.230 | 4.272 |
| 750 | 7.681 | 7.949 | 8.029 | 8.108 | 8.069 | 8.148 |
| 800 | 8.194 | 8.507 | 8.592 | 8.677 | 8.635 | 8.720 |
| 850 | 8.714 | 9.049 | 9.140 | 9.230 | 9.185 | 9.276 |
| 900 | 9.225 | 9.550 | 9.645 | 9.741 | 9.693 | 9.788 |
| 1000 | 10.289 | 10.538 | 10.644 | 10.749 | 10.696 | 10.802 |
| 1100 | 11.438 | 11.839 | 11.958 | 12.076 | 12.017 | 12.135 |
| 1200 | 12.485 | 13.015 | 13.145 | 13.275 | 13.210 | 13.340 |
| 1300 | 13.626 | 14.252 | 14.395 | 14.537 | 14.466 | 14.608 |
| 1500 | 15.874 | 16.624 | 16.791 | 16.957 | 16.874 | 17.040 |
| 1800 | 19.022 | 20.117 | 20.319 | 20.520 | 20.419 | 20.620 |
| 2000 | 21.212 | 22.512 | 22.737 | 22.962 | 22.850 | 23.075 |
| 2200 | 23.346 | 24.748 | 24.996 | 25.243 | 25.120 | 25.367 |
| 2500 | 26.317 | 28.361 | 28.645 | 28.928 | 28.787 | 29.070 |
| 2800 | 29.789 | 32.414 | 32.738 | 33.062 | 32.900 | 33.224 |
| 3000 | 32.269 | 35.245 | 35.597 | 35.950 | 35.773 | 36.126 |
| 3500 | 37.979 | 42.546 | 42.971 | 43.397 | 43.184 | 43.610 |
| 4000 | 43.688 | 50.458 | 50.963 | 51.467 | 51.215 | 51.720 |
| 5000 | 55.458 | 66.264 | 66.926 | 67.589 | 67.258 | 67.920 |
| 6000 | 68.096 | 86.933 | 87.803 | 88.672 | 88.237 | 89.107 |

| **M-1 (Near AWT interchange):** Base flow, Mixed flow and Subject flow | | | | | |
|---|---|---|---|---|---|
| **Volume** | **Density (Base flow)** | **Density (Mixed flow)** | **Density (4-axle Subject flow)** | **Density (5-axle Subject flow)** | **Density (6-axle Subject flow)** |
| 20 | 0.142 | 0.143 | 0.147 | 0.148 | 0.149 |
| 150 | 1.373 | 1.438 | 1.484 | 1.493 | 1.503 |
| 400 | 4.018 | 4.168 | 4.301 | 4.326 | 4.355 |
| 750 | 7.681 | 7.949 | 8.204 | 8.251 | 8.307 |
| 800 | 8.194 | 8.507 | 8.779 | 8.830 | 8.890 |
| 850 | 8.714 | 9.049 | 9.339 | 9.393 | 9.457 |
| 900 | 9.225 | 9.550 | 9.855 | 9.913 | 9.979 |
| 1000 | 10.289 | 10.538 | 10.876 | 10.939 | 11.013 |
| 1100 | 11.438 | 11.839 | 12.218 | 12.289 | 12.372 |
| 1200 | 12.485 | 13.015 | 13.431 | 13.509 | 13.600 |
| 1300 | 13.626 | 14.252 | 14.708 | 14.794 | 14.893 |
| 1500 | 15.874 | 16.624 | 17.156 | 17.256 | 17.372 |
| 1800 | 19.022 | 20.117 | 20.761 | 20.882 | 21.023 |
| 2000 | 21.212 | 22.512 | 23.232 | 23.368 | 23.525 |
| 2200 | 23.346 | 24.748 | 25.540 | 25.689 | 25.862 |
| 2500 | 26.317 | 28.361 | 29.269 | 29.439 | 29.637 |
| 2800 | 29.789 | 32.414 | 33.451 | 33.646 | 33.873 |
| 3000 | 32.269 | 35.245 | 36.373 | 36.584 | 36.831 |
| 3500 | 37.979 | 42.546 | 43.907 | 44.163 | 44.460 |
| 4000 | 43.688 | 50.458 | 52.073 | 52.376 | 52.729 |
| 5000 | 55.458 | 66.264 | 68.384 | 68.782 | 69.246 |
| 6000 | 68.096 | 86.933 | 89.715 | 90.237 | 90.845 |

| **N-35 (near Jahrikass Interchange):** Base flow, Mixed flow and Subject flow | | | | | | |
|---|---|---|---|---|---|---|
| **Volume** | **Density (Base flow)** | **Density (Mixed flow)** | **Density (Motorcycle Subject flow)** | **Density (HiAce Subject flow)** | **Density (Bus Subject flow)** | **Density (2-axle Subject flow)** |
| 40 | 0.227 | 0.258 | 0.255 | 0.262 | 0.263 | 0.262 |
| 300 | 2.033 | 2.389 | 2.365 | 2.425 | 2.437 | 2.427 |
| 800 | 5.547 | 6.808 | 6.740 | 6.910 | 6.944 | 6.917 |
| 1500 | 10.384 | 13.291 | 13.158 | 13.490 | 13.557 | 13.503 |
| 1600 | 11.057 | 14.196 | 14.054 | 14.409 | 14.480 | 14.423 |
| 1700 | 11.742 | 15.094 | 14.943 | 15.321 | 15.396 | 15.336 |
| 1800 | 12.456 | 16.100 | 15.939 | 16.341 | 16.422 | 16.357 |
| 2000 | 13.881 | 18.050 | 17.870 | 18.321 | 18.411 | 18.339 |
| 2200 | 15.516 | 20.317 | 20.114 | 20.622 | 20.723 | 20.642 |
| 2400 | 16.965 | 22.396 | 22.172 | 22.732 | 22.844 | 22.754 |
| 2600 | 18.460 | 24.502 | 24.257 | 24.870 | 24.992 | 24.894 |
| 3000 | 21.140 | 28.430 | 28.146 | 28.856 | 28.998 | 28.885 |
| 3600 | 25.526 | 35.325 | 34.971 | 35.855 | 36.031 | 35.890 |

| **N-35 (near Jahrikass Interchange):** Base flow, Mixed flow and Subject flow | | | | | | |
|---|---|---|---|---|---|---|
| **Volume** | **Density (Base flow)** | **Density (Mixed flow)** | **Density (3-axle Subject flow)** | **Density (4-axle Subject flow)** | **Density (5-axle Subject flow)** | **Density (6-axle Subject flow)** |
| 40 | 0.227 | 0.258 | 0.263 | 0.264 | 0.265 | 0.271 |
| 300 | 2.033 | 2.389 | 2.442 | 2.449 | 2.461 | 2.466 |
| 800 | 5.547 | 6.808 | 6.957 | 6.978 | 7.012 | 7.017 |
| 1500 | 10.384 | 13.291 | 13.583 | 13.623 | 13.689 | 13.621 |
| 1600 | 11.057 | 14.196 | 14.509 | 14.551 | 14.622 | 14.562 |
| 1700 | 11.742 | 15.094 | 15.426 | 15.472 | 15.547 | 15.504 |
| 1800 | 12.456 | 16.100 | 16.454 | 16.502 | 16.583 | 16.515 |
| 2000 | 13.881 | 18.050 | 18.448 | 18.502 | 18.592 | 18.515 |
| 2200 | 15.516 | 20.317 | 20.764 | 20.825 | 20.927 | 20.831 |

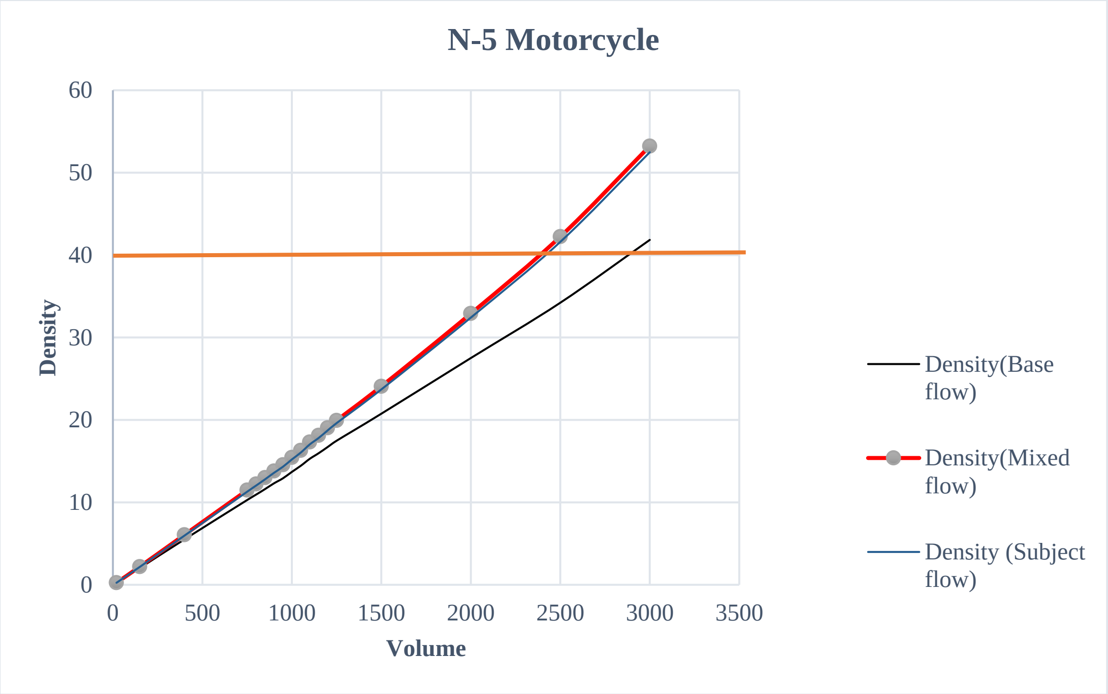
| **N-35 (near Jahrikass Interchange):** Base flow, Mixed flow and Subject flow | | | | | | |
|---|---|---|---|---|---|---|
| **Volume** | **Density (Base flow)** | **Density (Mixed flow)** | **Density (3-axle Subject flow)** | **Density (4-axle Subject flow)** | **Density (5-axle Subject flow)** | **Density (6-axle Subject flow)** |
| 2400 | 16.965 | 22.396 | 22.889 | 22.956 | 23.068 | 22.940 |
| 2600 | 18.460 | 24.502 | 25.041 | 25.115 | 25.237 | 25.075 |
| 3000 | 21.140 | 28.430 | 29.055 | 29.141 | 29.283 | 29.073 |
| 3600 | 25.526 | 35.325 | 36.102 | 36.208 | 36.384 | 36.914 |

| **N-45 (near Risalpur Cantt):** Base flow, Mixed flow and Subject flow | | | | | | |
|---|---|---|---|---|---|---|
| **Volume** | **Density (Base flow)** | **Density (Mixed flow)** | **Density (Motorcycle Subject flow)** | **Density (HiAce Subject flow)** | **Density (Bus Subject flow)** | **Density (2-axle Subject flow)** |
| 20 | 0.228 | 0.250 | 0.244 | 0.256 | 0.256 | 0.252 |
| 150 | 2.029 | 2.201 | 2.167 | 2.256 | 2.260 | 2.251 |
| 400 | 5.514 | 6.067 | 5.970 | 6.219 | 6.233 | 6.229 |
| 750 | 10.282 | 11.475 | 11.290 | 11.762 | 11.797 | 11.868 |
| 800 | 10.942 | 12.228 | 12.036 | 12.534 | 12.574 | 12.651 |
| 850 | 11.608 | 12.996 | 12.792 | 13.321 | 13.365 | 13.474 |
| 900 | 12.309 | 13.798 | 13.583 | 14.143 | 14.179 | 14.295 |
| 950 | 12.918 | 14.553 | 14.318 | 14.916 | 14.956 | 15.048 |
| 1000 | 13.696 | 15.455 | 15.206 | 15.842 | 15.879 | 15.994 |
| 1050 | 14.444 | 16.307 | 16.044 | 16.714 | 16.756 | 16.896 |
| 1100 | 15.285 | 17.312 | 17.029 | 17.745 | 17.794 | 17.935 |
| 1150 | 15.968 | 18.121 | 17.818 | 18.574 | 18.630 | 18.770 |

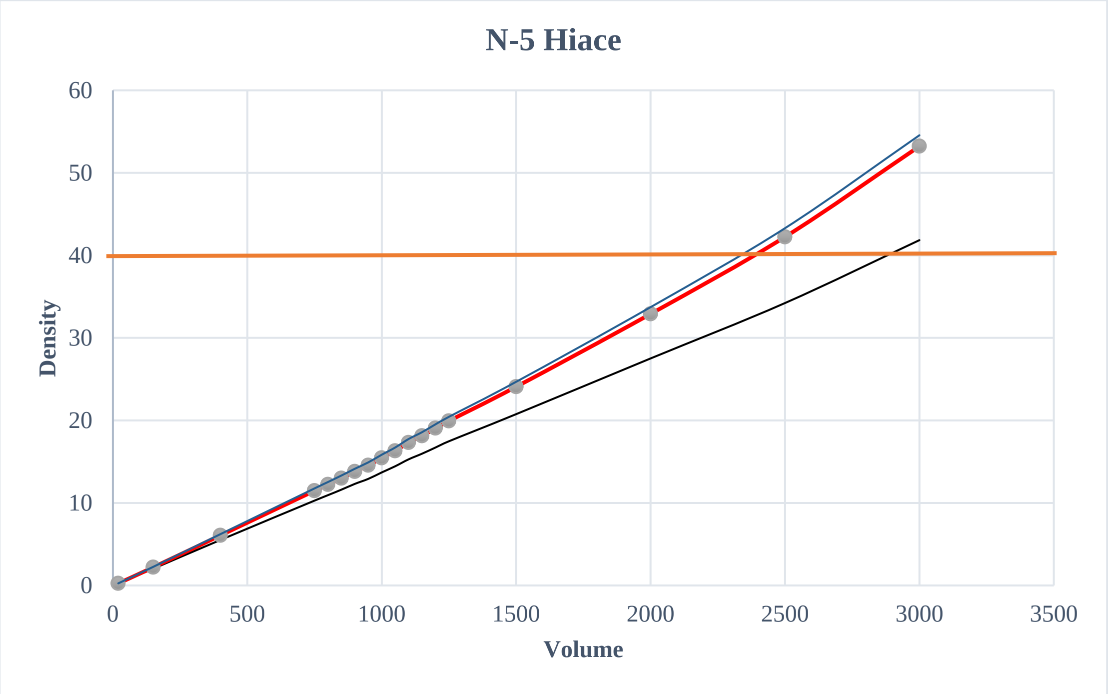
| **N-45 (near Risalpur Cantt):** Base flow, Mixed flow and Subject flow | | | | | | |
|---|---|---|---|---|---|---|
| **Volume** | **Density (Base flow)** | **Density (Mixed flow)** | **Density (Motorcycle Subject flow)** | **Density (HiAce Subject flow)** | **Density (Bus Subject flow)** | **Density (2-axle Subject flow)** |
| 1200 | 16.715 | 19.050 | 18.731 | 19.527 | 19.583 | 19.759 |
| 1250 | 17.476 | 19.939 | 19.616 | 20.438 | 20.502 | 20.727 |
| 1500 | 20.757 | 24.076 | 23.705 | 24.678 | 24.790 | 25.051 |
| 2000 | 27.510 | 32.904 | 32.419 | 33.727 | 33.935 | 34.295 |
| 2500 | 34.222 | 42.235 | 41.603 | 43.290 | 43.594 | 43.732 |
| 3000 | 41.844 | 53.224 | 52.477 | 54.555 | 55.021 | 54.735 |

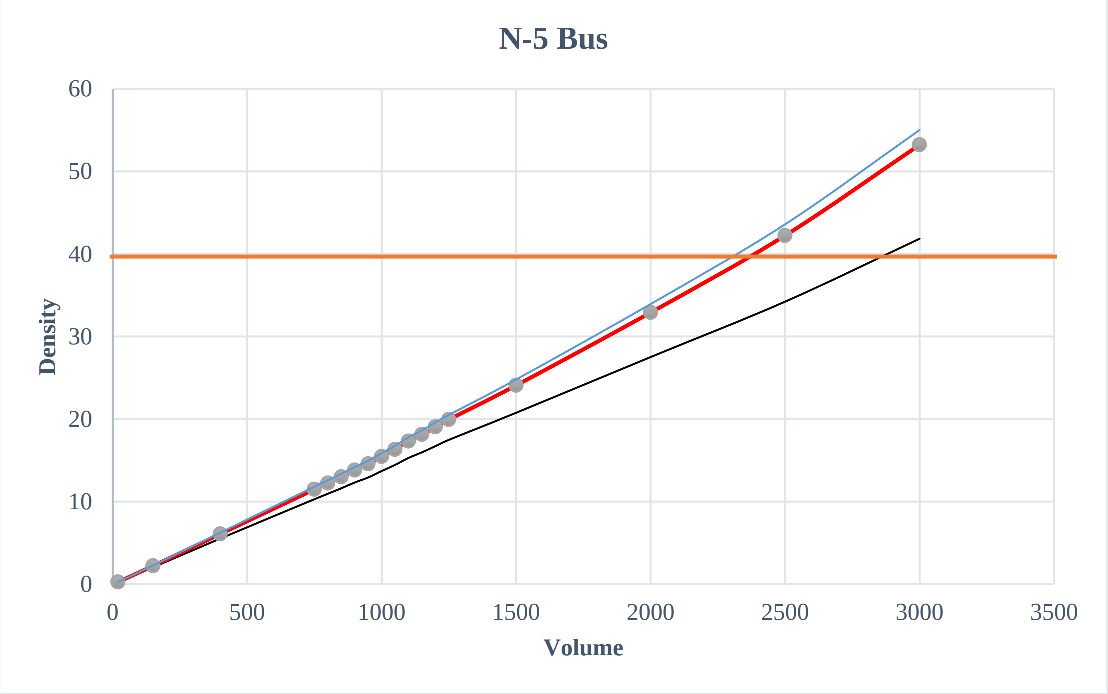
| **N-45 (near Risalpur Cantt):** Base flow, Mixed flow and Subject flow | | | | | |
|---|---|---|---|---|---|
| **Volume** | **Density (Base flow)** | **Density (3-axle Subject flow)** | **Density (4-axle Subject flow)** | **Density (5-axle Subject flow)** | **Density (6-axle Subject flow)** |
| 20 | 0.228 | 0.255 | 0.255 | 0.255 | 0.255 |
| 150 | 2.029 | 2.278 | 2.278 | 2.278 | 2.278 |
| 400 | 5.514 | 6.305 | 6.305 | 6.306 | 6.306 |
| 750 | 10.282 | 12.012 | 12.017 | 12.025 | 12.026 |
| 800 | 10.942 | 12.805 | 12.809 | 12.814 | 12.817 |
| 850 | 11.608 | 13.638 | 13.644 | 13.649 | 13.649 |
| 900 | 12.309 | 14.470 | 14.480 | 14.480 | 13.651 |
| 950 | 12.918 | 15.231 | 15.239 | 15.238 | 14.482 |
| 1000 | 13.696 | 16.189 | 16.198 | 16.198 | 16.201 |

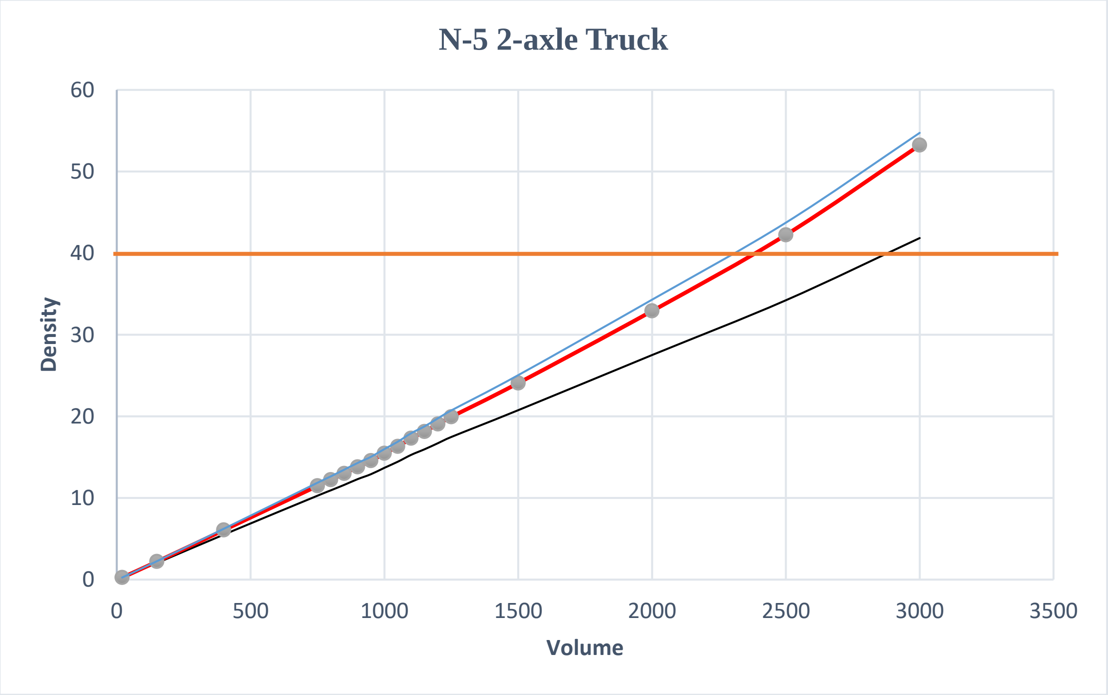
| **N-45 (near Risalpur Cantt):** Base flow, Mixed flow and Subject flow | | | | | |
|---|---|---|---|---|---|
| **Volume** | **Density (Base flow)** | **Density (3-axle Subject flow)** | **Density (4-axle Subject flow)** | **Density (5-axle Subject flow)** | **Density (6-axle Subject flow)** |
| 1050 | 14.444 | 17.102 | 17.113 | 17.120 | 17.126 |
| 1100 | 15.285 | 18.154 | 18.163 | 18.174 | 18.179 |
| 1150 | 15.968 | 18.999 | 19.012 | 19.032 | 19.034 |
| 1200 | 16.715 | 20.001 | 20.001 | 20.026 | 20.032 |
| 1250 | 17.476 | 20.980 | 21.001 | 21.019 | 21.023 |
| 1500 | 20.757 | 25.358 | 25.373 | 25.395 | 25.401 |
| 2000 | 27.510 | 34.718 | 34.759 | 34.803 | 34.801 |
| 2500 | 34.222 | 44.271 | 44.347 | 44.411 | 44.433 |
| 3000 | 41.844 | 55.426 | 55.509 | 55.614 | 55.689 |

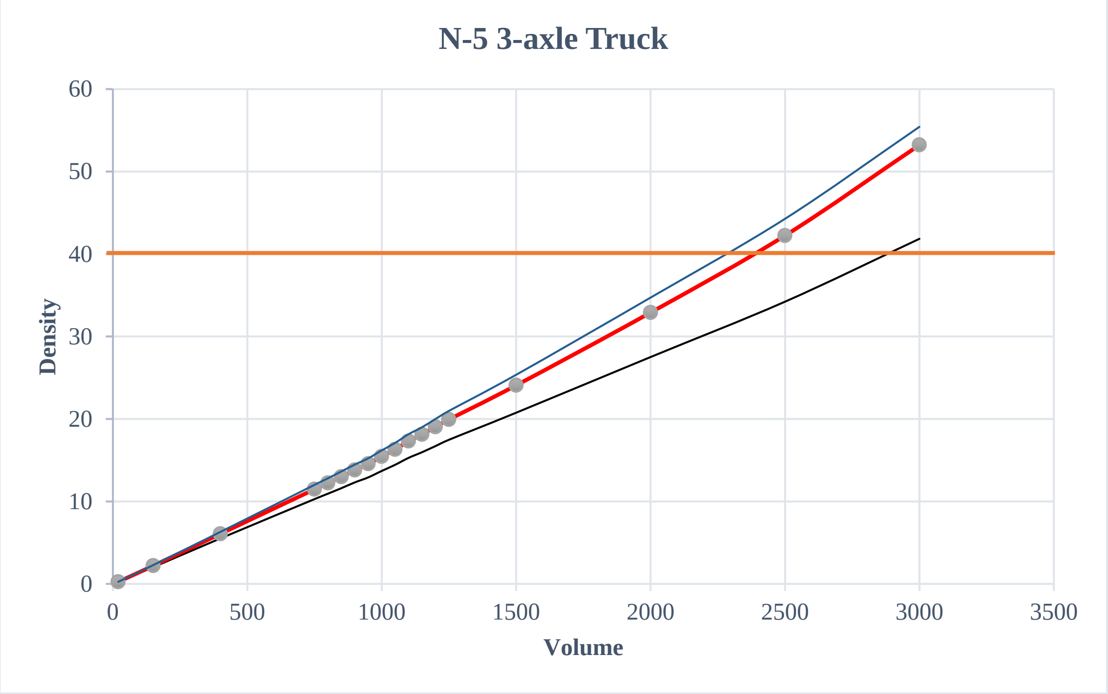


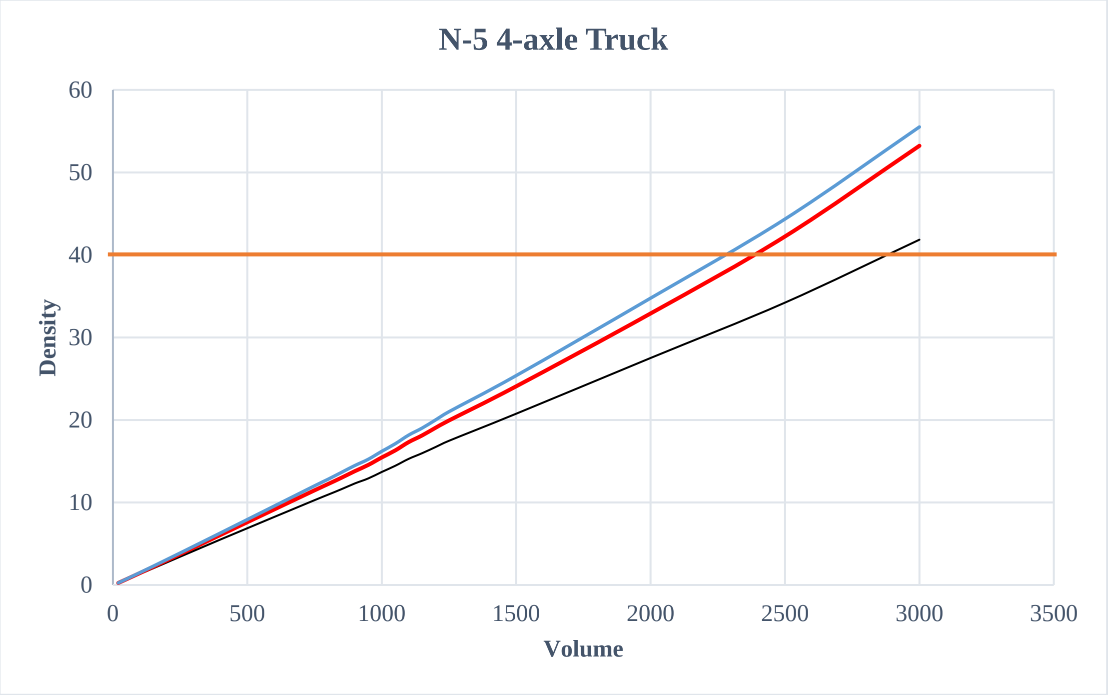

**Note:** The Legends in the graph above are same for all graphs in **Appendix B**

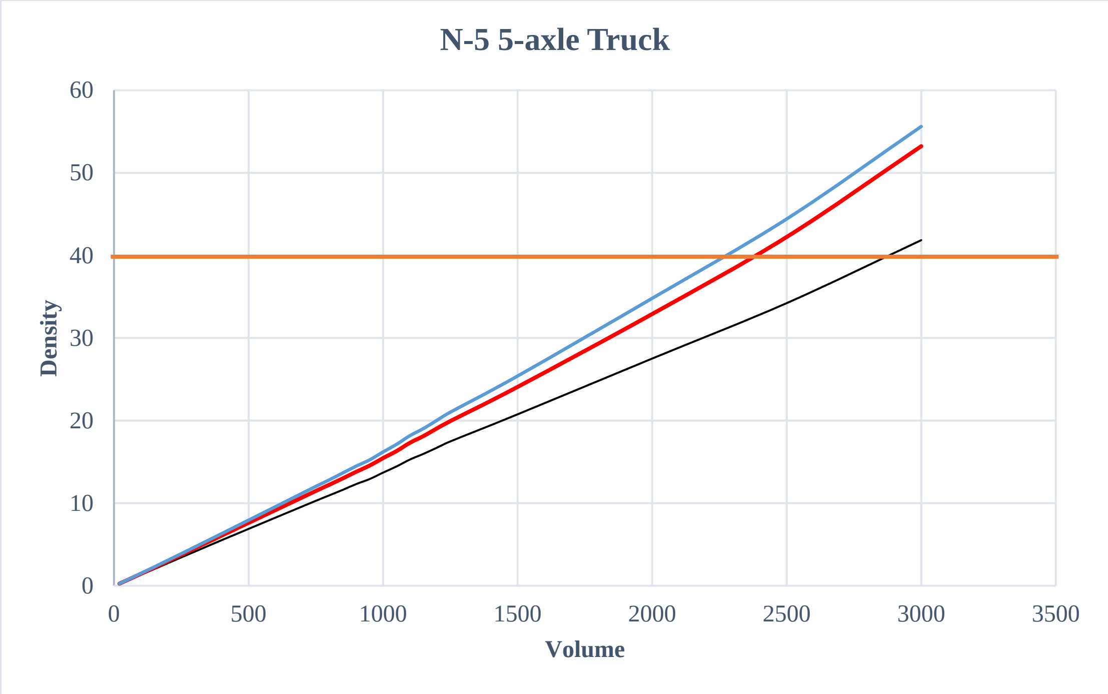


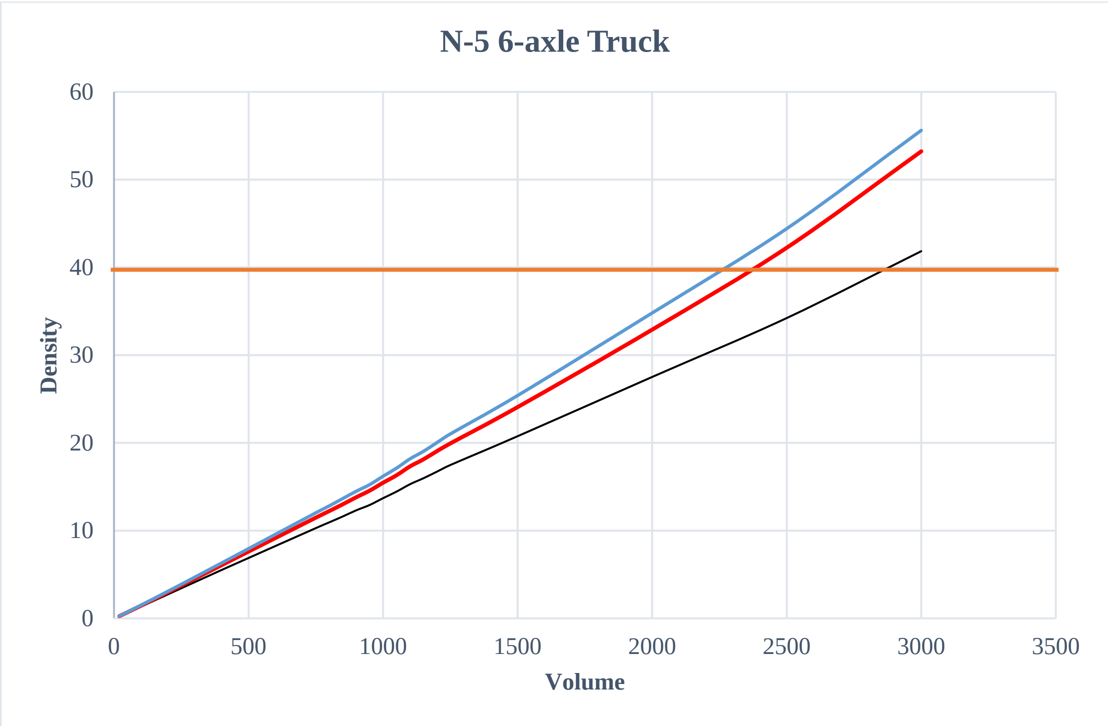

N-5 Bus
Density
Volume
0
10
20
30
40
50
60
0
500
1000
1500
2000
2500
3000
3500

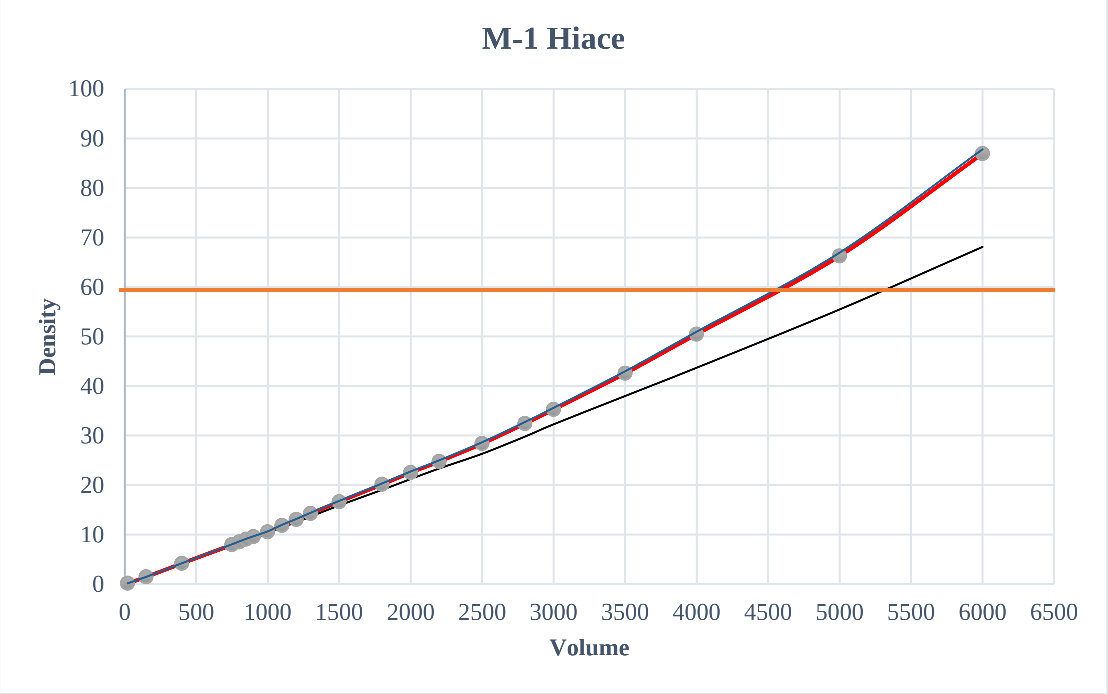

N-5 2-axle Truck
Density
Volume
0
10
20
30
40
50
60
0
500
1000
1500
2000
2500
3000
3500

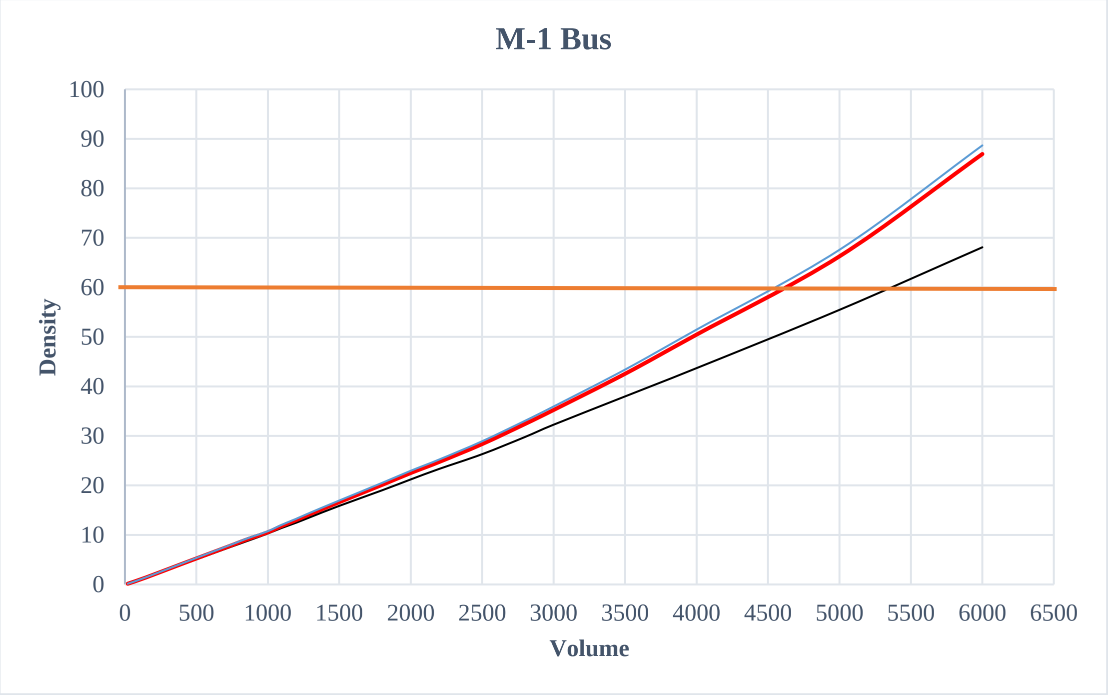

N-5 3-axle Truck
Density
Volume
0
10
20
30
40
50
60
0
500
1000
1500
2000
2500
3000
3500

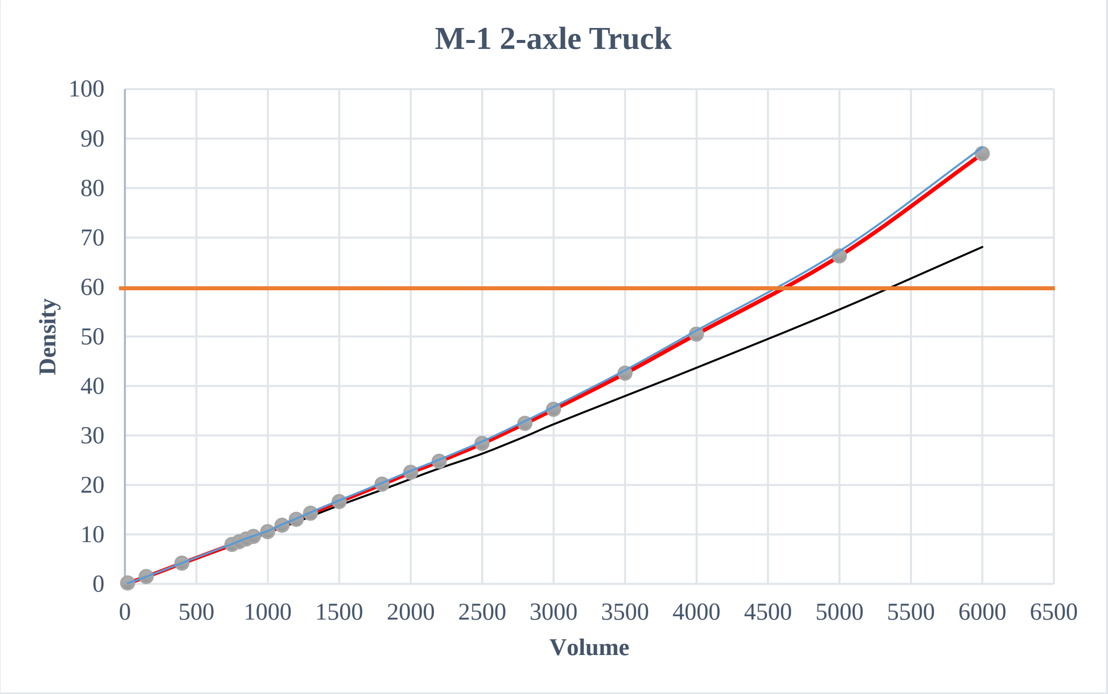

N-5 4-axle Truck
Density
Volume
0
10
20
30
40
50
60
0
500
1000
1500
2000
2500
3000
3500

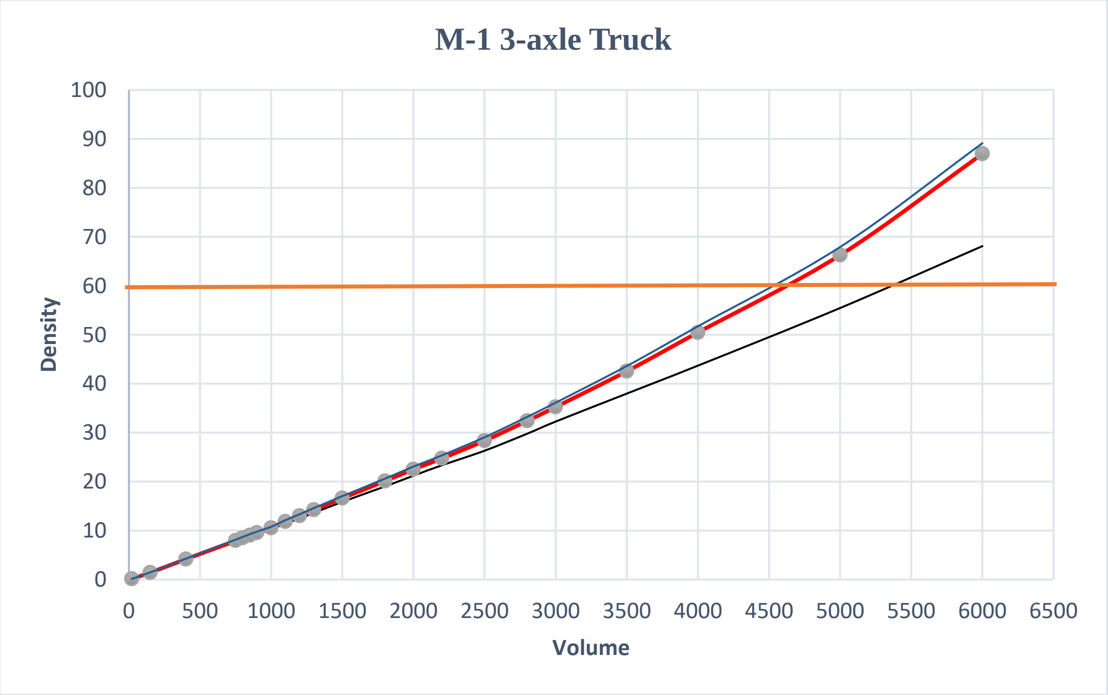

N-5 5-axle Truck
Density
Volume
0
10
20
30
40
50
60
0
500
1000
1500
2000
2500
3000
3500

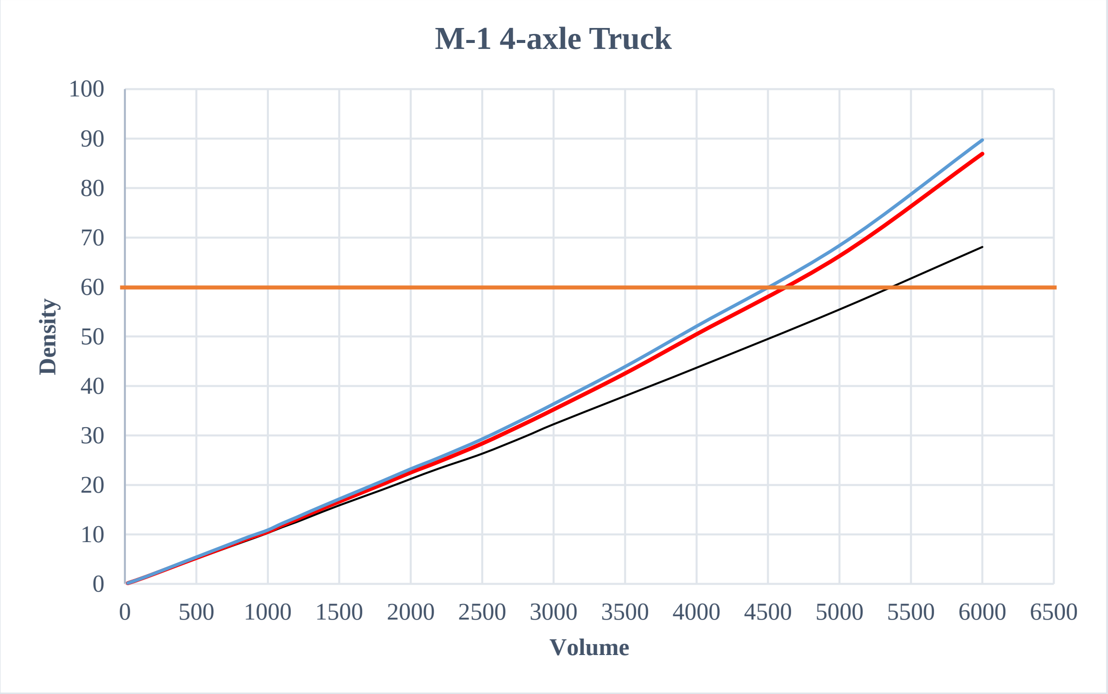

N-5 6-axle Truck
Density
Volume
0
10
20
30
40
50
60
0
500
1000
1500
2000
2500
3000
3500

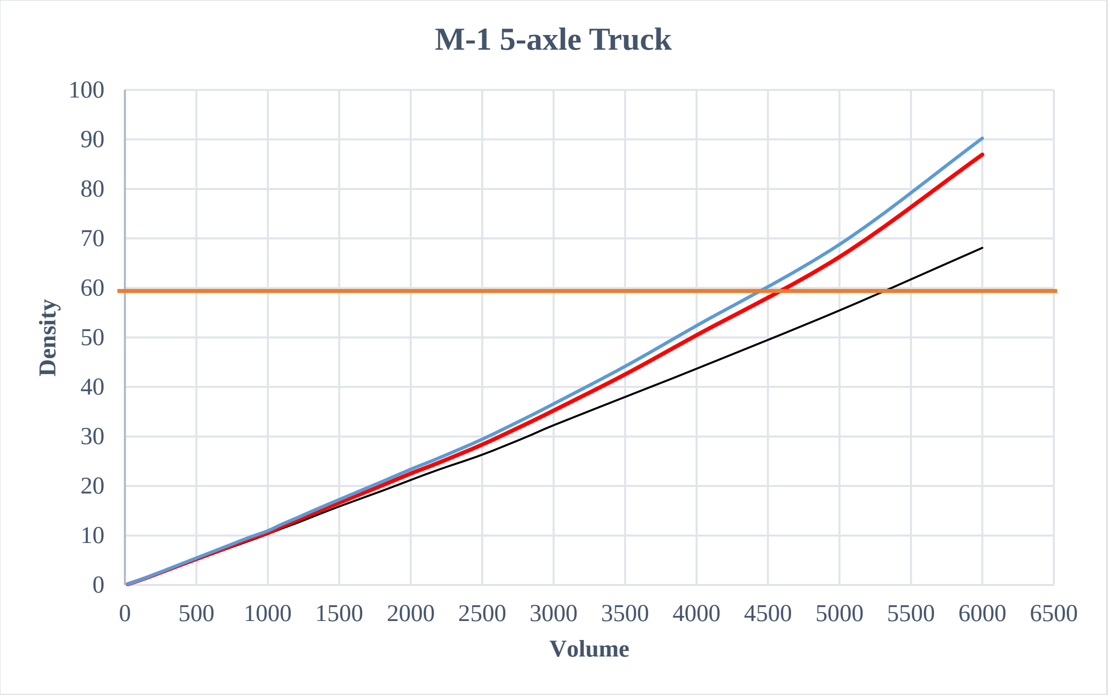

M-1 Hiace
Density
Volume
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500

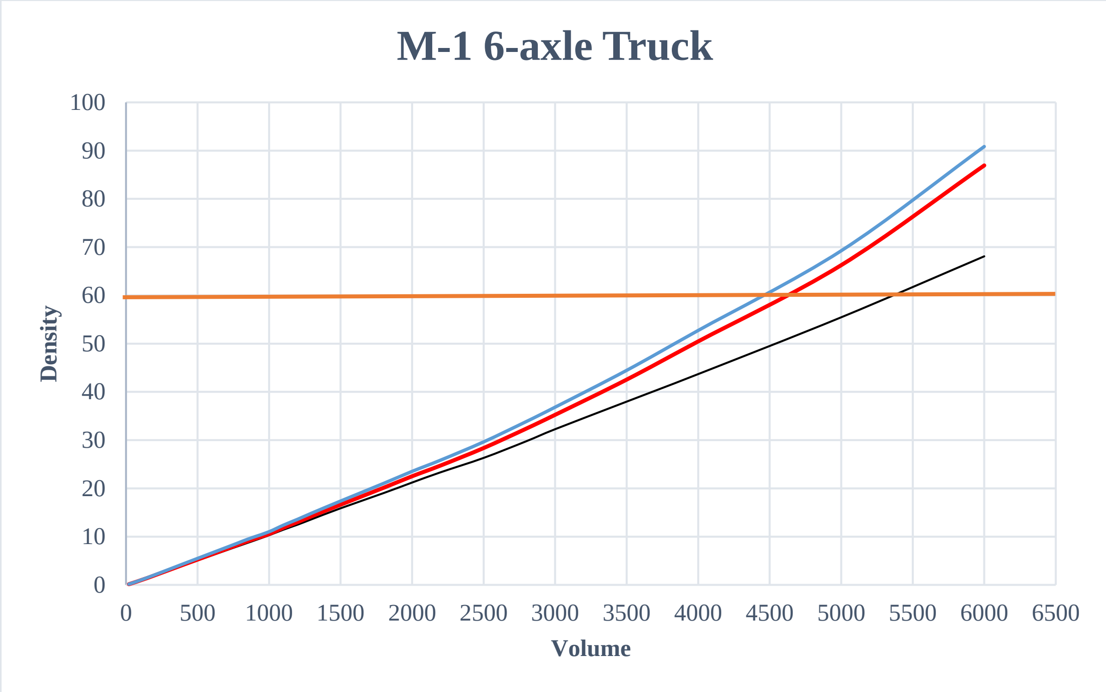

M-1 Bus
Density
Volume
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500


M-1 2-axle Truck
Density
Volume
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500


M-1 3-axle Truck
Density
Volume
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500


M-1 4-axle Truck
Density
Volume
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500


M-1 5-axle Truck
Density
Volume
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500


M-1 6-axle Truck
Density
100
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
Volume

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