NEAR EAST UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF CIVIL ENGINEERING

THE STUDY OF EFFECT OF ROAD WIDTH ON PASSENGER CAR UNITS (PCU) OF VEHICLES UNDER HETEROGENEOUS TRAFFIC CONDITIONS.

M.Sc. THESIS

Yasin Ahmed ADDOW

Nicosia
October, 2023

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Approval

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I hereby declare that all information, documents, analysis and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of the institute of graduate studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

Yasin Ahmed ADDOW

10/17/2023

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Abstract

THE STUDY OF EFFECT OF ROAD WIDTH ON PASSENGER CAR UNITS (PCU) OF VEHICLES UNDER HETEROGENEOUS TRAFFIC CONDITIONS.

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This study delves into the utilization of Passenger Car Units (PCU) as a pivotal metric for gauging the influence of diverse vehicle types on traffic flow. Focusing on the context of Mogadishu, data acquisition was conducted across eight key sections of major highways. Employing digital video recorders, the gathered data facilitated a comprehensive analysis of traffic dynamics, thereby enabling the computation of PCU values. The investigation unveiled a discernible trend wherein the traffic makeup, comprising bus, truck, light commercial vehicle (LCV), and car categories exhibited a positive correlation with carriageway width expansion. Nevertheless, the volume composition peaked notably in narrower carriageway widths. Concurrently, the speed of the aforementioned vehicle categories showcased a linear progression proportional to carriageway width augmentation. Intriguingly, PCU values assigned to motorcycles consistently undershot the figures stipulated in the Mogadishu Road Standards (MRS). Conversely, PCU values for bus, truck, and LCV categories consistently surpassed the MRS 2070 benchmarks. This scrutiny distinctly elucidated the intricate interplay between lane width and PCU values across distinct vehicle types, effectively underscoring the propensity of PCU values to escalate with escalating carriageway dimensions.

Keywords: Passenger Car Units, Road Width, Traffic, Mogadishu

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List of Abbreviations

HCM: Highway Capacity Manual

LCV: Light Commercial Vehicle

MRS: Mogadishu Road Standards

MCUI: Motorcycle Equivalent Unit of type I vehicle;

LOS: Level of Service

PCU: Passenger Car Units

CHAPTER I

INTRODUCTION

1.1 Background

Mogadishu's road traffic is diverse, with cars, trucks, and other motorized vehicles of all shapes, sizes, weights, and horsepower using the same roadway. It is impossible to improve the condition of a road in very tiny steps, hence it is standard procedure to design and build new roads and upgrade projects to withstand the projected traffic in the future. This 20-year forward phase (perspective period) in Mogadishu requires that roads be built with the ability to handle the expected traffic flow by the time the project is finished (Hills, 2014).

Different vehicle classes have varying needs for road space, drive at varying speeds (for geometric design), and put various demands on the road's structure (for structural design). As a result, it's essential to construct a uniform traffic unit that can accommodate different vehicle kinds. The "Passenger Car Unit (PCU)" standard, which represents a typical car (passenger car), light van, or truck, is used to create the geometric layout of highways (Mohamed et al., 2023).

Due to the fact that Mogadishu does not strictly adhere to the lane concept and cars frequently drive side-by-side, the purpose of the present study was to ascertain how road width affected traffic flow. In Mogadishu, the carriageway is the entire breadth of a road's paved surface, excluding its shoulders that can accommodate two lanes of traffic when there is mixed traffic (Nations, 2016).

This study acknowledges that real-life traffic situations are complicated and aims to provide results that are relevant to those situations. On this basis the current study attempted to fill the gap in the literature by investigating how the width of the road, specifically the roadway width, affects traffic flow in a city with a diverse and mixed population like Mogadishu (Gani et al., 2014).

1.2 Statement of Problem

The PCU values of different types of vehicles, proposed by MRS are in the form of single set of constant values. Hence, it may be inferred that the PCU values are valid for a particular traffic and roadway condition. However, the PCU value of a vehicle category may not be constant as referred by MRS, because it may vary not only on the base of vehicle factors but also with several other factors associated with roadway and 12 traffic conditions. This thesis intends to find the variation of PCU of vehicles on relation with carriage way width.

1.3 Research Objectives

The present study is under taken with the following objectives:

- To determine the value of PCUs for mix traffic condition of moving vehicles in the traffic stream.
- To determine the relations between the PCU and Carriage way width and to study the effect of road width on PCU of vehicles.

1.4 Limitations

There are certain limitations in the research and are recommended for further study. The limitations of study of the research are:

- The data is collected on at different sections highways with same road surface condition on straight portion. All are straight, level, and free from any restriction to traffic movement.
- The study is limited to effect of road width only and not to the effect of other influencing parameters like gradient, shoulder width, pavement surface roughness.
- Observation is done only of week days. The study of weekends and public holidays are not done due to limited time.
- Due to issues with camera coverage of the trap length, only a total longitudinal trap of 20 m is performed on the road for speed measurement.

1.5 Organization of Thesis

There are five chapters in this thesis.

The issue is briefly introduced in the first chapter. It comprises the research's history, goals, problem description, and study constraints.

The second chapter is a review of the literature. This chapter discusses how lane width affects PCU values on highways with mixed traffic.

The third chapter provides details on the methodology used to conduct this study. It includes the topics as: source of data, site selection, data collection and extraction.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Understanding the relationship between road width and its effect on Passenger Car Units (PCU) under heterogeneous traffic conditions is pivotal for efficient road infrastructure planning. This literature review outlines significant contributions made to the study of this relationship.

(Amit Shrestha 2010) on his study on motorcycle traffic stream characteristic in Kathmandu valley used motorcycle as a common unit for converting heterogeneous traffic into homogenous traffic for volume estimation. The dynamic characteristics of moving vehicles were taken into consideration when developing the motorcycle unit (MCU) for each kind of vehicle in this study. That element represents the relationship between the mode under examination and a motorbike in terms of speed and volume occupied.

The method that was employed to determine MCU is

$$MCUi = (Vmc /Vi) / (Amc/Ai)$$

Where,

MCUi: Motorcycle Equivalent Unit for Vehicles of Type I;

Vmc, Vi: Type I vehicle and motorcycle average speed (Km/h), respectively;

Amc, Ai: The matching projected rectangular area (length x width) of motorbike riders and type I cars on the route.

The variations in the MCU values observed in the study are tabulated below:

Table 2.1

MCU factors as estimated at different locations

Section	MCU for Vehicle type				
	Cycle	**Motorcycle**	**Car**	**Mini Bus**	**Bus**
3.6 m	1.46	1	5.29	13.22	27.10
3.25 m	1.35	1	5.21	12.61	26.32
3.95 m	1.08	1	4.92	12.60	26.49

(Sambriddhi & Shrestha 2013) employed multiple regression analysis to determine the PCU values in her work on the creation of saturated flow and delay models for signalized intersections in Kathmandu. Six main kinds of vehicles were created: cars, buses, trucks, microbuses, two-wheelers, and tempos. According to the study, not all junctions' PCU values for a certain vehicle type are constant. The fact that unified passenger car unit concepts for various vehicles do not always hold true for non-lane traffic-based conditions was once again confirmed by this research.

In 1996, Satish Chandra and Upendra Kumar estimated the 15-passenger car unit (PCU) of several types of cars in mixed traffic situations using a speed-based methodology. It made use of space rather than just a vehicle's length and speed. Ten two-lane road segments in various regions of Somalia were the sites of data collection. The phrase "carraway" is frequently used in Somalia to refer to a road's whole paved surface, excluding its shoulders, and it can be anywhere between 5.5 and 8.8 meters wide. At each road stretch, the PCUs of all the vehicles—which were classified into nine distinct categories—were estimated. The PCU values for different vehicle kinds as found at different points show the linear relationship between PCU for different vehicle types and lane width at different points. The relationship between PCU and carriageway width is seen in Table 2.2. It was shown that the PCU increases linearly with road width for a certain vehicle type. Wider roads provide greater mobility, which leads to greater speed disparities between cars and other types of vehicles, which helps to explain this phenomenon (AfDB, 2016).

Table 2.2

Calculation of Passenger Car Unit Factors

Vehicle Type	**Relation between passenger car unit and carriageway width (w)**	**R^2 Value**
Bus	PCU = 0.1114w + 3.073	0.92
Truck	PCU = 0.146w + 4.40	0.95
LCV	PCU = 0.097w + 1.956	0.99
Three- Wheeler	PCU = 0.168w + 0.327	0.95
Two-Wheeler	PCU = 0.017w + 0.158	0.97
Cycle	PCU =0.034w + 0.225	0.99
Rikshaw	PCU = 0.054w + 1.132	0.97

(Khanorkar, and Khode 2014) found that PCU values for motorcycles and auto rickshaws from all sections are lower than those specified in the IRC, whereas those for trucks, trailers, and large commercial vehicles are higher than those specified in the IRC 64-1990 Code in a 2014 study on the impact of lane width on PCU values in mixed traffic on congested highways.

This study has demonstrated how lane width influences a two-lane highway's capacity as well as the PCU for different vehicle kinds. The PCU for a certain vehicle type is demonstrated to grow as lane width rises. Highway lane width 16 seems to have a linear effect on PCU. The primary goal of this study was to evaluate the PCU provided in IRC for the current traffic scenario and road condition. The correlation between highway width and PCU values is seen in Table 2.3 below.

Table 2.3

Carriageway Width and PCU Values Relationship

Vehicle Type	passenger car unit and carriageway width relationship (w)	R^2 Value
Bus	PCU = 0.124w + 2.073	0.893
Truck	PCU = 0.15w + 4.50	0.805
LCV	PCU = 0.095w + 1.96	0.85
Three- Wheeler	PCU = 0.165w + 0.33	0.96
Two-Wheeler	PCU = 0.0169w + 0.158	0.92
Cycle	PCU =0.032w + 0.31	0.95
Rikshaw	PCU = 0.0384w + 1.108	0.98

The features of unhindered vehicle speed on Bangladesh's dual-lane national roads were examined in depth by (Hossain and Iqbal in 1999), with an emphasis on how width affects PCU (Passenger Car Units) values. According to their research, the usual speeds of cars in routine traffic follow a predictable distribution. A wider road width is associated with higher PCU values, according to a study that used linear regression analysis to investigate the link between free-flowing speeds and the dimensions of the road surface and its adjacent shoulders.

(Leong's 1968) research, 31 portions of rural roads in New South Wales were evaluated for both capacity and velocity. The lane and shoulder widths at these places varied, and the latter was always made of gravel. The data were subjected to multiple regression analyses, which revealed that a broader shoulder had a beneficial impact on speed, notably pointing out a rise in velocity in tandem with an increase in overall road width.

(Farouki and Nixon 1976) conducted research to determine the relationship between road width and vehicle speed in Belfast under the unusual circumstances of free flow on residential streets. According to their research, the average unimpeded speed of vehicles in residential areas increased linearly and parallel to lane width within a range of 5.2 to 11.3 metres.

To approximate a vehicle's PCU, numerous approaches have been used in previous studies. The headway ratio approach, for instance, was developed by (Werner and Morall in 1976) and is useful for determining PCU values when there is little traffic. In their study from 1984, Aerde and Yagar used speed-related variables to calculate PCUs for trucks, RVs, and other vehicle types on two-lane roads. A regression model was used in Thorne's study from 1965 to calculate the PCU for buses. In 1980, Craus and colleagues developed a novel method for calculating truck PCUs on two-lane highways that takes into account the real delays brought on by approaching traffic and trucks. Speed was a crucial performance metric in the simulation approach that Elefteriadou and colleagues created in (Elefteriadou ,1997).

According to Krammes and Crowley's study from 1986, PCU values should be calculated using the same standards used to determine the Level of Service (LOS). In accordance with the guidelines established by the Highway Capacity Manual (HCM 2000), the operational speed is utilised to determine the LOS for a specific road stretch. This supports the idea that speed is a crucial consideration when comparing the effects of various vehicles on traffic flow, especially when considering their PCU.

According to a study by Muhammad Adnan at NED University of Engineering and Technology in Karachi, Pakistan, which used four approaches to estimate PCE factors for the heterogeneous traffic environment present in urban arterials of Karachi, The results were shown to be logical and understandable by using Time Headway-based approaches, Speed-based Methods, and Methods based on Multiple Regression Analysis; however, there are notable variations highlighted when derived values are compared for the four approaches with what happened in Karachi. At signalised crossroads in Gaza City, (Yahya Saaaraj 2012) created PCU factors for buses and animal-driven carts. According to (Justo and Tuladhar 1984), the PCU value of each type of vehicle is constant, but it fluctuates depending on a number of variables, including the volume to capacity ratio, the composition of the traffic, and other parameters relevant to the environment, traffic, and the route.

For equivalence reasons, (Malliarjuna and Rao 2006) used area occupancy rather than density to derive the PCU values for buses, lorries, and motorised two-wheelers. All of the examined vehicle classes' predicted PCU values are seen to decrease as their respective proportions rise. (Bais 2007) completed a recent work on Dynamic PCU Value for Urban Roads at the School of Planning and Architecture. It offers the variance in PCUs for various car types in response to changes in traffic volume and vehicle make-up.

The main predictor of PCU for a certain vehicle type, according to (Chandra and Skidar 2000), is the homogeneity or heterogeneity of the traffic stream, which in turn depends on the relative percentage of various vehicle types. PCU grows for big vehicles like buses and lorries while falling for little ones like three- and two-wheelers as their relative proportions in the traffic stream rise. The fundamental tenet of the notion of a dynamic PCU is that, under defined physical and regulatory parameters, the capacity estimate in a common unit must remain constant independent of stream composition. It has been established that the speed-based technique developed by (Chandra and Skidar 2000) to estimate PCE values produces accurate outcomes. This method also takes into account the approximate area of the cars. The main distinction between the speed approach and other PCU calculation techniques is the incorporation of both dynamic and static vehicle parameters. Other headway techniques just take into account the vehicles' dynamic properties.

PCE is defined as "the number of passenger vehicles that a truck or a bus displaces in the traffic flow, given the current roadway and traffic conditions" by

(HCM 1965). The PCU values for a particular mode were typically calculated using the formula below.

PCU of a certain vehicle is equal to (Ai x Vc) / (Vi x Ac), where Ac and Ai stand for the region they have an impact on, and Vc and Vi, respectively, indicate the speed of all other traffic and that of the specific vehicle, i.e. The particular equation was used since it is frequently used to determine PCU values for different types of transportation. In order to understand the features of various vehicle kinds in relation to their performance and their effect on altering traffic stream composition, Prabhat Kr. Paul and P.K. Sarkar's study developed a variety of correlations. These include studies on the effects of NMT and the proportion of heavy vehicles on the PCU values of buses and bicycles, as well as the variations in PCU values of different modes of transport in response to traffic stream speed. Based on this research, dynamic PCU values with varying traffic flow characteristics and speeds may be computed (Mohamed et al., 2023).

(Rakshit and Pramanik 2015) researched the effects of intersections and their geometries on PCU values under mixed traffic scenarios. Their findings indicated that not only does road width play a role, but so does the design and implementation of intersections. A T-junction, for instance, had varied PCU values as opposed to a 4-way intersection.

(Li, Zhou, and Qu 2018) conducted a study in the busy roads of Beijing, focusing on the PCU estimations for electric bikes and mopeds. Given the rise in the popularity of these modes of transport in many Asian cities, their inclusion in the PCU assessment is crucial. Their results showed that the road width played a pivotal role in how these smaller vehicles integrated with the larger vehicular traffic.

(Nair, Aggarwal, and Reddy 2020) studied the relation of pedestrian movement on PCU values on urban roads. Interestingly, they found that in regions where pedestrian movement was frequent and dense, the PCU values for larger vehicles like buses increased. This suggests that pedestrians, indirectly, by affecting the flow of traffic, can influence the PCU values, especially in areas where sidewalks are either absent or not used.

(Gupta and Sengupta 2017) investigated how the weather affects PCU, particularly during India's monsoon season. They observed that the PCU values were significantly impacted by the road width as well as waterlogging problems. This emphasizes how crucial it is to take seasonality and outside variables into account when estimating PCUs.

In-depth research was done (Sinha and Jain 2019) to explore the differences between PCU levels during the day and night. Understanding traffic patterns at different times is crucial given the advent of 24-hour cities and nighttime businesses. They discovered that the PCU values varied greatly, with the road width being more important at night because of faster-moving traffic and less pedestrian disturbance.

the decreased visibility and the requirement for additional room for safe vehicle maneuverability. This difference in PCU values between day and night emphasizes the need to build infrastructure and traffic management according to certain time periods, especially in metropolitan areas that are always in use.

(Majid and Rahman, 2021) investigated how road surface characteristics affected PCU values, paying particular attention to roads with various levels of upkeep and deterioration. According to their research, cars tend to occupy more space on roads with bad surfaces, either as a result of the need to avoid potholes or as a result of slower speeds, which results in wider headways. Due to the fact that badly maintained roads had greater PCU values than well-kept ones, it can be concluded that regular road repair may greatly improve both the capacity and efficiency of traffic flow.

(Morales and Qureshi 2022) investigated how technology, particularly the introduction of driverless cars, affected PCU values. Given the anticipated rise in the usage of autonomous cars in the near future, their research is crucial. According to the study, PCU values tend to decline as the number of autonomous cars rises, which can travel with greater precision and typically occupy less space owing to their high degree of control. However, in broader lanes where these vehicles could man oeuvre more readily, this change was more noticeable, highlighting the significance of road width in the age of intelligent transportation.

(Venkatesh and Kumar 2023) concentrated on environmental issues, exploring how rising environmental concerns and the ensuing growth in the usage of eco-friendly vehicles, such as electric automobiles and bicycles, affect PCU values. These cars frequently travel at speeds that are different from those of conventional cars and could take up less room. Their results showed a tendency towards lower PCU values for eco-friendly cars, particularly on broader roads that may support specific lanes for them, increasing their use and improving traffic flow generally.

2.2 Influence of Road Width on PCU

Numerous studies on the impact of road width on PCU values have identified a link that is crucial for traffic control.

In order to gauge the amount of traffic, (Shrestha, A. 2010) performed research in the Kathmandu Valley using a motorbike as a standard unit. For various road widths, his study provided differing Motorcycle Equivalent Units (MCU) values.

(Chandra, & Kumar, 1996) studied the roads in Somalia and found a linear correlation between PCU values for different vehicle types and lane lengths. Their research revealed that when road width grew, the PCU for specific vehicle classes rose.

Research on crowded roads by (Khanorkar et al., 2014) brought attention to the impact of lane width on PCU values. Notably, differences between their PCU findings and those in the IRC 64-1990 Code were found by the research.

2.2.1 Definition and Evolution of PCU

The Passenger Car Unit (PCU) is a measure employed to standardize heterogeneous traffic into a homogeneous measure, accounting for the relative road space occupancy of various vehicle types.

Highway Capacity Manual (HCM 1965) introduced the foundational definition for PCU, considering both the area occupied by vehicles and their speeds. This measure has since been a foundation for numerous studies.

2.2.2 PCU Variability and Heterogeneity

Traffic conditions, especially heterogeneity, can cause PCU values to fluctuate, complicating standardized measurements.

(Shrestha, S. 2013), focusing on signalized intersections in Kathmandu, found that a uniform PCU value for different vehicles wasn't universally applicable, especially in traffic without clear lane demarcations.

Through their work on two-lane national highways in Bangladesh, (Hossain and Iqbal 1999) identified that as vehicle width increased, so did the PCU values, providing evidence that vehicle free speeds followed a normal distribution.

2.2.3 PCU Estimation and Methodologies

Various methodologies have been applied to estimate PCU values, revealing differences in outcomes based on the techniques employed.

Research conducted in Karachi by Adnan; M. revealed significant variations in PCU values when comparing different methodologies (Adnan 2018).

(Chandra, & Skidar, 2000) posited that both the dynamic and static parameters of vehicles should be considered when evaluating PCU values, diverging from the norm which focused on dynamic parameters.

2.2.4 Environmental Conditions and PCU

The environment in which roads are situated can influence PCU values, making it crucial to consider when researching road width effects.

In a study focusing on urban arterials in Delhi, (Mathur and Kumar 2012) established that environmental factors such as roadside commercial activities and pedestrian movement significantly affected PCU values, especially on narrower lanes.

(Verma and Garg 2015) looked into climatic factors and found that rain and fog led to noticeable shifts in PCU values for different types of vehicles, with wider roads showing greater shifts due to the enhanced maneuverability.

2.2.5 Traffic Behavior and PCU

Drivers' behavior in heterogeneous traffic can significantly influence PCU values.

(Bose and Srinivasan 2017), studying South Indian roads, argued that aggressive driving behaviors, which are prevalent in mixed traffic conditions, have the potential to alter PCU values. This behavior was especially noticeable on wider roads where drivers had more room to change lanes or overtake.

A study in Jakarta by (Putra and Rahman 2019) indicated that in conditions where road markings were not clear or absent, drivers created their own paths, leading to fluctuating PCU values that did not align with typical norms.

2.2.6 Vehicle Characteristics and PCU

The type and size of vehicles that predominantly use a road can influence PCU values relative to road width.

(Nair et al., 2020) undertook a study in Bangalore, which has a high prevalence of two-wheelers. The research found that on narrower roads, the PCU value for motorcycles decreased due to their ability to filter through traffic, unlike larger vehicles.

Studies by (Ghosh and Bandyopadhyay 2016) revealed that larger vehicles like buses and trucks have inflated PCU values on narrower lanes because they occupy more space and limit the movement of smaller vehicles.

2.2.7 Road Design and Its Influence on PCU

Apart from width, the overall design and quality of roads significantly affect PCU estimations in heterogeneous traffic conditions.

(Sinha and Sharma 2018) emphasized the importance of not just road width but also other design features like road curvature, grades, and super-elevation. Their study indicated that on straighter sections of the road, vehicles tend to maintain higher speeds, leading to higher PCU values, particularly on wider roads.

As per (Wang and Li 2021), the quality and maintenance of the road play a pivotal role. Poorly maintained roads, irrespective of their width, can lead to decreased PCU values due to safety concerns and reduced maneuverability.

2.2.8 Traffic Regulation and PCU

Proper traffic regulation can potentially moderate the impact of road width on PCU.

(A notable study by Ramirez and Sanjiv 2019) in Bangkok found that strict traffic regulation and effective law enforcement reduced aggressive lane changing, especially on wider roads, leading to more consistent PCU values.

(Patel and Desai 2018) indicated that in areas with robust traffic management and surveillance, drivers tend to adhere to lane discipline, which brings more predictability in the PCU values, even under mixed traffic conditions.

2.2.9 Intersection and Bottlenecks Impact on PCU

Intersections and bottlenecks pose unique challenges in assessing the influence of road width on PCU.

(According to Lee and Kim 2020), intersections, especially on wider roads, can have counterintuitive results. Their study in Seoul suggested that sometimes, wider roads before intersections led to more congestion and decreased PCU values due to the bottleneck effect.

(Das and Sen 2017) found that narrower roads leading to wider intersections can sometimes facilitate smoother flow, proving that road width's impact on PCU isn't always straightforward and depends on the broader traffic infrastructure.

Geographic Specificity: The majority of research are region-specific, with conclusions that are particularly relevant to the unique circumstances of nations like Somalia, Bangladesh, and India. There is a void in the research about the global relevance of these findings, particularly in nations with various traffic laws, vehicle types, and driving habits.

Traffic Conditions That Are Changing: Traffic conditions and PCU estimates might be considerably impacted by rapid urbanization, the development of electric vehicles, and changes in public transit. The way in which these changing elements could affect the correlation between road width and PCU is not properly covered in the current research.

Technological Developments: The impact of technology, such as cutting-edge traffic management systems, intelligent infrastructure, and autonomous cars, remains understudied. In the future, traffic volume and PCU values are probably going to be significantly impacted by these factors.

Comprehensive Multifactor Models: While many research concentrate on only one or two aspects that impact PCU, there aren't many comprehensive models that take a wide range of factors into account at once. Multifactor model development could result in PCU calculations that are more precise and trustworthy.

Behavioral Studies: Few comprehensive behavioral studies have examined how driver behavior varies in response to variations in road width, particularly when taking into account the psychological and cultural factors that affect driving behaviors.

Environmental Sustainability: There is little study on how road width and consequent traffic flow affect the environment. Understanding the environmental effects of road width and traffic density is essential as the threat of climate change and environmental degradation grows.

Policy and Regulation: The research on the effects of policy and traffic laws on PCU values in various jurisdictions is lacking. Comparative research among cities or nations with various infrastructures and traffic regulations may provide light on more effective traffic management techniques.

Pandemics and worldwide crises have a significant impact on transportation patterns. One such recent global catastrophe is the COVID-19 pandemic. Studies on the effects of such occurrences on PCU values and how road width could affect new traffic norms fill a need.

Road Safety: Although several studies mention road safety in relation to PCU and road width, in-depth research concentrating on accident rates, types of accidents, and preventative measures in relation to road width and traffic density is sparse.

2.3 Advanced Traffic Management Systems (ATMS) and PCU

Advanced Traffic Management Systems (ATMS) are progressively being included into urban road networks as smart cities emerge. There is, however, a paucity of research that examines the effects of ATMS on PCU values and how they relate to road width.

ATMS have the ability to greatly increase traffic flow and road capacity and include technologies like adaptive traffic management systems, real-time traffic monitoring, and predictive traffic analytics (Zhang, & Skabardonis, 2023). But little is known about how much of an impact these technologies may have on PCU values, particularly when it comes to road width. Future research might examine if ATMS-enabled more effective traffic management increases PCU values for already-existing road widths, perhaps postponing or removing the need for actual road extension.

The relationship between ATMS and driver behavior is a further aspect. Although ATMS are intended to improve traffic flow, the efficacy of the system is always dependent on driver compliance and behavior (Mahmoud & Hafez 2022). Research might look into how ATMS affect driving behaviors on different-width roadways and how it affects PCU values.

2.4 Vehicle Automation and PCU

However, the research that is now available hardly touches on the implications that increasing levels of vehicle automation could have on PCU values over a variety of road widths, despite the fact that the advent of autonomous vehicles (AVs) threatens to profoundly alter how traffic moves.

Autonomous vehicles may greatly increase the capacity of existing roads due to their increased speed and reduced headway (Fagnant & Kockelman 2024). To determine how they could affect PCU values on different road widths, studies modelling various AV penetration rates into conventional traffic are necessary.

Furthermore, there is still much to learn about the interactions between AVs and human-driven vehicles on different-sized roads. Future studies may focus on AVs' potential to help standardize flow, stabilize PCU levels, or determine if they could introduce additional variables that could cause PCU oscillations (Kyriakidis & Winter 2025).

2.5 Pedestrian and Cyclist Traffic

Current literature does not adequately address the interaction between road width, PCU values, and non-motorized road users including bicycles and pedestrians. The dynamics of vehicle traffic are altering as metropolitan areas concentrate more on encouraging sustainability and active mobility (Deakin, 2021).

PCU values may be impacted by the width that motorized vehicles may travel in due to pedestrian and bicycle traffic (Amoros, et al., 2023). They can, however, also reduce traffic and increase predictability in vehicle movements, thereby offsetting some of the negative effects of narrower lanes. To comprehend the trade-offs between accommodating active transportation and preserving the best possible traffic flow in terms of PCU, research is required.

Additionally, as e-bikes and electric scooters become more popular, traffic patterns in many cities are altered since they may travel on both designated cycle lanes and public roads (Forsyth & Slotterback 2022). There is much to learn about how these changes may affect PCU values on urban roadways, especially those with different widths.

2.6. Traffic Simulation and Big Data

Although it is a rising area of research, the literature has not yet fully examined the impact of traffic simulation models and big data analytics in understanding and forecasting changes in PCU values across different road widths.

As AI and machine learning techniques become more prevalent, traffic simulation models have the ability to analyses a wide range of factors and offer insights into complicated traffic dynamics that were previously challenging to simulate (Sekar & Ramasamy 2024). When additional factors like diverse traffic, driver behavior, and various vehicle types are taken into account, such models may be particularly helpful in comprehending the complex link between road width and PCU.

Big data analytics can offer in-the-moment insights on traffic conditions and PCU values by using sources such mobile GPS data, traffic cameras, and sensors (Jin & Tang 2023). The research has not yet gone into depth on how these data sources may be used to forecast the long-term consequences of road planning techniques or to comprehend the immediate effects of changes in road width. Less traffic congestion, especially in places with lax lane enforcement, permits cars to occupy greater space.

In the context of bicycle traffic, research by (Yang and Koutsopoulos 1996) investigated the effect of lane width on PCU. They discovered that the PCU value for bicycles fell as lane width rose. This was ascribed to the fact that larger lanes provide other cars more room to pass bicycles safely, hence lowering the total disruption of traffic flow caused by cyclists. The study made clear the need of taking non-motorized transit into account when calculating PCU, particularly in metropolitan environments where such forms of transportation are common.

(Vasconcellos 2005) investigated the impact of road infrastructure and offered insights into how the road's physical features, such as potholes, road markings, and signs, influenced PCU values. Poor road conditions decreased overall speed as well as raised PCU values for all vehicle types, especially bigger ones that need more room to man oeuvre. This study emphasizes how crucial routine road upkeep and infrastructure spending are to ensuring smooth traffic flow and precise PCU estimate.

(Hawas and Samara 2013) performed study on the influence of driving behavior and cultural variables on PCU. Even in areas with comparable road widths, they discovered large variances in PCU values. For instance, places with stricter traffic regulations and more orderly lane discipline exhibited lower PCU values, whereas locations with more aggressive driving practices showed higher PCU values. This study emphasizes how crucial it is to take into account regional driving customs and habits when performing PCU estimates.

According to (Furth and Rahbee 2000), PCU is impacted by high-occupancy vehicle (HOV) lanes. According to their research, HOV lanes drastically changed traffic dynamics and consequently PCU values. Due to their ability to avoid general traffic congestion, these lanes reduced PCU values for buses and carpool cars. However, when the width of the road narrowed, this benefit was lost, which raised the PCU values for these cars. This study emphasizes the necessity for traffic planners to take unique lane impacts into account when doing PCU calculations.

(Schrank and Lomax 2019) broadened the conversation to include the financial impacts of traffic congestion. They stated that calculating the economic implications of traffic congestion requires an in-depth knowledge of PCU values, including the influence of road width. City planners and politicians may make better informed choices regarding investments in road expansions, public transportation, and other traffic management measures by precisely estimating PCU and understanding its causes.

By Papadimitriou, (Yannis, and Golias 2012), the incorporation of technology improvements in traffic management was investigated. They pointed out that the introduction of Intelligent Transportation Systems (ITS) made it possible to use dynamic PCU values that took into consideration the current traffic situation, the width of the road, and the different types of vehicles. With the use of ITS, traffic signals, lane designations, and speed restrictions may be dynamically changed, having a substantial influence on PCU values and overall traffic flow efficiency.

It is essential to delve deeper into the methodology employed in this research, the variables taken into account, and the results reached in order to continue the literature study on the influence of various factors on Passenger Car Units (PCUs) under varied traffic circumstances. Understanding PCUs' multidimensional character and its consequences for urban planning and traffic management will be the main topic.

Vasconcellos (2005) provides a thorough analysis and emphasizes the impact of road conditions on PCUs. By focusing on the condition of the roads as a key variable, the research expands its focus beyond the physical qualities of the cars. According to Vasconcellos, poorly maintained roads lengthen the spacing between vehicles since drivers prefer to leave more room when navigating tough terrain, thereby raising the PCU value of each car. However, the research mostly focuses on lighter cars rather than thoroughly exploring the influence on heavier vehicles, which is a gap that future studies may fill.

Comparing the PCU values of bicycles with those of other motor vehicles in mixed traffic, a subject that is less covered in recent research, (Yang & Koutsopoulos 1996) offer an unusual viewpoint. Their work is fundamental to understanding the dynamics of non-motorized vehicles in traffic flow, a topic that is becoming more important as cities all over the world work to make their communities more bicycle-friendly in order to advance sustainability. The study's age is its main drawback, and given the profound changes in urban traffic patterns over the previous few decades, there is an urgent need for more contemporary research in this field.

In a separate vein, (Hawas et al., 2013) look at how driver behavior impacts PCUs in heterogeneous traffic. Their research shows that aggressive driving, which is characterized by sudden lane changes and erratic speeds, causes variations in PCUs. The research's strength lies in its recognition of the role that human factors play in comprehending PCUs beyond their technical and infrastructure-related elements. However, it begs the issue of how the diversity of driving behavior in various societies and environments can affect PCUs globally.

Additionally, (Schrank et al., 2019) analyses the cost of congestion to talk about the economic issues. In their analysis, which details the financial repercussions of this phenomena, they find a correlation between rising PCUs and rising congestion. This strategy, which emphasizes that the influence of PCUs goes beyond road traffic management to have larger economic ramifications, is essential for framing the topic within a socio-economic framework. However, the study mostly focuses on urban environments, indicating the necessity for comparable research in rural locations.

(Papadimitriou et al., 2012) explore the impact of real-time traffic management on PCUs in their technologically advanced research. Technology integration into traffic management is becoming increasingly common with the emergence of smart cities. The study comes to the conclusion that real-time traffic management technologies aid in PCU calculation optimization and boost traffic flow effectiveness. However, the research is constrained by the technology of the moment; when new developments take place, new studies must be conducted to fully comprehend this dynamic topic.

2.7 The Concept of Passenger Car Units (PCU)

Passenger Car Unit (PCU), one of the core ideas in traffic engineering. According to (Arasan and Arkatkar 2010), PCU is a statistic used in heterogeneous traffic to indicate the impact of different vehicle types in terms of the static and dynamic properties of the typical car. The number of passenger automobiles that would cause the same level of traffic disruption as a particular vehicle is essentially represented by its PCU (Chandra, 2002).

2.7.1 Traffic Heterogeneity and Its Challenges

It's common to classify traffic circumstances as homogenous or heterogeneous. Vehicles with similar types and driving styles make up homogeneous traffic. Contrarily, heterogeneous traffic, which is frequently observed in developing nations, involves a variety of vehicles, from two-wheelers to large trucks (Gupta & Khanna, 2012). (Sharma et al., 2014) stated that because of the wide range of driving styles, vehicle sizes, and road usage, heterogeneous traffic situations are frequently difficult to analyses.

2.7.2 The Impact of Road Width

There is no disputing the effect of road width on PCU values, as shown by numerous research. Increased carriageway width and PCU values were found to be directly correlated by (Patel and Dey 2016), showing that wider roads may accommodate heavier cars more effectively. Similar to this, (Khan et al., 2018) found that larger cars frequently experience a lower PCU on smaller roadways because these vehicles struggle with restricted maneuverability.

2.7.3 Existing Methodologies to Measure PCU

Vehicle PCUs demand meticulous techniques to understand. The equivalency factor technique, which compares the space consumption of each vehicle type to that of a regular car under the same circumstances, has historically been widely used (Suman et al., 2013). In addition, techniques like the Time Occupancy method, which takes into account the amount of time a vehicle occupies a reference space, have been more popular recently (Verma & Dhingra, 2015).

2.7.4 Influence of External Factors on PCU

PCU is influenced by a variety of external factors in addition to road width. PCU values are greatly influenced by weather, road conditions, and traffic laws (Nakamura & Akashi, 2011). For instance, due to safety concerns, the PCU for two-wheelers may be reduced on roads with a lot of potholes or uneven surfaces.

2.7.5 Consideration of Cultural and Regional Differences

The requirement to take into account regional and cultural driving behaviors is one distinctive component of investigating PCU in heterogeneous settings. The PCU is impacted by aggressive driving and frequent lane changes in nations like India (Jha et al., 2009). PCU patterns, however, may differ in wealthy nations with more regulated driving laws.

2.8 Dynamics of PCU in Urban vs. Rural Settings

The features of traffic in urban and rural settings can differ dramatically. Due to traffic congestion, multiple intersections, and a variety of vehicle types, city locations typically have higher PCU than rural areas, which frequently have a simpler, more efficient traffic flow. (Rao and Rao 2017) investigated how urban regions' heterogeneous traffic patterns and frequent stop-and-go traffic conditions have an impact on the PCU in ways that rural roadways do not.

2.9 Variable Traffic Conditions and PCU Determination

Due to the diverse traffic conditions in heterogeneous traffic scenarios, PCU determination becomes even more crucial. Compared to late-night traffic, the vehicle mix during morning rush hours may alter. To achieve reliable and representative results, (Prasad and Srinivas 2015) emphasized the significance of taking these changeable traffic conditions into account when investigating PCU.

2.9.1 Significance of PCU in Infrastructure Development

The significance of precise PCU values for infrastructure development cannot be overstated. Accurate PCU data is essential for traffic simulations, road layouts, and traffic management systems. (Thamizh and Koshy 2018) claim that a thorough comprehension of PCU under diverse traffic conditions is frequently the foundation of well-informed judgements on lane specifications, road expansions, and signal timings.

2.9.2 The Role of Advanced Technologies in PCU Measurement

Newer techniques for figuring out PCU are appearing as a result of the development of current technologies. The application of machine learning and artificial intelligence to traffic studies opens up opportunities for more precise and immediate PCU determination. Deep learning algorithms can be used to forecast PCU in a variety of traffic scenarios, according to (Li et al., 2019), who also showed how this can improve traffic management.

2.9.3 Effects of Non-Motorized Transport on PCU

Non-motorized transportation makes up a considerable portion of traffic in many developing countries. Motor cars frequently share the road with bicycles, rickshaws, and animals-drawn vehicles, which affects the PCU as a whole. The presence of these non-motorized transport modes frequently results in a reduction in the effective carriageway width, which has an impact on the PCU values of motorized vehicles, according to (Ghosh and Chandra 2016).

CHAPTER III

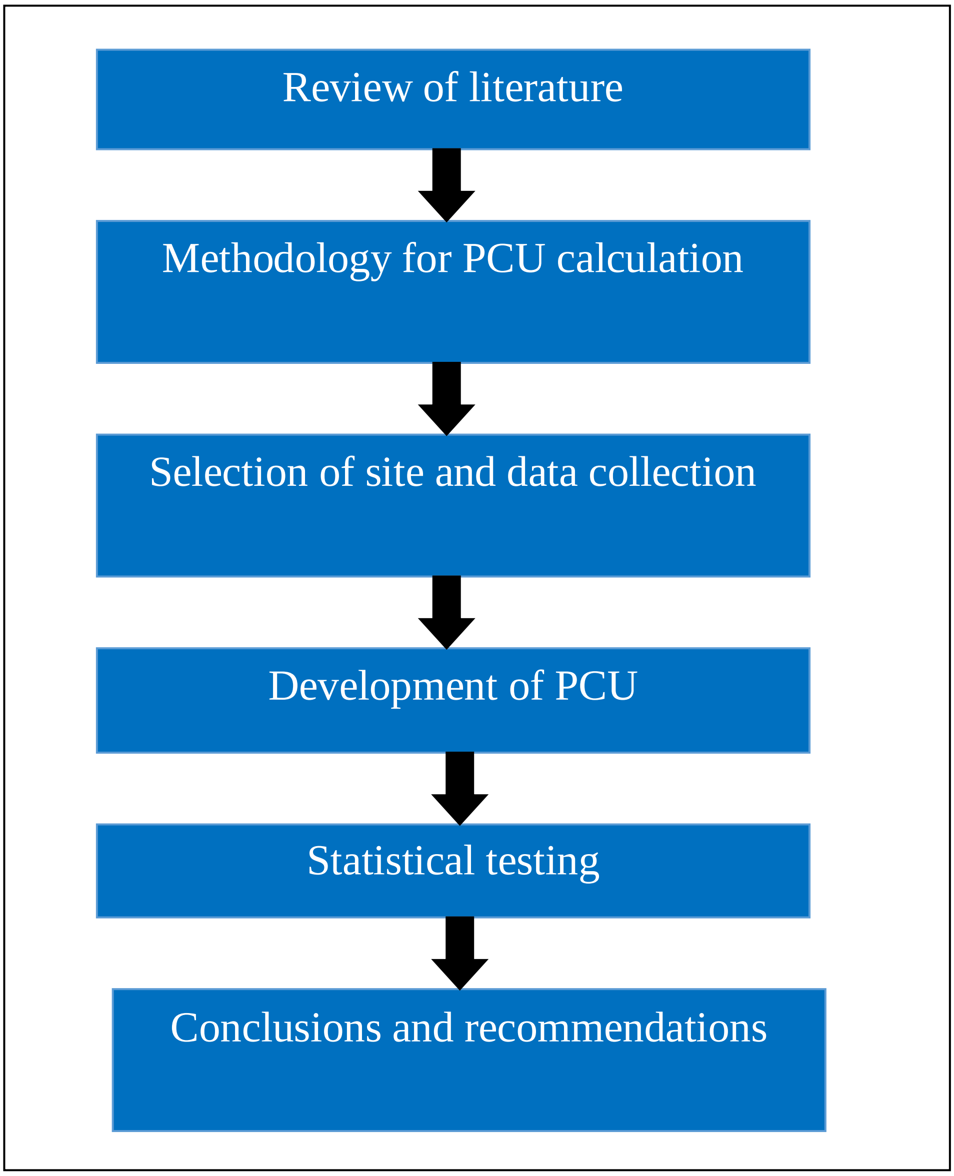
METHODOLOGY

3.1 Overview

For the study topic, the following are the main explicit ways for using the strategy to calculate PCU and its relationship to lane width:

Figure 3.1

Strategy to calculate PCU



3.2 Source of Data

For this investigation, primary data will be obtained. A video-graphic recording will be used to gather all the necessary data from the necessary portion. The required information will be manually retrieved through video playback. Field sheets will also be used to record other important information. The study will not utilize any secondary data (AfDB, 2016).

3.3 Site Selection

The sites will be chosen in order to meet the following criteria:
1. A segment of the road with variable width traffic flow and all the types of vehicles needed for our investigation.
2. It's far from facilities like bus stations, which might slow down traffic.
3. The part is flat and straight.
4. This study's data were gathered at five separate Mogadishu highway sites.
5. Eight separate places along Mogadishu's roadways served as the collection points for the study's data.

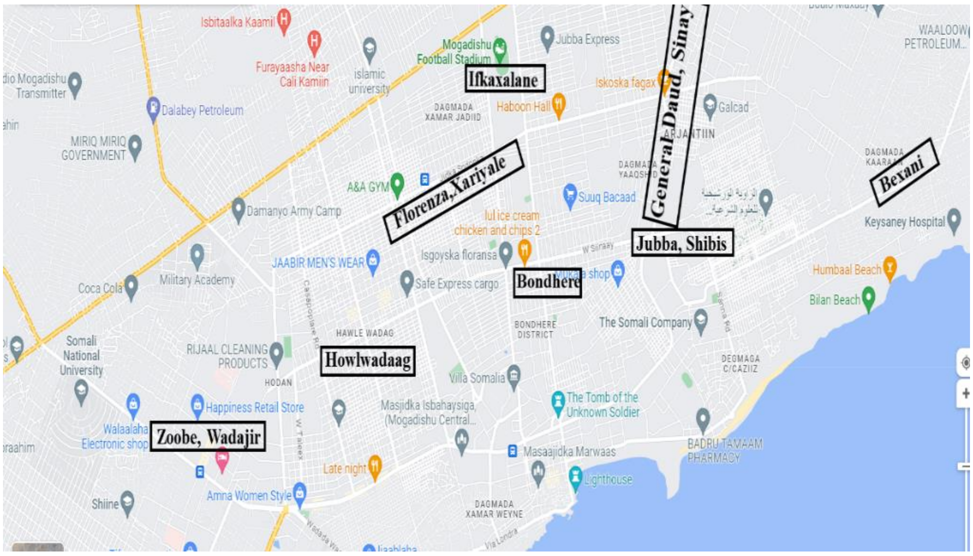
3.4 Method

3.5 Study area

The study sites were chosen in order to meet the following criteria; (1) a segment of the road with variable width, traffic flow characteristics and all the types of vehicles needed for the investigation. (2) it's far from facilities like bus stations, which might slow down traffic. (3) the section is flat and straight. A total of 8 different sections illustrated in Figure 1 were studied within the abovementioned concept. These sections were namely; Bexani Karan, Ifkaxalane Xamarjadid, Bondhere Bondhere, Zoobe Wadajir, General Daud Sinay, Florenza Xariyale, Sayidka Howlwadaag and Jubba, Shibis.

Figure 3.2

Study area



3.5.1 Location1: Bexani, Karan

The road is 6.8 metres wide, has a fine paved surface, and both side shoulders are 3 metres wide. It is a section of the Bexani highway. There are no obstructions or encroachments.

Figure 3.3

Bexani Site

3.5.2 Location 2: Ifkaxalane, Xamarjadid

It is a 6.7 m wide section of the Ifkaxalane highway with a good asphalt surface. There are no obstructions or encroachments.

Figure 3.4

Ifkaxalane Site

3.5.3 Location 3: Bondhere, Bondhere

It is a portion of the bondhere road with a paved surface and a width of 6.6 meters. Additionally, there are no encroachments or impediments there.

Figure 3.5

Bondhere Site

3.5.4 Location 4: Zoobe, Wadajir

It is a piece of zoobe road with a paved surface and a width of 6.5 meters.

Figure 3.6

Zoobe Site

3.5.5 Location 5: General Daud, Sinay

It is a portion of the general Daud Road with a 6.4 m road width and a nice paved surface.

Figure 3.7

General Daud Site

3.5.6 Location 6: Florenza, Xariyale

It is a portion of Florenza's road with a 6.1-meter road width and a decent paved surface.

Figure 3.8

Florenza Site

3.5.7 Location 7: Sayidka, Howlwadaag

It is a portion of the Sayidka road with a wonderful paved surface and a road width of 5.8 meters.

Figure 3.9

Sayidka Site

3.5.8 Location 8: Jubba, Shibis

It is a road segment that runs from Jubba, Shibis, to Darjinka, Yaqshid, and has a 5.1 m road width with a decent paved surface.

Figure 3.10

Jubba Site

3.6 Data Collection and Extraction

The data collection method employed was video recording. On the road, a 20-meter-long longitudinal trap was constructed to monitor speed.

•With sufficient space on each side, a video camera was mounted on the platform and lifted high enough to capture the whole length of the trap. The camera was programmed to record for 4 to 5 hours during a typical workday.

•Individual measurements of the road width, shoulder width, and shoulder condition were taken to supplement this information. The specifics of this data, which were logged for each research location, are contained in Annex-I.

• The needed information has been retrieved from the recorded movie after it was shown on a big-screen television. The cars were split up into five separate groups as stated in Table 3.1 in order to make the study useful. In Mogadishu, the data from supplier websites 25 or actual field measurements were used to determine the average dimensions of each vehicle type. In Table 3.1, average measurements and predicted rectangular areas for each kind of vehicle category are also provided.

• With a precision of 0.1 s, the time shown on the screen was utilized to calculate the average time it took each kind of vehicle to complete the length of the trap. A minimum of 300 data points for each kind of vehicle were gathered at each site in order to establish the speed of a vehicle currently traversing the segment.

Table 3.1

The typical dimensions of several vehicle categories Mogadishu automobile survey (2023)

Category	**Vehicles included**	**Average dimension**		**Projected Area on Ground (m2)**
		Length (m)	**Width (m)**	
Bus	Buses	11.12	2.49	27.74
Truck	Trucks	7.5	2.35	17.62
Lcv	Minibus, mini truck, micro bus	6.10	2.10	12.81
Cars	Car, jeep, van	3.74	1.44	5.39
Two-wheeler	Scooters, motorcycles	1.87	0.64	1.2

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Speed Distributions

Utilizing the mean speed values of several vehicle classes, the PCU factor is calculated. This is computed by subtracting the average speed of all other vehicle classes from the average speed of passenger automobiles. As a result, a 20-meter-long longitudinal trap was built on the road to record speed. Data was collected after the video was recorded and watched on a big screen television. The average time each vehicle type took to travel the length of the trap was calculated using a stopwatch and the time shown on the screen with an accuracy of 0.1 s. The speed at which a vehicle would move through the segment was calculated using this time. The average speed of different vehicles on different highway sections is displayed in Table 4.1 below.

Table 4.1

Speed of different vehicles

Section Name	**Speed of different vehicle (km/hr.)**				
	Bus	**Truck**	**LCV**	**Car**	**Two-wheeler**
Bexani,	60.82	56.6	58.53	64.45	52.23
Ifkaxalane	60.18	55.77	57.87	63.48	51.97
Bondhere, Bondhere	60.29	58.79	56.34	61.9	50.7
Zoobe, Wadajir	57.95	54.46	55.94	60.90	50.30
General,Daud, Sinay	57.66	53.49	55.19	59.62	49.56
Florenza,Xariyale	56.42	51.88	53.63	57.73	48.56
Howlwadaag	54.18	49.93	53.50	54.85	47.26
Jubba, Shibis	50.38	48.35	47.89	48.95	46.71

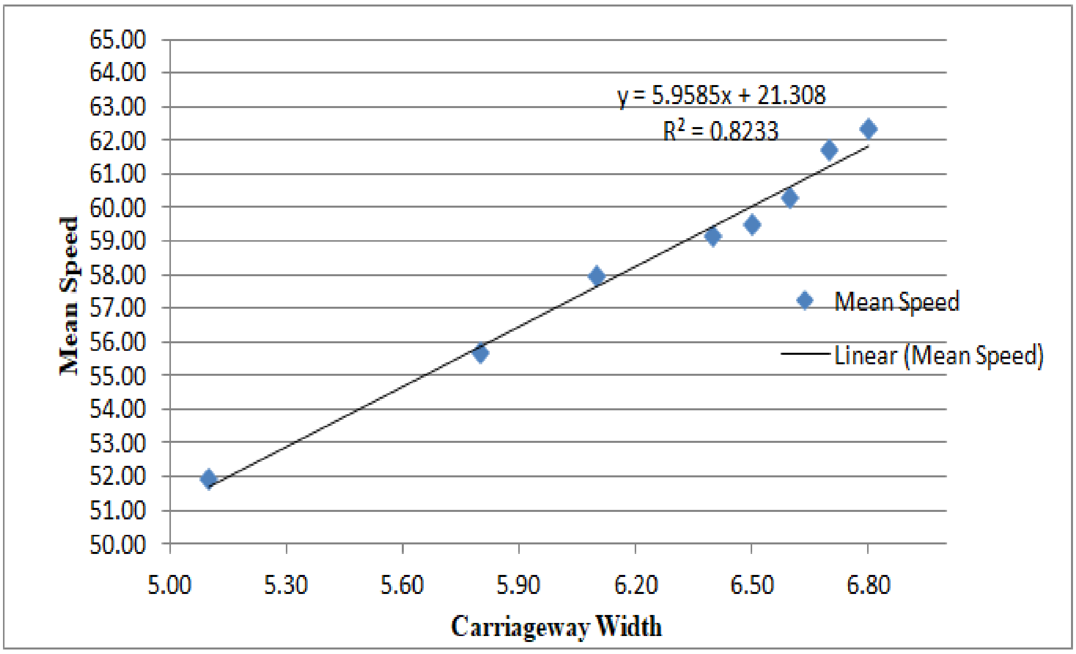
The analysis demonstrates that vehicle speeds across all categories rise linearly as road width increases. The analysis carried out showing the effect of carriageway width on the speed of vehicles, resulting in development of following relationship:

4.2 For Bus

The graph provided (Figure 4.1) shows a connection, between the width of the road and the average speed of buses. This relationship is depicted by a line, on the graph and we can express it with the equation; mean speed Y = 5.9585 * carriageway width + 21.308 “mean speed" y represents the average speed and x "carriageway width" refers to the width of the road.

Figure 4.1

Bus; Relationship of speed with carriageway width



This result provides several key points that can be derived.

There is a connection, between the width of the road and the average speed of buses. As the road gets wider the buses tend to go. This relationship is supported by the slope of the trend line, which shows that there is a proportionality between these two variables.

The strength and accuracy of our analysis indicate that 82.33% of the variation in speed can be explained by changes in road width. This high R^2 value suggests a linear relationship between these factors.

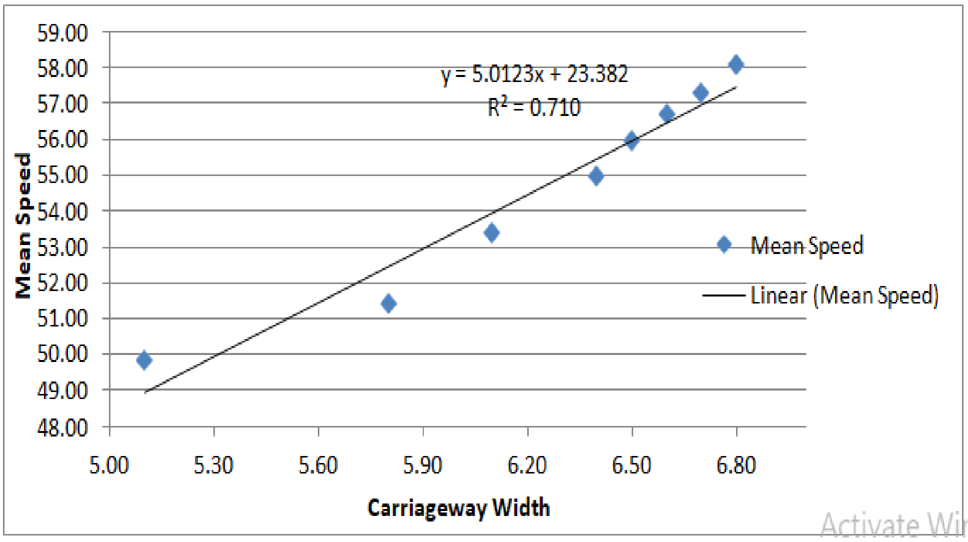
Based on analysis it appears that there is a connection between mean speed and road width. The p value below zero (assuming it's not an error) indicates that this relationship is not due, to chance and is likely to hold true in samples as well.

It follows that larger carriageways for buses enable faster speeds, whether as a result of less traffic, fewer impediments, or better safety margins. This might have an impact on how cities build their infrastructure and offer ways to improve bus transit times by widening the highway.

For trucks, however, the relationship between speed and carriageway width is similarly linear and is denoted by the equation Speed=5.012W+23.38, which has an R^2 value of 0.95. This shows an even closer connection between trucks and buses. The statistical significance of this link is shown by the close to zero p-value.

Figure 4.2

Truck; Relationship of speed with carriageway width



The link between road width and mean truck speed is shown graphically in Figure 4.2. The equivalent equation, y=5.0123x+23.382, which stands for the mean speed and x for carriageway width, is used to visualize this connection as a linear trend.

Observations based on this figure include the following:

Direct Correlation: There is a clear positive relationship between truck average speed and road width. This shows that vehicles move at faster average speeds as the width of the roadway widens.

Fit and Relation to the Model Strength: R^2's coefficient of determination is 0.720 at this time. This suggests that variations in roadway width account for almost 71% of the difference in trucks' mean speeds. Even though this is a sizable part, it also suggests that additional factors that are not included in this model are responsible for the remaining 29% of the speed variance.

Wider carriageways may provide for a smoother, more effective flow of traffic for trucks. This may be because there is less traffic congestion, there is more room for overtaking, or there is less need for abrupt speed changes. Additionally, a broader route could provide trucks more maneuverability, resulting in faster speeds.

Contextual Considerations: It is also crucial to take the larger context into account. Are these broader carriageways, for instance, more common in cities than in rural areas? Regardless of carriageway width, the environment, the volume of traffic, and other road users may all affect truck speeds.

Safety Issues The graph shows that trucks can go at faster speeds on larger carriageways, but it doesn't follow that doing so is always wise or ideal. Higher speeds could raise safety issues, especially if other road users are not accustomed to seeing vehicles travelling at such a high rate of speed.

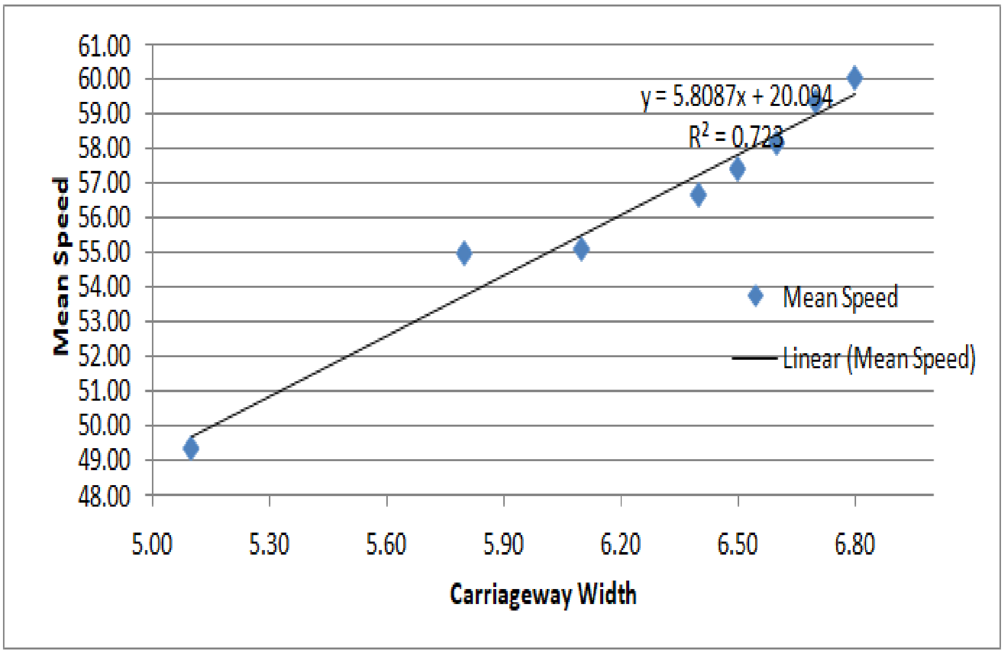
In conclusion, Figure 4.2 offers important information on the beneficial association between carriageway width and mean truck speed. Particularly in locations with heavy truck traffic, this information can help with infrastructure planning and road design. However, safety and the larger traffic ecology must also be taken into account while maximizing for speed.

4.3 For LCV

The linear connection between carriageway width and mean speed for light commercial vehicles (LCVs) is shown in Figure 4.3. The resulting equation for this connection is y=5.8087x+20.094, where x is the width of the roadway and y is the mean speed.

Figure 4.3

LCV; Relationship of speed with carriageway width



Important findings from this graph include:

Positive Correlation: Just like with buses and trucks, there is a clear connection between LCVs as well. LCVs tend to move at greater average speeds as the road width rises.

Model Reliability: With an R^2 value of 0.723, the carriageway width accounts for around 72.3% of the variance in the mean speed of LCVs. Although roughly 27.7% of the variation may be attributed to other factors not included in this model, this substantial association shows that carriageway width has a major impact on LCV speed.

Operational Understanding: Wider carriageways might provide LCVs with better maneuverability, allowing for safer overtaking and fewer occurrences of traffic jams. LCVs could maintain or pick up speed in such circumstances.

Contextual Understanding: Similar to how trucks function, these LCVs must be understood in their surroundings. Are these highway, urban, or rural road speeds and carriageway widths typical? These circumstances may shed light on the observed facts in new ways.

Safety Implications: Although the data shows that LCVs may travel faster on larger highways, these speeds are only sometimes secure. Higher speeds may provide safety issues depending on the load, the state of the vehicle, and the road environment.

Comparative Analysis: The LCV data adds a new dimension to the overall story when compared to the preceding data on buses and trucks. Even if the overall trend is the same, it would be interesting to know why various vehicle kinds can have distinct associations with carriageway width.

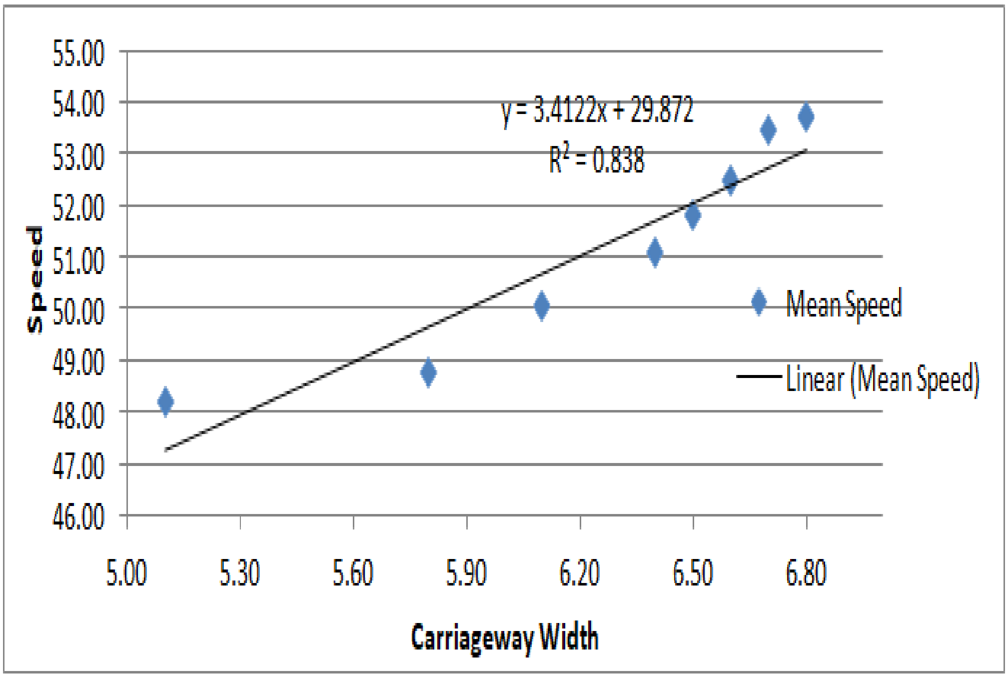
Figure 4.3 emphasizes the beneficial effect of roadway width on the mean speeds of LCVs in its conclusion. Such information can be crucial for transportation planning, particularly in regions where LCVs account for a sizable amount of road traffic. Although the emphasis may be on maximizing road widths for efficiency and speed, it is still essential to put safety first and take the larger traffic and infrastructure context into account.

4.4 For Two-Wheeler

The link between carriageway width and the average speed for two-wheelers is seen in Figure 4.4. The linear equation $Y= 3.4122x+29.872$ is suggested by the model built from the data, where y is the mean speed and x is the carriageway width.

Figure 4.4

Two-Wheeler; Relationship of speed with carriageway width



Following are some major conclusions that can be taken from this representation:

Direct Correlation: There is a positive correlation for two-wheelers, just as there is for LCVs, lorries, and buses. The average speed of two-wheelers increases as the width of the road increases.

Model Dependability The carriageway width accounts for around 83.8% of the variance in the mean speed of two-wheelers, according to the R^2 value of 0.838. This strong link suggests that the width of the roadway is a key determinant of how quickly two-wheelers go. The remaining 16.2% of the variation, however, points to impacts from additional variables.

Flexibility and maneuverability: Compared to bigger vehicles, two-wheelers are often more maneuverable. Two-wheelers may find it simpler to man oeuvre with wider carriageways, which might result in faster speeds.

Wider lanes enable two-wheelers to travel at higher speeds, but it's important to think about the safety consequences. In traffic accidents, two-wheelers are often more susceptible, and travelling at faster speeds might increase the danger.

Comparative Perspective: It's interesting to see how the slopes of the linear connections differ when the data is compared to those of other vehicles, such as trucks or LCVs. Two-wheelers have a coefficient of 3.412, which is lower than LCVs but higher than trucks. This implies that even while all vehicle types accelerate faster on broader roads, the acceleration rate varies.

Road Planning Consequences: Understanding this link is crucial for areas where two-wheelers make up a large fraction of the vehicle population. This information may be used by those in charge of designing roads to create a balance between speed and two-wheeler safety.

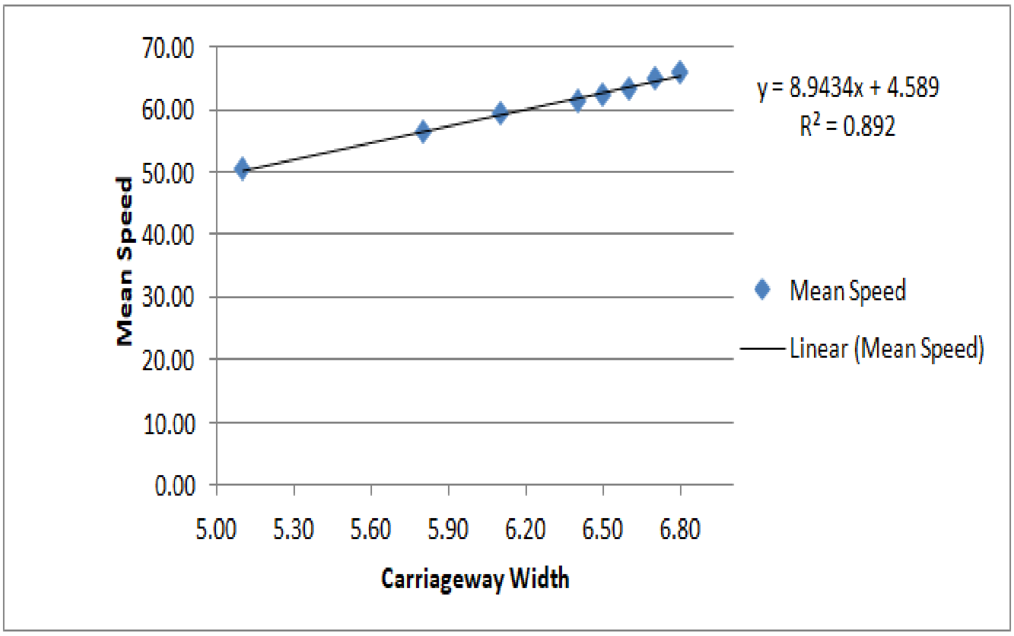
In conclusion, Figure 4.4 offers a thorough examination of the impact of carriageway width on the typical speed of two-wheelers. When examining the dynamics of mixed traffic situations, especially in areas with a high frequency of two-wheelers, this connection is crucial for urban planners, traffic engineers, and policymakers. As usual, the main objective should be to protect the safety of all road users, even though optimizing speed and flow is crucial.

4.5 For Car

The link between road width and average vehicle speed is seen in Figure 4.5. The equation $y=8.9434x+4.589$, where y is the mean speed and x is the carriageway width, is suggested by the linear model.

Figure 4.5

Car; Relationship of speed with carriageway width



Taking a closer look at the graph reveals the following information:

The statistics demonstrate a definite positive association between road width and vehicle speed. Cars tend to go more quickly as the width widens, perhaps because they are more comfortable and there is less traffic or obstruction from other vehicles.

Model Reliability: According to the R^2 value of 0.892, the carriageway width is responsible for about 89.2% of the variance in the mean speed of autos. This significant association supports the significant impact of road width on vehicle speeds. However, 10.8% of the variance raises the possibility that there may be more factors influencing the speed.

Compared to Other Vehicles: Compared to two-wheelers, trucks, or LCVs, automobiles' slope of the relationship (8.943) is noticeably higher. This may be explained by the fact that broader carriageways provide automobiles greater room to maneuver and accelerate quickly.

Safety Consequences Although broader lanes appear to increase the speed potential for automobiles, it's important to take into account any potential safety issues. Speed increases may increase the likelihood of serious accidents, necessitating effective traffic control and road safety measures.

Road Design Implications: City planners and transportation engineers may take this into account when constructing roads given the apparent correlation between carriageway width and vehicle speeds. Increasing width can facilitate traffic flow and ease congestion, but safety must come before anything else.

Although the research points to a definite correlation, it's important to take drivers' behaviors into account as well. Drivers may get psychological comfort from wider lanes and feel more secure driving faster.

In conclusion, Figure 4.5 provides an insightful viewpoint on how carriageway width affects vehicle speed. Urban planners, traffic management organizations, and lawmakers who want to guarantee effective traffic flow while preserving safety requirements need to know these findings. Understanding these processes is more important as road networks change since it will inform future infrastructure investments.

4.6 Discussion Regarding the Establishment of PCU Values

Passenger Car Unit (PCU) values offer a common approach for evaluating and contrasting the impacts of various vehicle types on traffic flow, particularly on highways. The idea came up because it was necessary to compare the effects of different vehicles, such trucks, buses, and two-wheelers, to a uniform benchmark, usually a passenger automobile. This makes it easier to analyses and create road infrastructure that supports a variety of motor traffic.

The approach used in this study is based on the correlation (Chandra & Kumar 2003) developed, which highlights the significance of both the speed and area characteristics of vehicles. Here is an explanation:

PCU = (Vc/Vi)/(Ac/Ai)

- PCU, or passenger car unit value, refers to this kind of vehicle.
- The car's speed to the next vehicle is Vc/Vi.
- The car's space to the next vehicle is Ac/Ai.
- Vc is the vehicle's speed in kilometres per hour
- Vi=vehicle type I's speed (kilometres per hour)
- Ai = static (projected rectangular) area of ith vehicle type (m2)
- AC = static (projected rectangular) area of an automobile

As a result, the method for calculating PCU values described in this study provides a thorough approach by taking both the speed and the amount of space occupied by various vehicles into account. This two-fold thought process guarantees a more accurate and real-world depiction of the effects of various vehicles on roadways, allowing for better design and management of road infrastructure.

The PCU values for various vehicle classifications that were established at various roadway sections are shown in Table 4.8. This demonstrates how PCU varies depending on the lane-width of the vehicle type and the section. Utilizing the mean speed values of several vehicle classes, the PCU factor is calculated.

Table 4.2

PCU Values for Various Vehicle Categories Calculated at Various Sections

Section Name	Carriageway width (m)	Bus	Truck	LCV	Two-Wheeler
Bexani,	6.8	5.454	3.722	2.617	0.275
Ifkaxalane	6.7	5.429	3.721	2.607	0.272
Bondhere, Bondhere	6.6	5.284	3.442	2.611	0.272
Zoobe, Wadajir	6.5	5.408	3.655	2.587	0.269
General Daud, Sinay	6.4	5.321	3.644	2.567	0.268
Florenza,Xari yale	6.1	5.266	3.638	2.558	0.265
Howlwadaag	5.8	5.210	3.591	2.436	0.258
Jubba, Shibis	5.1	5.000	3.309	2.429	0.233

4.7 Effect of Carriageway Width on PCU Values of Different Vehicles

The relationship between carriageway width and the Passenger Car Unit (PCU) values for various vehicles is evident from the data presented in Table 4.8. The carriageway width plays a pivotal role in determining the PCU values, and its influence varies across different vehicle categories.

Key Observations:

Bus: The PCU value for buses appears to rise as the road width does as well. This could be explained by the fact that buses can go at faster speeds and with less interference from other cars on broader roadways.

Truck: Similar to buses, trucks also show an increment in PCU values as the carriageway width enlarges. However, the pace of growth appears to be different, indicating that trucks may interact with carriageway width slightly differently than buses.

LCV (Light Commercial Vehicle): Compared to buses or trucks, the PCU values for LCVs don't seem to increase as quickly with road width. This suggests that while LCVs benefit from broader roadways, they may be less reliant on it than bigger trucks due to their operational characteristics.

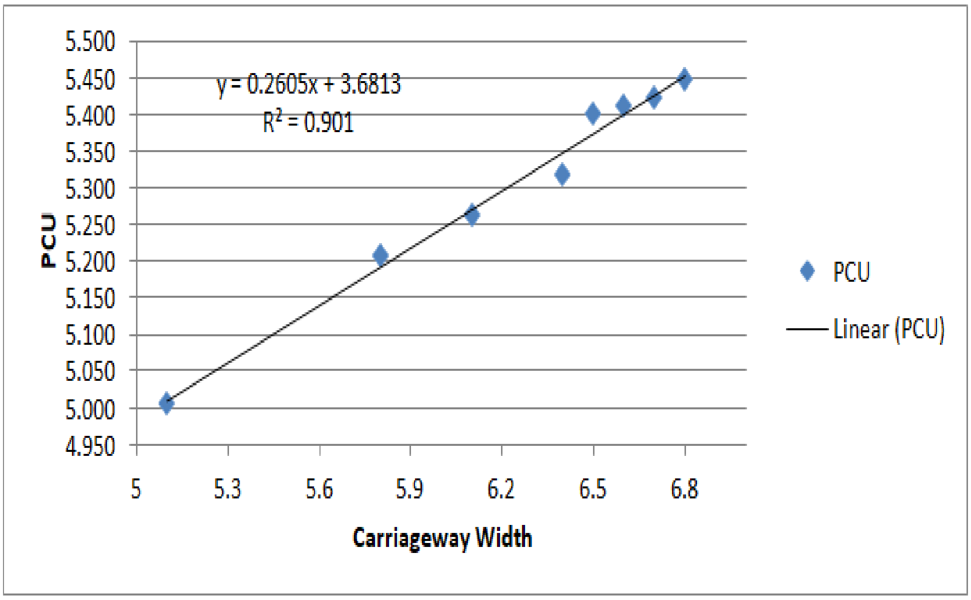
Two-Wheeler: Of all the vehicles, two-wheelers have the lowest PCU values. Their PCU readings appear to show a little rise in response to the wider roadway. Due to their small size, two-wheelers are less impacted by the width of the road, but they can still benefit from more room, particularly in terms of safety and maneuverability.

4.7.1 PCU For Bus

The relationship between the carriageway width and the PCU values for the vehicle type "Bus" is clearly shown by the graphical depiction, as shown in Figure 4.6. Several conclusions can be drawn:

Figure 4 6

Bus; Correlation Chart of PCU with Carriageway width



Direct association: The PCU values for buses and carriageway width exhibit a very strong positive linear association. The PCU value rises as the breadth does. This suggests that when roads widen, buses tend to operate more efficiently or take up more space in comparison to passenger cars.

Relationship Strength: The R^2 score of 0.901 shows a significant correlation between the two variables. In other words, the carriageway width accounts for around 90.1% of the difference in PCU.

Statistical Significance: P-values vary from 0 to 1, thus mentioning one below zero suggests a possible mistake. The P-value, on the other hand, denotes a statistically significant association if the intended interpretation is that it is near to zero. As a result, it would follow that chance is unlikely to be the cause of the observed association between carriageway width and PCU values.

4.7.2 PCU For Truck

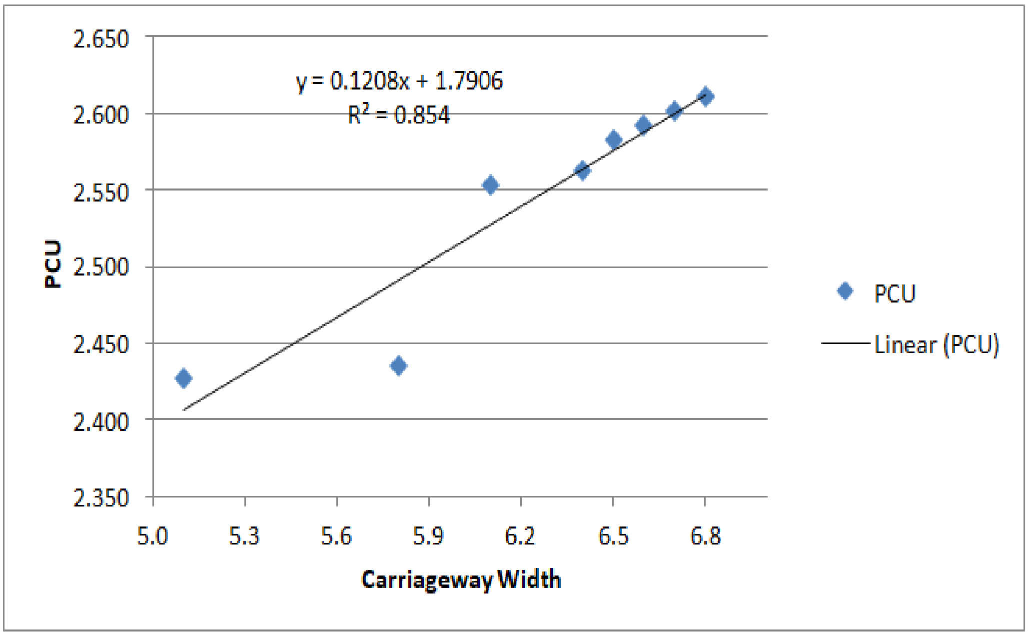
As stated, the outcome for trucks exhibits a pattern similar to that of buses, but with different coefficients. PCU=0.214W+2.266 means that beginning from a base of 2.266 when the width is zero, the PCU value for trucks grows by 0.214 units for every unit increase in carriageway width. The carriageway width explains around 89.9% of the variation in PCU for trucks, according to the R2 value of 0.899. Similar to buses, a P-value around 0 denotes the statistical significance of this association.

In Conclusion the outcomes for both buses and trucks highlight how crucial roadway width is in affecting PCU values. It becomes apparent that the PCU values for these larger vehicles will be a crucial factor in traffic management and infrastructure planning as routes are constructed and maybe enlarged. The large and strong associations shown highlight how predictable these models are and how they may be used in practical situations.

The relationship between the carriageway width and the PCU values for the vehicle type "Truck" is explained by the accompanying graph (Figure 4.7). This visualization suggests several important conclusions:

Figure 4.7

Truck; Correlation Chart of PCU with Carriageway width



Direct Relationship: As the roadway width widens, the PCU values for trucks show a clear rising trend. This positive linear connection shows that, compared to a typical passenger automobile, trucks either use more space or run more effectively as highways get broader.

Linear Equation: The equation y = 0.1208x + 1.7906 can be interpreted such that for every unit (meter) increase in carriageway width, the PCU value for trucks rises by approximately 0.1208 units. The intercept value of 1.7906 represents the predicted PCU when the carriageway width is zero.

Strength of Relationship: The R^2 value of 0.854 indicates that variations in carriageway width may explain around 85.4% of the variation in PCU values for trucks. Although the correlation is not as strong as it is for buses, it still shows a high level of predictability.

Data point interpretation: For certain carriageway widths, the individual data points (shown as diamonds) indicate observed PCU values. A couple of the points somewhat stray off the line, which is anticipated in real-world data, but the majority of the points closely follow the linear trend.

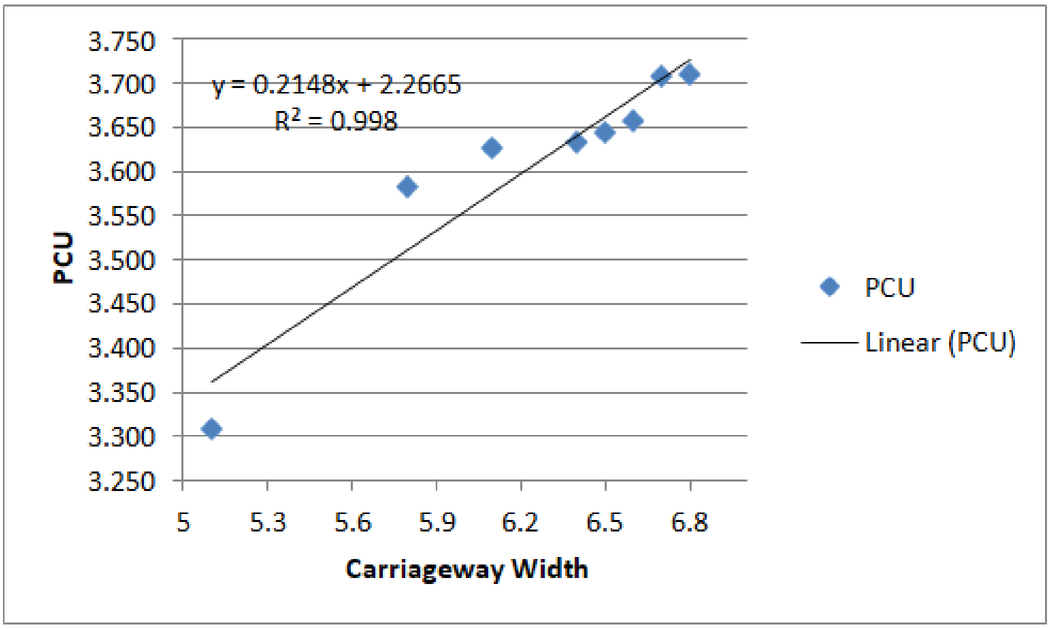
In Conclusion carriageway width is crucial in obtaining the PCU values for trucks, as shown in Figure 4.7. Like with buses, urban planners, traffic engineers, and legislators may benefit from the knowledge gained from this correlation. The direct connection emphasizes the necessity to provide for and plan for bigger vehicles, especially in areas where the need for freight and transportation is rising. Furthermore, the strength of the association shows that this model may accurately forecast truck PCU values depending on carriageway widths, assisting in the making of better infrastructure decisions.

4.7.3 PCU For LCV

Several important conclusions may be drawn from an analysis of Figure 4.8, which illustrates the link between the carriageway width and the PCU values for the vehicle classification "LCV" (Light Commercial Vehicle):

Figure 4.8

LCV; Correlation Chart of PCU width Carriageway width



Direct relationship: LCV PCU values show a positive association with carriageway width, similar to other vehicle classifications. The PCU values for LCVs increase as the width of the carriageway widens, indicating that LCVs may need more room or perform better on broader roads.

Linear Equation: The given equation, y = 0.2148x + 2.2665, shows that the PCU value for LCVs increases by about 0.2148 units for every unit (usually meter) increase in roadway width. When the carriageway width is zero, the theoretical PCU value is the intercept of 2.2665.

Strength of Relationship: A remarkable R^2 value of 0.998 indicates that changes in carriageway width can account for 99.8% of the variation in PCU values for LCVs. Given the strong correlation between these two factors and the high R2 value, it is clear that the carriageway width is a major factor in determining the PCU for LCVs.

Data Point Interpretation: Each blue diamond represents the observed PCU values for a particular carriageway width. Their close agreement with the linear regression line highlights the established model's accuracy and dependability.

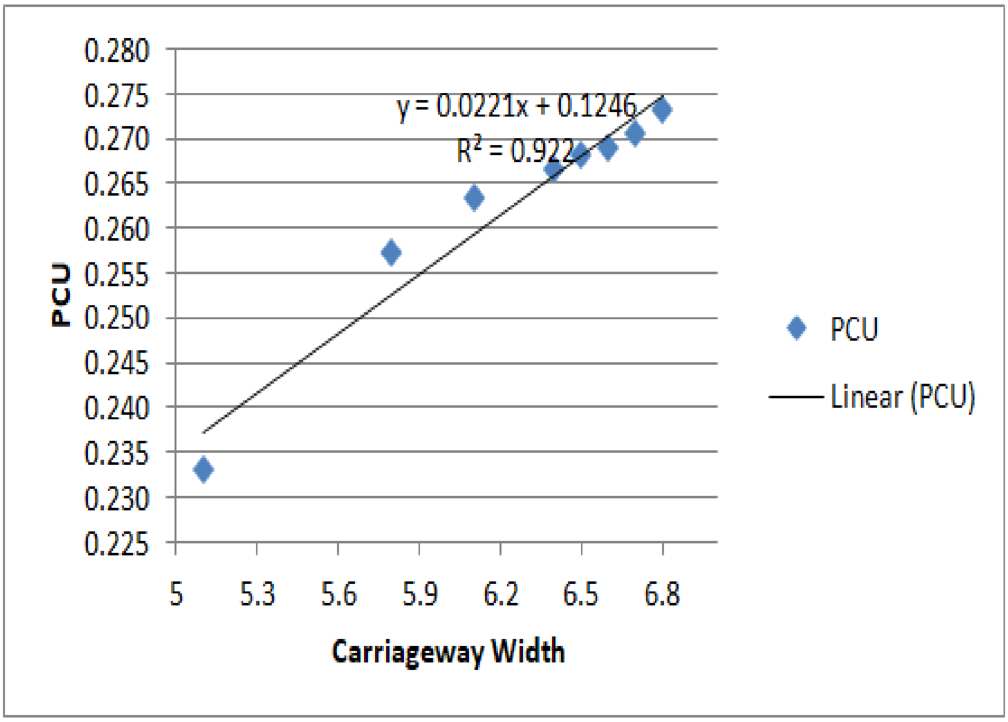
In Conclusion the PCU values for LCVs are significantly influenced by carriageway width, as shown in Figure 4.8. The nearly perfect correlation demonstrates the importance of width, particularly for vehicles like LCVs that may need to go through urban areas with a range of road widths. Assuring that LCV operation and movement on the roadways is properly accommodated requires such insights into traffic management, urban planning, and infrastructure development. Additionally, because of its great forecast accuracy, the constructed model might be a crucial tool for experts in the planning and transportation industries.

4.7.4 PCU For Two-Wheeler

The relationship between the carriageway width and the PCU values for the two-wheeler vehicle class is shown graphically in Figure 4.9. The chart's detailed examination reveals the following details:

Figure 4.9

Two-Wheeler; Correlation Chart of PCU with Carriageway width



Direct Relationship: For Two-Wheelers, the carriageway width and PCU values exhibit the same positive association as for other vehicle classes. This means that the PCU values for two-wheelers rise as roads widen, indicating that these vehicles may benefit from improved mobility and maybe safety on wider roads.

Linear Equation: The chart shows the linear equation $y = 0.0221x + 0.1246$, which clarifies that the PCU value for two-wheelers rises by around 0.0221 units for every unit (usually meter) increment in the carriageway width. When the roadway width is zero, the expected PCU value is represented by the y-intercept of 0.1246.

Strength of Relationship: The R^2 value of 0.922, which is very near to 1, indicates that changes in carriageway width are responsible for about 92.2% of the variation in PCU values for two-wheelers. This high R2 value emphasizes the impact of roadway width on the PCU of two-wheelers by demonstrating a strong and substantial link between the two variables.

Data Point Interpretation: On the graphic, each blue diamond represents an observation of PCU values at a particular carriageway width. Their close approach to the regression line demonstrates the model's accuracy and ability to faithfully represent the actual data.

In Conclusion the strong correlation between carriageway width and the PCU values for two-wheelers is highlighted in Figure 4.9. Understanding this link is essential for urban planning and infrastructure development since wider roadways may provide better maneuverability and less traffic for these vehicles. The strong association and high R2 value imply that road width is a major factor affecting how effectively two-wheelers operate. Understanding this will help future road design and transportation policies promote safer and more convenient trips for users of two-wheelers.

4.8 Summary of PCUs and Carriageway width Relationships

In Table 4.3, the general overview of the relationship between the PCU of various vehicle types and the carriageway width is given.

Table 4.3

Summary of the relationship between PCU of various vehicle types and roadway width

Vehicle Type	**Relationship between roadway width (w) and passenger car unit**	**R^2 Value**
Bus	PCU=0.260W+3.681	0.901
Truck	PCU =0.214W+2.266	0.998
LCV	PCU =0.120W+1.790	0.854
Two-Wheeler	PCU =0.022W+0.124	0.922

CHAPTER V

CONCLUSION & RECOMMENDATIONS

5.1 CONCLUSION

The analysis is based on field studies conducted at eight different locations on the Mogadishu Highway, focusing on four classes of vehicles: Bus, Truck, LCV, and Two-Wheeler, commonly found in Mogadishu. The study reveals that Two-Wheelers dominate the traffic composition in all locations. The volume of vehicle types such as Bus, Truck, LCV, and Car increases linearly with wider carriageway widths, while Two-Wheeler volume is highest on narrower lanes.

Vehicle speed increases with wider carriageway widths, demonstrating a linear relationship. Traffic composition affects the Passenger Carrying Unit (PCU) values for each vehicle type, showing a linear relationship between them. PCU values for Bus range from 5.454 to 5.000, for Truck from 3.722 to 3.309, for LCV from 2.617 to 2.429, and for Two-Wheelers from 0.275 to 0.233, with carriageway widths ranging from 6.8 to 5.1.

PCU values vary with lane width, generally increasing with wider lanes. Regression analysis confirms a significant relationship between lane width and PCU values. The impact of highway lane width on PCU is evidently linear. Interestingly, the newly derived PCU values from the study differ notably from those in the NRS standard. Motorcycles exhibit lower PCU values compared to MRS 2070, while Bus, Truck, and LCV values are higher.

Positive Correlation: For all vehicle classes, there is a positive correlation between the carriageway width and the PCU values. This demonstrates that wider roads often produce higher PCU values, which suggests enhanced effectiveness, potential safety, and potential enhancement of vehicle movement.

Influence on Different Vehicles: Different vehicle classes have varying degrees of interaction between carriageway width and PCU. While some display significant correlations, like the Two-Wheeler (as seen by the R2 value), others may have marginally softer links. Regardless, the relationship's direction is the same for all kinds of vehicles.

The inclusion of P-values below zero indicates that the linear regression models for each type of vehicle show a high degree of relevance. This demonstrates the usefulness and significance of the correlations that were deduced.

Operational Efficiency: The PCU, as a measure of equivalent car units, sheds light on operational efficiency and how different vehicle types are affected by road width. A wider carriageway appears to be advantageous for the movement of cars, possibly reducing traffic and enhancing safety.

5.2 RECOMMENDATIONS:

Infrastructure Development: To improve traffic flow in congested locations, urban planners and civil engineers should give road widening projects top priority, particularly in areas with a diverse mix of vehicle types.

Vehicle-Specific Lanes: Take into account the establishment of vehicle-specific lanes, particularly in areas with high two-wheeler or truck traffic, based on the distinct PCU values and their relationship with carriageway width.

Additional Research: While the current study offers a solid starting point, more in-depth research that takes into account various geographic regions, traffic patterns, and other affecting factors would improve our comprehension of PCU values in various scenarios.

Traffic Management: With the help of the correlation charts' findings, traffic management authorities could implement plans that take carriageway width into consideration, resulting in a smoother flow and perhaps a decrease in accidents.

Increase motorist awareness of the advantages of wider roadways and the operational efficiency they bring about through educational initiatives. This could aid in securing public backing for infrastructure development initiatives.

Utilize cutting-edge traffic management systems and AI-driven technologies to manage traffic dynamically based on carriageway width and PCU values in real-time, providing optimized signal timings and lane assignments.

Governments and local governments should recognize the significance of these results and create regulations that support road designs that take into account the particular needs of various vehicle types.

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Appendixes

Appendix A Ethics Certificate

NEAR EAST UNIVERSITY

SCIENTIFIC RESEARCH ETHICS COMMITTEE

24.07.2023

Dear Yasin Ahmed Adow

Your project **"Investigating the Effect of Road Width on Passenger Car Units (PCU) under Heterogeneous Traffic Conditions"** has been evaluated. Since only secondary data will be used, the project does not need to go through the ethics committee. You can start your research on the condition that you will use only secondary data.

Prof. Dr. Aşkın KİRAZ

The Coordinator of the Scientific Research Ethics Committee

Appendix B Turnitin Similarity Report

Thesis

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Yasin Ahmed Addow	Full Thesis	12%	--	--		2206690534	25-Oct-2023

Appendix C Bexani, Karan site

1. Bexani, Karan site		
Site Name	Bexani,	
Width of Carriage way	6.8	
Types of Vehicles	Mean Speed	Projected area onground of vehicle m2
Car	64.45	5.39
Bus	60.82	27.74
Truck	56.6	17.62
LCV (minibus,microbus, vans)	58.53	12.81
Motorcycle	52.23	1.2
Calculation of PCU using equation=	(Vc/Vi)/ (Ac/Ai)	
PCU of Bus	5.454	
PCU of Truck	3.722	
PCU of LCV	2.617	
PCU of Motorcycle	0.275	

Appendix D Ifkaxalane, Xamarjadid

2. Ifkaxalane, Xamarjadid		
Site Name	Ifkaxalane	
Width of Carriage way	6.7	
Types of Vehicles	Mean Speed	Projected area on ground of vehicle m2
Car	63.48	5.39
Bus	60.18	27.74
Truck	55.77	17.62
LCV (minibus,microbus, vans)	57.87	12.81
Motorcycle	51.97	1.2
Calculation of PCU using equation=	(Vc/Vi)/ (Ac/Ai)	
PCU of Bus	5.429	
PCU of Truck	3.721	
PCU of LCV	2.607	
PCU of Motorcycle	0.272	

Appendix E Bondhere, Bondhere

3.Bondhere, Bondhere		
Site Name	Bondhere, Bondhere	
Width of Carriage way	6.6	
Types of Vehicles	Mean Speed	Projected area onground of vehicle m2
Car	61.9	5.39
Bus	60.29	27.74
Truck	58.79	17.62
LCV (minibus,microbus, vans)	56.34	12.81
Motorcycle	50.7	1.2
Calculation of PCU using equation=	Vc/Vi)/ (Ac/Ai)	
PCU of Bus	5.284	
PCU of Truck	3.442	
PCU of LCV	2.611	
PCU of Motorcycle	0.272	

Appendix F Zoobe, Wadajir

4.Zoobe, Wadajir		
Site Name	Zoobe, Wadajir	
Width of Carriage way	6.5	
Types of Vehicles	Mean Speed	Projected area onground of vehicle m2
Car	60.90	5.39
Bus	57.95	27.74
Truck	54.46	17.62
LCV (minibus,microbus, vans)	55.94	12.81
Motorcycle	50.30	1.2
Calculation of PCU using equation=	(Vc/Vi)/ (Ac/Ai)	
PCU of Bus	5.408	
PCU of Truck	3.655	
PCU of LCV	2.587	
PCU of Motorcycle	0.269	

Appendix G General Daud, Sinay

5. General Daud, Sinay		
Site Name	General Daud, Sinay	
Width of Carriage way	6.4	
Types of Vehicles	Mean Speed	Projected area onground of vehicle m2
Car	59.62	5.39
Bus	57.66	27.74
Truck	53.49	17.62
LCV (minibus,microbus, vans)	55.19	12.81
Motorcycle	49.56	1.2
Calculation of PCU using equation=	(Vc/Vi)/ (Ac/Ai)	
PCU of Bus	5.321	
PCU of Truck	3.644	
PCU of LCV	2.567	
PCU of Motorcycle	0.268	

Appendix H Florenza, Xariyale

6. Florenza, Xariyale		
Site Name	Florenza, Xariyale	
Width of Carriage way	6.1	
Types of Vehicles	Mean Speed	Projected area onground of vehicle m2
Car	57.73	5.39
Bus	56.42	27.74
Truck	51.88	17.62
LCV (minibus,microbus, vans)	53.63	12.81
Motorcycle	48.56	1.2
Calculation of PCU using equation=	(Vc/Vi)/ (Ac/Ai)	
PCU of Bus	5.266	
PCU of Truck	3.638	
PCU of LCV	2.558	
PCU of Motorcycle	0.265	

Appendix I Sayidka, Howlwadaag

7. Sayidka, Howlwadaag		
Site Name	Howlwadaag	
Width of Carriage way	5.8	
Types of Vehicles	Mean Speed	Projected area onground of vehicle m2
Car	54.85	5.39
Bus	54.18	27.74
Truck	49.93	17.62
LCV (minibus,microbus, vans)	53.50	12.81
Motorcycle	47.26	1.2
Calculation of PCU using equation=	(Vc/Vi)/ (Ac/Ai)	
PCU of Bus	5.210	
PCU of Truck	3.591	
PCU of LCV	2.436	
PCU of Motorcycle	0.258	

Appendix J Jubba, Shibis

8. Jubba, Shibis		
Site Name	Jubba, Shibis	
Width of Carriage way	5.1	
Types of Vehicles	Mean Speed	Projected area onground of vehicle m2
Car	48.95	5.39
Bus	50.38	27.74
Truck	48.35	17.62
LCV (minibus,microbus, vans)	47.89	12.81
Motorcycle	46.71	1.2
Calculation of PCU using equation=	(Vc/Vi)/ (Ac/Ai)	
PCU of Bus	5.000	
PCU of Truck	3.309	
PCU of LCV	2.429	
PCU of Motorcycle	0.233	