Jimma University

School of Post Graduate Studies

Jimma Institute of Technology, Faculty of Civil and Environmental Engineering, Program of Civil Engineering,

(Highway Engineering)

EFFECT OF CONSTRICTED WIDTH PAVEMENT AT BRIDGE APPROACH ON TRAFFIC FLOW: A CASE STUDY IN JIMMA TOWN

A final thesis submitted to program of Civil Engineering, Faculty of Civil & Environmental Engineering, Jimma Institute of Technology, and Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Highway Engineering).

By:

WAKJIRA DINSA NEMERA

July 27, 2021

Jimma, Ethiopia

APPROVAL PAGE

As members of the examining board of the final M.Sc. open defense, we verify that we have read and evaluated the thesis prepared by **Wakjira Dinsa**, entitled: **"Effect of Constricted Width Pavement at Bridge Approach on Traffic Flow: A Case Study In Jimma Town"** and recommended for acceptance as a fulfillment of the requirement for the Degree of Master of Science in Civil Engineering (Highway Engineering).

Principal Advisor

Jemal J. Muhammed (Ph.D.). ______________________ ___________________

Signature Date

Members of Examining Board:

1. ___________________ ____________________ _________________
External Examiner Signature Date

2. ___________________ _____________________ _________________
Internal Examiner Signature Date

3. ___________________ _____________________ _________________
Chairperson of Examiner Signature Date

4. ___________________ _____________________ _________________
Head, Civil Department Signature Date

5. ___________________ ____________________ _________________
Dean, School of CEE Signature Date

6. ___________________ _____________________ _________________
Director, School of Graduate Studies Signature Date

DECLARATION

I, the undersigned, declare that this proposal entitled: **"Effect of Constricted Width Pavement at Bridge Approach on Traffic Flow: A Case Study In Jimma Town"** is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material will be used for this thesis has been duly acknowledged.

Candidate:

Wakjira Dinsa ___________________ _____________

Signature Date

As Master's Research Advisors, we hereby certify that we have read and evaluated this MSc Thesis prepared under our guidance by **Wakjira Dinsa** entitled: **"Effect of Constricted Width Pavement at Bridge Approach on Traffic Flow: A Case Study in Jimma Town."**

Main Advisor

Jemal J. Muhammed (Ph.D.) _______________ ________________

Signature Date

Co-Advisor

Eng. Teyba Wedajo (Ph.D. Candidate) _______________ ________________

Signature Date

ACKNOWLEDGEMENT

Before all, I would like to thank almighty God for helping me through all my ways of preparing and organizing this research.

Next, my deepest gratitude was go to my advisors **Jemal J. Muhammed (Ph.D.) and Eng. Teyba Wedajo (Ph.D. Candidate**) for their willingness to be my advisors and their effort to give me their very constructive comments and guidance through all the time of my research study.

I would also thanks Desalegn Beyene (Ph.D.), Mrs. Bekalu Ferede, and Ms. Tsehay Dinsa for their immense effort while I was preparing my research. At last, I would like to thank my intimate friends for the peer discussion made during the compilation.

ABSTRACT

Urban traffic is growing from day to day following a high demand along the roads. This traffic growth contributes a bottleneck at bridge approaches with constricted widths. In Jimma town, vehicles passing the town are increasing, and causing traffic congestion along the highway, particularly where the bridges are located. Effects of constricted width pavement at Bridge Approach on traffic flow caused a dilemma to the town administration regarding which appropriate measures to implement. This study focused on five bridges along the main thoroughfare in the town. These five bridges observed with narrowed or constricted width approaches relative to the width of approach roads. Collecting observed traffic survey was conducted for continuous 12hrper day using both tally and video recording. A stratified sampling technique was used to determine the minimum number of end-users or respondents to answer the structured questionnaire survey. The respondents like a pedestrian, driver, traffic police, engineers, and others were taken part. Regression analysis was used to correlate the dependent variable with an independent one. AutoCAD, PTV Vissim, SPSS, and R-codes software were used for data analysis and interpretation. As per the study, traffic flow characteristics like travel speed, traffic density, and traffic flow were identified per bridge location from both primary and secondary data sources. Traffic composition of different motorized and the non-motorized vehicle was also observed along a bottleneck structure. Vehicles like animal carts, bicycles, motorcycles, small cars, medium cars, and large cars were observed along with a bottleneck structure. Traffic crashes like rear-end, head-on, sideswiping, and others were observed all over the bridges. "Best fit model "was also formulated to predict the effect of constricted width Pavement Bridge Approach on current and future traffic flow. Possible remedial actions like widening bridge width, smoothening sudden constriction, constructing cost efficient pedestrian walkway and installing traffic guide warning sign was suggested to reduce negative effect of constricted width Pavement Bridge Approach on traffic flow. From the result, it was observed that constricted width Pavement Bridge Approach profoundly affect traffic characteristic and travel safety of end-users. In the future, traffic flow along this structure would be a danger. Possible remedial action like a widening bridge shall be taken to smooth traffic flow.

Keywords: *Bridge Approach, Constricted Pavement Width, Jimma Town, Traffic flow, and Traffic crash*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AADT:	Average Annual Daily Traffic
AASHTO:	American Association for State Highway and Transportation Office
ADT:	Average Daily Traffic
ANOVA:	Analysis of Variance
AutoCAD:	Automated Computer Aid Design
CWPBA:	Constricted Width Pavement Bridge Approach
ERA:	Ethiopian Road Authority
GC:	Gregorian calendar
GIS:	Geographical Information System
IRC	Indian Roads Congress
JU:	Jimma University
LOS:	Level of Service
MBC:	Micro Business College
PBA:	Pavement Bridge Approach
RSD:	Reduced Sight Distance
R-code:	Regression code
SPSS:	Statistical Package for Social Science

CHAPTER ONE

INTRODUCTION

1.1 Background

Standing on the different author's studies, the performance of the transportation system affects public policy like economic development, safety, and security, air quality, consumption of other environmental resources, social equity, land use, and urban growth [Canada, 2006]. On the other hand, the study of traffic flow has attracted many researchers from different fields because of its complexity and comprehensiveness. Hence, traffic characteristics and composition vary from rural to urban as well as country to country in all. In some parts of the world, traffic flow at the entrance and exit of the bridge approach has been studied [Gandhi, 1983]. There is also some study which focuses on traffic stream characteristic, urban traffic expansion, bridge safety, and driver's behavior towards bridge approach has also been discussed. New findings and technology were also implemented to address their effect on traffic flow in general.

The effect of constricted pavement width at the bridge on safety has been studied by a few scholars. In presenting the results of past research, studies are categorized as those that (a) use surrogate measures, (b) evaluate safety at bridge sites in general, and (c) specifically evaluate the safety effect of bridge width. Some studies are in more than one of these categories. Pertinent portions of these studies are reviewed separately under the appropriate category [Gunnerson, 1961]. Most of the Ethiopian narrow bridges were constructed in the late 1950th during Italy's invasion to control the country. By that time, the number of vehicular traffic flows was almost negligible. The number and composition of vehicles were comparatively small with a number of the pedestrian [Admasu, 2012]. But today, the country is under multi-dimensional growth in terms of political, social, and economic aspects. Different types of roads have been under construction to counterbalance the current demand and increase traffic movement. To use as an existing bridge with the current geometric alignment, constricting the pavement width at the bridge approach should be furnished as one option. This intern caused different problems on traffic flowing in general. Currently, when most of the new and upgraded alignment was constructed, its travel way width was proposed to be accommodating the current and future traffic flow. Different types of paved roads in town have been upgraded to counterbalance the current demand and increase traffic movement. But the existing bridge along the alignment is not parallel upgraded. This leads to constricting the pavement width at the bridge approach. In the case of Jimma town, five different bridges were forced to constrict due to an upgrade of the existing travel way width. Different vehicle passes constricted bridges per minute. Hence traffic conflict and delay were experienced where the roads were forced to narrow. Traffic composition, like a pedestrian, motorized, and non-motorized as well as others, were observed to study the effect of constricted width pavement bridge approach on traffic flow. Therefore the study was undertaken carefully and the effect of constricted width pavement at the bridge was stated. And also possible remedial action was proposed for smooth current and future traffic flow.

1.2 Statement of the Problem

The road traffic flow is the key factor of the traveler's route choices. These route choices establish the traffic assignment of the road network. Therefore, the flow function is related to the traveler's interest and the effective usage of the whole road network system including the bridge. In a case, where the road corridor is constricted at the bridge, disturbance of traffic flow will be common. The effect was visible in every part of the world where pavement bridge approach constricted [ERA, 2017]. Most of the Ethiopian narrow bridge was constructed in the late 1950th during Italy's invasion to control the country. By the time, traffic flow was almost negligible except pedestrian movement due to the poor industrial revolution of the country [Admasu, 2012]. To use an existing bridge with the current road infrastructure width, that leads the alignment to constrict the pavement width around the bridge approach. These caused different problems on traffic flow over the upper and lower chainage of the bridge approach. Currently, when most of the new and upgraded alignment was constructed, its travel way width was proposed to be accommodating the current and future traffic flow. Following the growth of population density, the town was found to be the crowdies. Different types of link roads in town have been upgraded to counterbalance the current demand and increase traffic movement. But the existing bridge along the alignment is not parallel upgraded. This leads to constricting the pavement width at the bridge approach. In the case of Jimma town, five different bridges were forced to constrict due to an upgrade of the existing travel way width. Different vehicles were passing on the constricted pavement bridge approach per minute. Hence traffic conflict and delay were experienced where the road couldn't accommodate traffic volume.

1.3 Research Questions

Here are some sorts of questions that was raised and needed to answer at the end of the study;

1. What are the traffic flow characteristics within the identified segments at the bridge approaches (entrance and exit)?
2. What are the types of traffic conflicts resulting from the constricted width pavement bridge approach?
3. Which model could provide the "best fit" relating the effect of constricted bridge approach and traffic flow characteristics?
4. What are the possible suggested improvements to reduce the negative effect of the constricted width of the bridge approach on traffic flow?

1.4 Objectives

1.4.1 General Objectives

The research's general objective is to study the effects of a constricted width pavement at bridge approach on traffic flow in Jimma town.

1.4.2 Specific Objectives

- To determine the traffic flow characteristics within the identified segments at bridge approaches (entrance and exit).
- To describe traffic conflict as a result of constricted width pavement at bridge approaches.
- To develop a model relating to the effect of constricted bridge approach and traffic flow characteristics.
- To suggest the possible measures to reduce the negative effect of constricted width of bridge approach on traffic flow.

1.5 Scope and Limitation of the Study

1.5.2 Scope

This research mainly focuses on assessing the "Effect of Constricted Width Pavement at Bridge Approach on Traffic Flow: A case Study in Jimma Town." Hence the scope was limited to Jimma town. The existing constricted width pavement road at the bridge approach is five in number. All are asphalt road type and two lane roads. To study the effect, the following parameters were identified. Those are;

- Number of lanes available on both bridge approach and at the bridge,
- Traffic volume of pedestrian, vehicles, motorist, and animal carts using the bridge to pass the obstacle per day,
- Available width of the pedestrian walkway on the bridge,
- Maximum and minimum queuing length develop near bridge approach,
- Average travel time of vehicles to pass obstacles considering study segment length.

1.5.2 Limitation of Study

To develop a strong "best fit" model, these small size data was not provide researcher representative data. And it was difficult to get relevant information from the Jimma municipal city of transport office, Jimma traffic authority, and Jimma zone statistics office to my research because of the poor data encoding system. Therefore, scarcity in collecting secondary data of traffic accidents and composition was cumbersome and time-consuming. Also, because the bus station in the town is under construction there are more than four temporary stations were made. This cause the normal traffic flow of vehicles and pedestrians in the town were disturbed and may not be to get representative data. And also, the COVID-19 virus and national election were affecting the researcher to get representative data.

1.6 Significance of the Research

Most of the bridge in the town was constructed as masonry arch, box culvert, and girder bridge long years ago. Currently, different traffic conflicts were happening along those bridges. This is due to the constriction of bridge width relative to the approach road. Studying the effect of the constricted road at the bridge in the case of Jimma town had a relatively significant benefit for the Town's social, political, and economic development. As the town's traffic flow increases from day to day, it is necessary to address traffic conflict within the city. At the end of the research, it was easy to know the current and future effect of a constricted pavement width approach on traffic flow for better development. On the other hand, standing on this study, it was possible either to upgrade or construct a new roadway bridge to combat traffic conflict. It was also believe to use the result of the study for a different part of the country where the effect of the constricted road at the bridge was observed.

1.7. Justification

Urban traffic is growing from day to day following a high demand along the roads, and mostly creating a bottleneck before and after the bridge approaches due to constricted width pavement. In Jimma town, urbanization and population growth make the roads and bridges busy in comparison with other similar towns. The number of vehicles passes the town was increasing, causing traffic conflict along the highway, particularly where the bridge was located. Effects of Constricted width pavement of the approach bridge on traffic flow caused a dilemma to the town administration regarding which appropriate measures to implement. According to different scholars and researchers, the leading cause of such kinds of traffic problems was missed correlation in the design life of Bridge structure capacity with future traffic volume.

CHAPTER TWO
LITERATURE REVIEW

2. General

With the development of the transportation system, the number of vehicles and their proportion of freeway traffic have been increasing significantly in the world. Although vehicles play a key role in road freight transport, they are also an important factor in traffic crashes and congestion. Vehicles have a great impact on freeway capacity and freeway overall performance, among others, because of their physical (e.g., size) and operational characteristics [Banks, 2003]. Bridge width, both absolute and relative, has long been considered a major factor affecting safety at bridge sites. Ideally, the bridge width should be at least the same as the approach roadway width from a safety standpoint. However, the costs associated with bridge structures are very high in comparison to a normal roadway section, especially for long-span structures. In terms of costs, it is economically prohibitive to upgrade all existing bridges to the full approach roadway width [King K. Mak; Texas Transportation Institute].

Traffic Bottleneck: A localized constriction of traffic flow that experiences reduced speeds and inherent delays due to a recurring operational influence or a nonrecurring impacting event. In layman's terms, a bottleneck is distinguished from "congestion" because it occurs on a subordinate segment of a parent facility, and not pervasively along the entire facility. It is mandatory only for recurring bottlenecks that "traffic over-demand" be present. "Rubbernecking" past traffic incidents that do not require a lane closure, or simply driving into sun glare, often results in slowdowns even though excess traffic demand may not be present. The mere act of one or more lead vehicles slowing creates a rippling effect; a shock wave that reverberates back to vehicles that are following. In other words, this slowing could be the result of a traffic confluence or the rubbernecking. The slowing reduces room to maneuver, which self-perpetuates the shock wave. The problem begins to clear once past the incident, as vehicles begin to accelerate away, and maneuvering room downstream of the incident increases. [In a 2006 survey of state and local agencies California]

2.1. Basic Traffic Terminologies

2.1.1 Traffic Flow

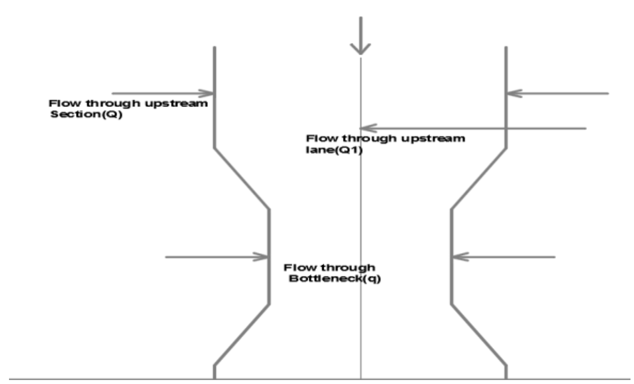
In mathematics and transportation engineering, traffic flow is the study of interactions between travelers (including pedestrians, cyclists, drivers, and their vehicles) and infrastructure (including highways, signage, and traffic control devices), with the aim of understanding and developing an optimal transport network with efficient movement of traffic and minimal traffic congestion problems [ERA, 1997-2007]. Width of the carriage way or the width of the pavement depends on the width of the traffic lane and number of lanes. Width of a traffic lane depends on the width of the vehicle and the clearance. Side clearance improves operating speed and safety. The maximum permissible width of a vehicle is 2.44 and the desirable side clearance for single lane traffic is 0.68 m. This require minimum of lane width of 3.75 m for a single lane road. However, the side clearance required is about 0.53 m, on both side and 1.06 m in the center. Therefore, a two lane road require minimum of 3.5 meter for each lane. The desirable carriage way width recommended by IRC is given in Table 2.1 [Mathew, 2019]

Table 2.1: IRC Specification for carriage way width

Types of lane	**width (m)**
Single lane	3.75
Two lane, no kerbs	7
Two lane, raised kerbs	7.5
Intermediate carriage	5.5
Multi-lane	3.5

(Source: Mathew, 2019)

2.1.2 Queuing Of Traffic Flow



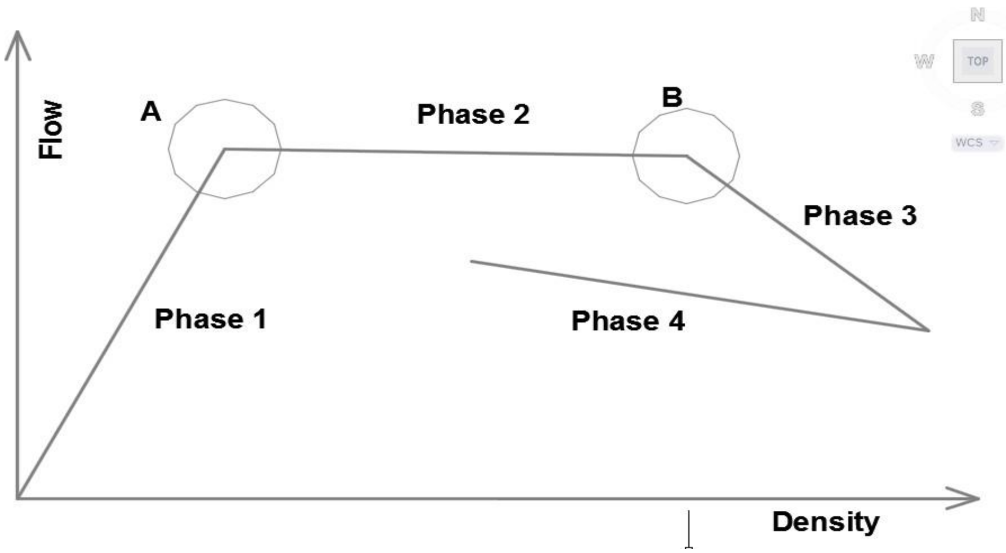


Figure 2. 1: Illustrative plan of a highway bottleneck [*Nico Vandaele*, Jan2000]*

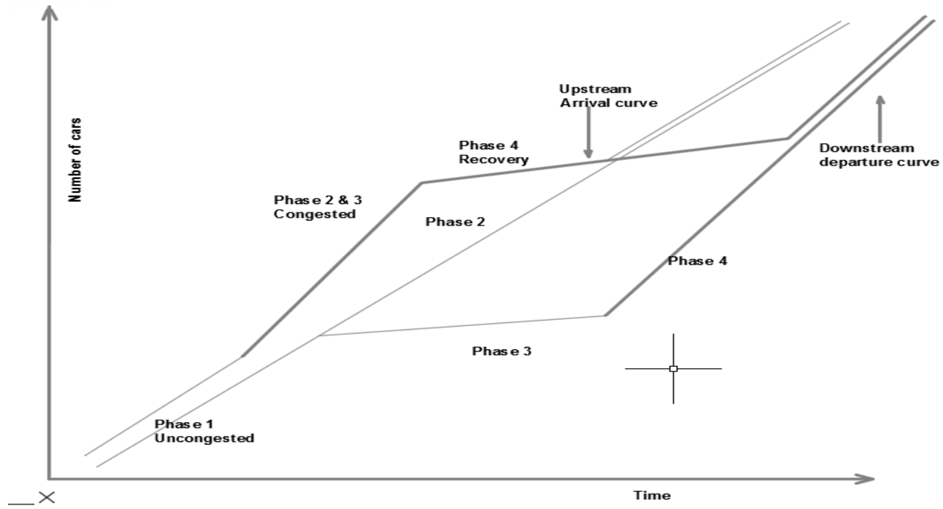


Figure 2.2: Traffic phase in (Newell) diagram [*Nico Vandaele*, Jan2000]*

The first side figure illustrates a traffic bottleneck that drops the roadway from two lanes to one. It allows us to illustrate the changes in the capacity, the lane changes, and the stability in the total section flow. Over an extended period, by laws of conservation, flow through the bottleneck (q) must equal flow through the upstream section (Q).

$\Sigma qt = \Sigma Q$--Eq(1)t

A bottleneck causes lane flow (Ql) to drop, but not section flow (Q), where:

$Q = \Sigma Qt1$--Eq(2)

When researchers observe a "backward-bending" flow-travel time curve, this is occasionally what is observed.

$\Sigma qt = \Sigma qt > \Sigma Qt1$--Eq(3)

The lane flow drops upstream of a bottleneck when demand for a bottleneck exceeds the bottleneck's capacity. Thus, the same level of flow can be observed at two different speeds on an upstream lane. The first is at free-flow speed in uncongested conditions, and the second is at a lower speed when the downstream bottleneck is at capacity.

In other words, congestion (a queue) forms when $Q > qmaxf$ or any period. Ultimately, what enters the queue must eventually exit; otherwise, the queue will grow to infinity. This is illustrated with the queuing input-output (IO) diagram shown in the second side figure. One can identify four distinct phases in traffic [Nico Vandaele*, Jan2000].

Phase 1 is the uncongested phase when there is no influence on the increasing density of the vehicles. The speed does not drop with the introduction of newer vehicles onto the freeway.

Phase 2 finds the freeway cannot sustain the speed with an injection of newer vehicles into the traffic stream. The density increases while speed falls, maintaining the flow.

Phase 3 shows decreased speed and decreased flows. This is caused by very low speeds because the queue discharge to drop (slightly) at an active bottleneck or a queue from a downstream bottleneck may be constraining the flow. As reported by many researchers, the reduced bottleneck capacity after breakdown ranges from 0% to 8%. A majority of papers conclude that the section capacity reduction a queue presents is negligible. (As noted above, lane flow upstream of a bottleneck does drop, but this is due to the downstream bottleneck). This is a second source of the “backward-bending” phenomenon.

Phase 4 is the recovery phase. During this phase, the density of traffic starts decreasing, and speed starts increasing.

2.1.3 Structure of Queuing model

One of the most important equations in traffic flow theory incorporates the interdependence of traffic flow q, traffic density E, and speed s:

$q=E*S$---Eq(4)

When two of the three variables are known, the third variable can easily be obtained. If traffic count data are available, traffic flows can be assumed as given, which leaves us to calculate either traffic density or speed to complete the formula and use either as input for the appropriate queuing model. Common parameters used in developing queuing models are;

Table 2. 2: Queuing based traffic flow parameters

Parameter	Description
E	Traffic density (Veh/km)
C	Maximum traffic density (Veh/km)
S	Effective speed (km/h)
R	Relative speed
SN	Nominal speed (km/h)
Q	Traffic flow (Veh/h)
Λ	Arrival rate (Veh/h)
M	Service rate (Veh/h)
P	Traffic intensity = λ / μ
W	Time in the system (h)

Source:[Nico Vandaele, Jan2000]*

Plotting the traffic flow, density, and (relative and effective) speed on a graph gives us well-known speed-flow-density diagrams. The exact shape of these diagrams depends upon the queuing model and the characteristics of the arrival and service processes. Queuing models are often referred to using the Kendall notation, consisting of several symbols - e.g., M/G/1. The first symbol is shorthand for the distribution of inter-arrival times, the second for the distribution of service times, and the last one indicates the number of servers in the system [Nico Vandaele*, Jan2000].

2.1.4 Hyper congestion

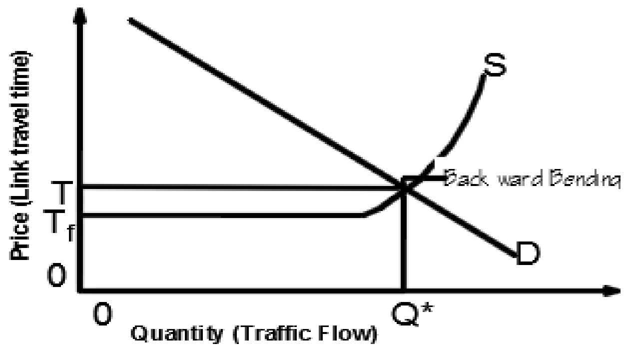


Figure 2.3: Backward Bending [*Kenneth and Xuehao Chu, 1997]*

It has been observed that the same flow can be achieved on many links at two different speeds. Some call this the "backward-bending" phenomenon. The queuing analysis framework also has implications for "Hyper-congestion" or "backward-bending" flow-travel time curves, such as shown in the figure above. Recall that two sources for "backward-bending" speed-flow relationships were identified. The first has to do with the point of observation. Observing the lane flow upstream of a bottleneck gives the impression of a backward bending relationship, but this disappears at the bottleneck itself. Under any given demand pattern, flow and speed are a unique pair. When demand is below the downstream active bottleneck's capacity, flow on an upstream link can be achieved at high speed. When demand is above the downstream active bottleneck's capacity, the same flow on the upstream link can only be achieved at a low speed because of queuing. The second has to do with a capacity drop at the bottleneck itself under congested conditions. However, much research reports that this drop is slight to non-existent [Kenneth and Xuehao Chu, 1997].

As in the bottleneck, lowercase q to flow (vehicles per hour) departing the front of the bottleneck and uppercase Q to flow arriving at the back of the bottleneck. Also define k to be density (vehicles per kilometer), v to be speed (kilometers per hour), and s to be service rate (seconds per vehicle). The fundamental diagrams of traffic flow (q-k-v curves) represent a model of traffic flow as stylized in the traditional textbook representation of the fundamental traffic flow diagram. The reasons why q should drop ask increases beyond a certain point at an isolated bottleneck are unclear. In other words, why should flow past a point drop just because the number of vehicles behind that point increases [Kenneth and Xuehao Chu, 1997]?

2.1.5 Traffic Congestion

Traffic congestion is a condition of transport that is characterized by slower speeds, longer trip times, and increased vehicular queuing. Traffic congestion on urban road networks has become increasingly problematic since the 1950s. When traffic demand is great, the interaction between vehicles slows the traffic stream; this results in some congestion as demand approaches the capacity of a road (or of the intersections along the road) and extreme traffic congestion sets in. When vehicles are fully stopped for periods, this is colloquially known as a traffic jam or traffic snarl-up. Traffic congestion can lead to drivers becoming frustrated and engaging in road rage [Agent. K. R., 1975].

2.2. Traffic stream properties

Traffic flow is generally constrained along a one-dimensional pathway (e.g., a travel lane). A time-space diagram shows the flow of vehicles graphically along a path over time. Time is displayed along the horizontal axis, and distance is shown along the vertical axis. Traffic flow in a time-space diagram is represented by the individual trajectory lines of different vehicles. Vehicles following each other along a given travel lane will have parallel trajectories, and trajectories will cross when one vehicle passes another. Time-space diagrams are useful tools for displaying and analyzing the traffic flow characteristics of a given roadway segment over time [Dewen, 1997].

There are three main variables to visualize a traffic stream: speed (v), density (indicated k; the number of vehicles per unit of space), and flow (indicated q; the number of vehicles/time)

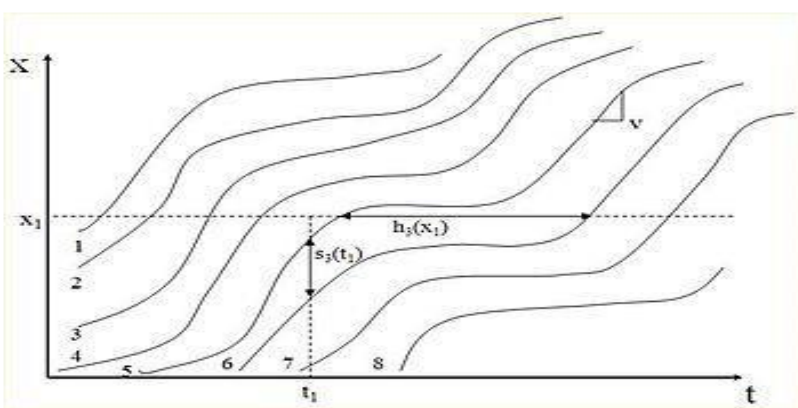


Figure 2.4: Time-Space diagram [*Dewen Kong, 1997]*

2.2.1. Speeds

Speed is the distance covered per unit time. One cannot track the speed of every vehicle. So, in practice, the average speed is measured by sampling vehicles in a given area over a while. Two definitions of average speed are identified: "Time mean speed" and "space mean speed."

"Time mean speed" is measured at a reference point on the roadway over a while. In practice, it is measured by the use of loop detectors. Loop detectors, when spread over a reference area, can identify each vehicle and can track its speed. However, average speed measurements obtained from this method are not accurate because instantaneous speeds averaged over several vehicles do not account for the difference in travel time for the vehicles that are traveling at different speeds over the same distance. Where *m* represents the number of vehicles passing the fixed point, and *vi* is the speed of the *i*th vehicle [Dewen, 1997]. "Space mean speed" is measured over the whole roadway segment. Consecutive pictures or videos of a roadway segment track the speed of individual vehicles, and then the average speed is calculated. It is considered more accurate than the time-mean speed. The data for space calculating space mean speed may be taken from satellite pictures, a camera, or both.

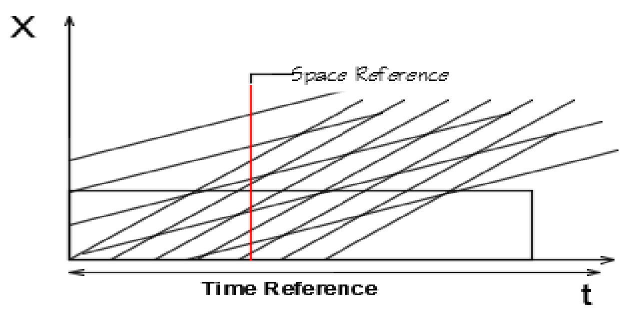


Figure 2.5: Space Mean- and Time Mean speeds [*Dewen, 1997]*

In a time-space diagram, the instantaneous velocity, v = dx/dt, of a vehicle is equal to the slope along the vehicle's trajectory. The average velocity of a vehicle is equal to the slope of the line connecting the trajectory endpoints where a vehicle enters and leaves the roadway segment. The vertical separation (distance) between parallel trajectories is the vehicle spacing (s) between a leading and following vehicle. Similarly, the horizontal separation (time) represents the vehicle headway (h). A time-space diagram is useful for relating headway and spacing to traffic flow and density, respectively [Dewen, 1997].

2.2.2. Density

The traffic flow, q, a measure of the volume of traffic on a highway, is defined as the number of vehicles, n, passing some given point on the highway in a given time interval.

q=NT---q(5)

Where, q = flow rate in vehicle/hr

N = Number of vehicles

T = observation period

Density (k) is defined as the number of vehicles per unit length of the roadway. In traffic flow, the two most important densities are the critical density (*kc*) and jam density (*kj*). The maximum density achievable under free flow is *kc*, while *kj* is the maximum density achieved under congestion. In general, jam density is seven times the critical density. The inverse of density is spacing (s), which is the center-to-center distance between two vehicles.

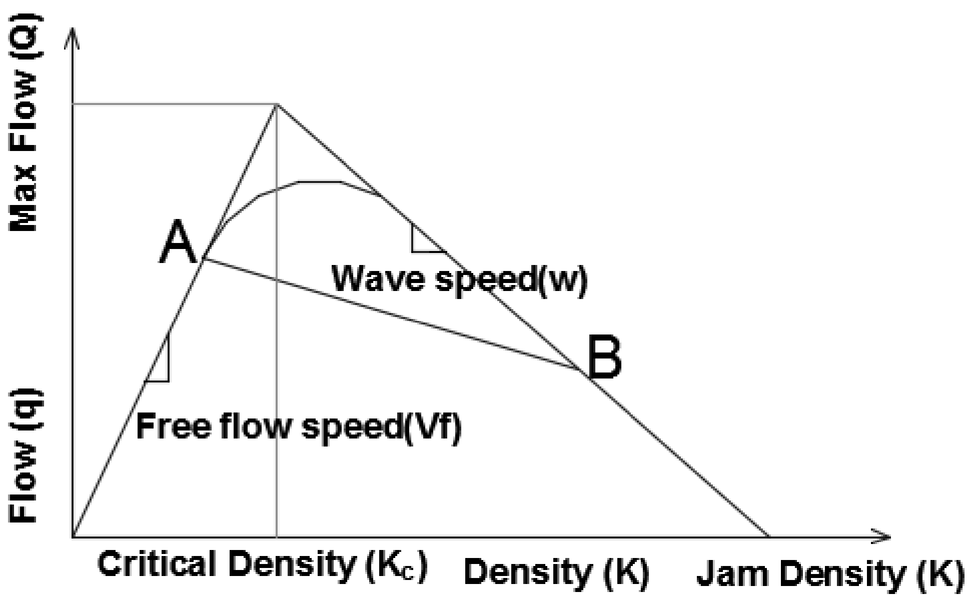


Figure 2.6: Flow Density relationship [*Dewen Kong, 1997]*.

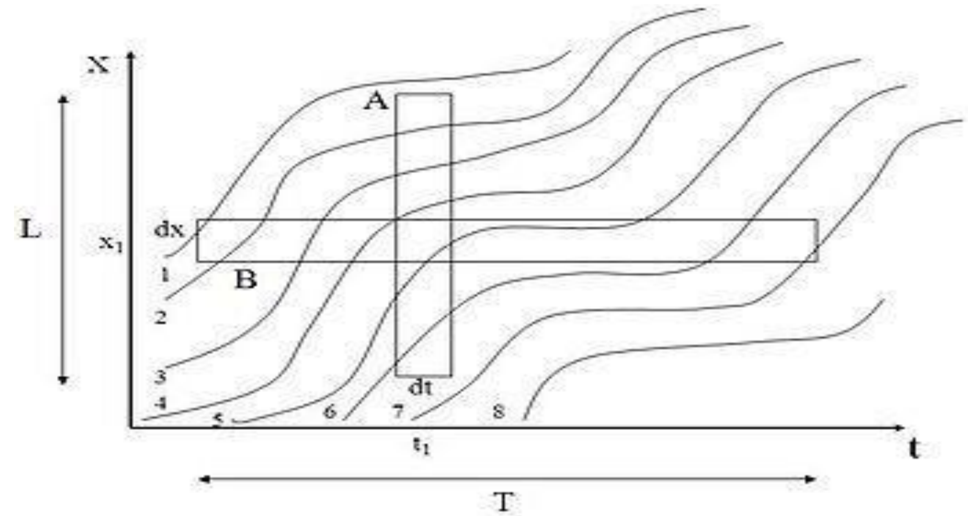


Figure 2.7: Relationship between roadway length (L) and travel time (T)

[Dewen, 1997]

2.2.3. Flow

Flow (*q*) is the number of vehicles passing a reference point per unit of time, vehicles per hour. The inverse of flow is headway (*h*), which is the time that elapses between the *i*th vehicle passing a reference point in space and the (*i* + 1)th vehicle. In congestion, *h* remains constant. As a traffic jam forms, *h* approaches infinity. The flow (*q*) passing a fixed point (*x*1) during an interval (*T*) is equal to the inverse of the average headway of the *m* vehicles. In a time-space diagram, the flow may be evaluated in region *B*. where *td* is the total distance traveled in *B* [Dewen, 1997].

The results of manual counting were enlarged and corrected to convert into average annual daily traffic (AADT) [Transport, 2004]: Conversion of Average Daily Traffic to Annual Average Daily Traffic is the average traffic that is expected to use a particular road over a year (365 days). The Average Daily Traffic, conversion to Annual Average Daily Traffic is determined from the following expression:

AADT=T−ADT*365---Eq(6)

Where: AADT = Average Annual Daily Traffic.

T-ADT = Total Average Daily Traffic.

Traffic (ADT) Peak hour traffic used for design is the traffic, which passes a point during the severest peak hour(s) of the counting period. To convert peak hour traffic to Average Daily Traffic (ADT), the peak hour traffic should first be converted to 12 hours traffic flow and then to 24-hour traffic flow. For instance, if peak hour flow is 10% of 12-hour counts, then for any given number of vehicles and using a 95% confidence limit for the 24-hour traffic flow with 5% tolerance, ADT is given by the following:

$peak\ hour\ factor * conversion\ \ factor$= ADT $(12hr)$ −−−−−−−Eq(7)

$Then$, $(12hr) * conversion\ \ factor = ADT\ (24hr)$ −−−−−−−$Eq(8)$

The conversion factor is the proportion of traffic flow over a given peak time as it relates to that prevailing traffic counted under the same traffic conditions and over a specific counting period. To convert Day Time Traffic to Average Daily Traffic and subsequently to Annual Average Daily Traffic, derived factors based on the duration of counts were used.

2.2.4. Driver characteristics

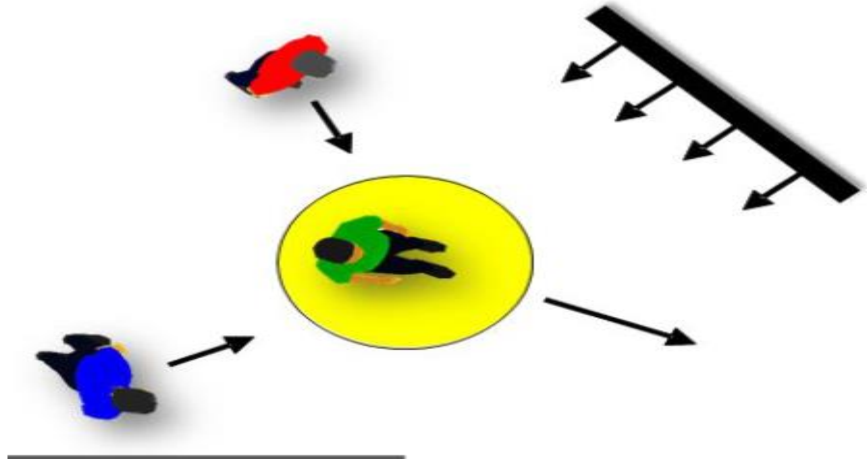
Distance traveled during Perception reaction time also a major factor of flow characteristic for the driver. Recommendations made by the. Stipulate 2.5 seconds for stopping-sight distances. This encompasses the decision times for about 90 percent of drivers under most highway conditions [American Association of State Highway and Transportation Officials (AASHTO), 1998].

Hence, for vehicle moving 30km/hr,

Perception−reaction distance (m) = speed in ms∗time in s--Eq(9)

2.2.5. Pedestrian characteristic

Different study indicates that for 95% percentile, Shoulder breadth of 58cm and a body depth of 33cm were needed to avoid bodily contact. About 0.214m2 area was needed to stand in general. For sidewalks or other pedestrian corridors, dynamic spatial requirements for avoiding collisions with other pedestrians are needed. Allow space of 2.30 m2 / pedestrian for walking freely. Average distance preferred between two pedestrians following each other 244 cm = 2.40m, time spacing of 2 seconds [American Association of State Highway and Transportation Officials (AASHTO), 1998].



[Source: From PTV VISSIM software manual]

Figure 2.8 Allow spaces of 2.30 m2 / pedestrian for walking freely

2.3. Urban Road Capacity Expansions

Previous research has presented explanations and evidence on how road capacity expansions are pressured urban road systems induce traffic, and contribute to traffic growth that would otherwise not have occurred. This is understood as being the result of combined mechanisms, working at different time scales, where the interactions between land-use development, transport-systems development, and travel behavior play important roles [Gudisa, 2008].

Road capacity expansions in congested urban road systems result in reduced travel time by car, triggering relocations of households and businesses in existing built structures in more transport-demanding and car-dependent ways, as well as increased pressure on developing housing, workplaces, retail, and so on at the outskirts of cities and urban regions [Feldges, 2016]. This is a development toward more sprawled and car-dependent urban areas, causing modal shifts towards higher car-driver shares and increased travel lengths, and consequently to increased traffic volumes (vehicle kilometers) per capita [P.G.Madisson, 2001].

2.4. Improving Traffic Flow at Long-term Roadwork's

Long-term road works on highways are a vital part of roadway and bridge renovations. They generate bottlenecks and, consequently, congestion and accidents. If the number of lanes is reduced, it also leads to a significant decrease in capacity. Even when all lanes can be kept operational, narrower lanes and roadway switching will affect the capacity. The impact of roadwork on capacity has been analyzed in detail [Beckmann, 2006]. For every capacity-influencing factor, parameters and thresholds were determined for various roadwork configurations, so that a deterministic value of capacity can be set for any planned roadwork site. On 6lane freeways (3+3 lanes), for example, a 6+0 roadwork traffic routing (6 auxiliary lanes on one, 0 lanes on the other roadway) is not possible. Normally a 5+1 or a 4+2 traffic routing is used. That means part of the traffic (1 or 2 lanes) uses the roadway where the roadwork is situated.

2.5. Road Safety Check List

Road traffic accident occurs worldwide, but the incidence rate is higher in developing countries such as Ethiopia. The problem of road accidents in Ethiopia has reached an alarming proportion in such a way that the highways seemed converted into dead zones, killing citizens daily. Road traffic accidents, which are unintended and preventable, are a common risk every day of life that can happen to almost everyone, anywhere [Galeta Chala, 2017]. The number of people killed and injured as a result of traffic accidents has been steadily increasing, and the country is experiencing a tremendous loss of life and property each year as one of the leading countries of the world with the worst accident record. Recent studies reveal that Ethiopia has 170 deaths per 10000 vehicles per annum, and road accident is costing the country in the order of 350-430 million Birr annually [Conference, 23-24, 2018].

2.6. Accident Studies on Bridge Width

Few studies have been specifically designed to address the safety effects of bridge width. These studies were all of the cross-sectional (comparative evaluation) design except for the study by Gunnerson, which used a retrospective before-and-after design. Gunnerson studied the accident data on 72 narrow, rural two-lane bridges in Iowa over 12 years from 1948 to 1959. Of the 72 bridges studied, 65 had widths less than 24 ft, which remained unchanged while the approach pavements were widened to 24 ft. The remaining seven bridges had both the bridge and approach roadway width widened to 30 ft and was used for control purposes. Comparisons were made between the number of total accidents, the number of bridge hits, injuries, and the number of property damages in the before and after periods. [Lytton, 1983] To account for differences in the amount of time in the before and after periods, the accident frequencies were adjusted to be on a per month basis. No adjustment was made for any change in traffic volume on these bridges, although the data were divided into separate average daily traffic (ADT) groups for analysis. It was concluded that accident frequencies increased sharply when only the approach roadway pavement width was widened and not the bridge width or, conversely, when the approach traveled way width was wider than the bridge width. When both the approach roadway and bridge were widened to the same width, the accident frequency decreased. The study design suffered from a lack of control sites for comparison purposes. The seven bridges used as control sites received a different treatment, and the comparison was more that of differences between the two treatments. A long study period of 12 years, changes to the bridge or approach roadway widening, or both were likely to have occurred, which could affect accident frequencies, especially when no adjustments for traffic volume changes were made. Despite the drawbacks to the study design, the results illustrated that the bridge width should, at the very minimum, be as wide as the approach traveled way width [Lytton, 1983].

On the other hand, Cirillo reported on the effect of lateral clearance (distance from the edge of traveled way to bridge rail) at bridge structures on accident frequency and severity. The accident data covered 3 years from 1961 to 1963 and approximately 2,000 vehicles on Interstate highways in 16 states. Accident rates were tabulated for various combinations of structure length and lateral clearance. Cirillo concluded that an increase in minimum lateral clearance would reduce accident rates. Also, as the structure length increased, there was a need for larger lateral clearance as indicated by the increase in the accident rate. Similar tabulations were compiled for accident severity, expressed in terms of property damage costs. The results are not too meaningful, however, because property damage cost is not a good indicator of occupant-injury severity [Cirillo, 1981].

Plots of accident rate by bridge relative width for each approach roadway width category displayed a similar trend of high accident rates at small relative widths. That decreased with increasing relative width. Also, approach roadway width was found to be non-significant in the regression analysis and was dropped from further consideration. The data were then combined for all approach widths, and accident rates were regressed against bridge relative widths using weighted regression analysis. The resulting weighted regression equation is as follows, and the curve is shown as follows [Cirillo, 1981].

$Y=0.5-0.061 (RW) + 0.0022(RW)^2$ ---Eq(10)

Where Y is the number of accidents per million vehicles, and RW is the relative bridge width in feet. At relative widths of 6 ft. or wider, the curve remained fairly flat with an accident rate of between 0.07 and 0.2 accidents per million vehicles.

If the curve had a steep slope, the accident rate rapidly increases with decreasing relative widths. The results suggest that a minimum of 3-ft-wide shoulders should be provided for bridges on rural two-lane highways; wider shoulders would be of a little additional safety benefit. The study has some problems, such as the reliability of accidents identified as bridge-related in the accident reports. There is some concern over the small sample size for very narrow or very wide bridges because more than 98 percent of the bridges are located on roadways 18 to 26 ft wide, as illustrated by the drastic difference between the two equations. Also, there is the question of the effect of responsible factors other than bridge width [Cirillo, 1981].

2.7. Drivers' Behavior towards Bridge Approach

Many studies have been conducted on driver behavior at the bridge where the bridge is constricted. In a 1941 study, Walker reported about driver behavior over bridge approach on 11 bridge sites. Data were collected on lateral positions of more than 20,000 vehicles traversing the bridges at these sites on both straight and level sections of the highway. A West Virginia study on driver behavior involved both an experimental and a field study. In the experimental study, 10 subjects were asked to drive an instrumented car over a mock-up two-lane, two-way, 50-ft-long bridge 30 times for each increment of bridge width from 16 to 48 ft. All tests were conducted during daylight hours. A variety of data were collected, including steering wheel reversals and lateral vehicle placement. In the field study, the shoulder width of a two-lane, one-way bridge on an Interstate highway was varied from 2 to 10 ft. using a mock-up curb and guardrail. [Ivey et al, 2002] Two hundred passenger cars traversing the bridge were monitored for speed and lateral placement for each shoulder width. Again, the data were collected only during daylight hours and under fair weather conditions. *Ivey et al.* gathered vehicle speed and lateral placement data for more than 2,000 vehicles at 25 bridge sites on rural two-lane, two-way highways in 7 states. The characteristics of the bridge sites, as in the Walker study, varied widely, with different bridge and approach roadway widths, lengths, traffic volumes, and bridge structure types-from truss to open deck design. The following conclusions were drawn from the studies on driver behavior;

1. Vehicle speed was affected very little by bridge width but was more a function of other bridge and approach characteristics, such as vertical alignment.

2. Walker concluded that drivers tended to maintain a more or less uniform distance between their right wheel and the curb or parapet of the bridge. This resulted in a lateral movement of the vehicles toward the left if the bridge was narrower than the approach roadway. This distance varied by bridge width, time of day, and whether the vehicle was free-moving or meeting another vehicle. Other factors that influenced driver behavior included the presence or absence of centerline stripes, truss versus deck design, and bridge length. Ivey et al. reported that the lateral movement was a function of both the absolute and relative bridge widths.

3. Under the more critical condition of meeting another vehicle, Ivey et al. found that the drivers tended to maintain approximately the same clearance between their vehicle and the opposing vehicle to the left and between their vehicle and the curb or parapet of the bridge to the right.

4. In the instrumented vehicle study, shoulder widths of 4 to 6 ft. were found to result in the lowest number of steering wheel reversals and the greatest lateral distance between the left wheel of the vehicle and the centerline.

5. Walker reasoned that, for complete freedom of movement on a bridge, one-half of the bridge width should equal to the sum of one-half the clearance allowed between vehicles while meeting on the highway, the width of the vehicle (assumed to be 5 ft.}, and the clearance to the curb or parapet of the bridge under free-moving condition [Ivey et al, 2002].

2.8. Sight distance

Simply put, sight distance is the distance visible to the driver of a passenger car. For highway safety, the designer must provide sight distances of sufficient length that drivers can control the operation of their vehicles. They must be able to avoid striking an unexpected object on the traveled way. Two-lane highways should also have sufficient sight distance to enable drivers to occupy the opposing traffic lane for passing maneuvers, without the risk of an accident. Two-lane rural highways should generally provide such passing sight distance at frequent intervals and for substantial portions of their length (see Table 2-3). The length and interval of passing sight distance should be compatible with specific highway design classifications [ERA, 1997-2007].

2.8.1. Stopping sight distance

The stopping sight distance on a roadway must be sufficiently long to enable a vehicle traveling at the design speed to stop before reaching a stationary object in its path. The minimum stopping sight distance is determined from the following formula, which takes into account both the driver reaction time and the distance required to stop the vehicle. The formula is:

D=0.2789(t) (V)+V2254(f)---Eq(11)

Where

d = distance (meter)

t = driver reaction time, generally taken to be 2.5 seconds

V = initial speed (km/h)

F = coefficient of friction between tires and roadway (see Table 2-3)

Table 2. 3: Design speed versus sight distance

Design Speed (km/hr)	Coefficient of friction (f)	Stopping sight distance (m)	Passing sight distance (m) from formulae	Reduced passing sight distance for design(m)
20	0.42	20	160	50
30	0.4	30	217	75
40	0.38	45	285	125
50	0.35	55	345	175
60	0.33	85	407	225
70	0.31	110	482	275
85	0.3	155	573	340
100	0.29	205	670	375
120	0.28	285	792	425

Source; [ERA design manual, 2002]

2.8.2. Passing sight distance

Passing Sight Distance is the minimum sight distance on two-way single roadway roads that must be available to enable the driver of one vehicle to pass another vehicle safely without interfering with the speed of an oncoming vehicle traveling at the design speed.

Within the sight area, the terrain should be the same level or a level lower than the roadway. Otherwise, for horizontal curves, it may be necessary to remove obstructions and widen cuttings on the insides of curves to obtain the required sight distance. Care must be exercised in specifying passing/no-passing zones in areas where the sight distance may be obscured in the future due to vegetative growth [ERA, 1997-2007]. The passing sight distance is generally determined by a formula with four components, as follows:

d1 = initial maneuver distance, including a time for perception and reaction

d2 = distance during which passing vehicle is in the opposing lane

d3 = clearance distance between vehicles at the end of the maneuver

d4 = distance traversed by the opposing vehicle

The formulae for these components are as indicated below:

d1=0.278(t1) (v−m+at12) ---Eq(12)

Where

t1 = time of initial maneuver, s a = average acceleration, km/h/s

v = average speed of passing vehicle, km/h

m = difference in speed of a passed vehicle and passing vehicle, km/h

d2=0.278(v) (t2) ---Eq(13)

Where: t2 = time passing vehicle occupies left lane, s

v = average speed of passing vehicle, km/h

d3 = safe clearance distance between vehicles at the end of the maneuver is dependent on ambient speeds as per the table below:

Table 2. 4: Clearance distance versus ambient speed

Speed group (km/hr.)	50-60	66-80	81-100	101- 120
d3(m)	30	55	80	100

Source; [ERA design manual, 2002(page 7-5)1997-2007]

d4 = distance traversed by the opposing vehicle, which is approximately equal to d2 less the portion of d2 whereby the passing vehicle is entering the left lane, estimated at:

d4 =2d3--Eq(14)

Hence, passing sight distance shall be calculated as; PSD (m) = D1+D2+D3+D4------------Eq(15)

2.9 Remedial Action

- Here is a sampling of remediation that would apply to low-cost, quick-fix, operationally influenced bottlenecks. Use a short section of traffic bearing shoulder as a peak-hour lane.
- Re-stripe merge or diverge areas to better serve demand.
- Reduce lane widths to add a travel and/or auxiliary lane. (One may have to reduce speeds to affect a safer condition past the narrowed lanes.)
- Modify weaving areas - add a collector/distributor lane or similar.
- Meter or close entrance ramps.
- Effect "speed harmonization". This heretofore European practice entails using a succession of overhead gantries spaced every kilometer or so upstream of problem areas to adjust (reduce) approach speeds and/or lane use to calm the "shock waves" that often result through congested corridors.
- Effect "zippering". This is self-metering or policed metering that promotes fair and smooth merges at points of traffic confluence. A motorist who is 10^{th} in his lane knows that he will be 20^{th} to merge with the adjacent lane. This helps eliminate line jumpers that would otherwise bull ahead and create potentially unfair and even violent disagreements.
- Improve traffic signal timing on arterials.
- Use access management principles to clean up corridors.
- Provide traffic diversion information.
- Implement road pricing to bring supply in line with demand.

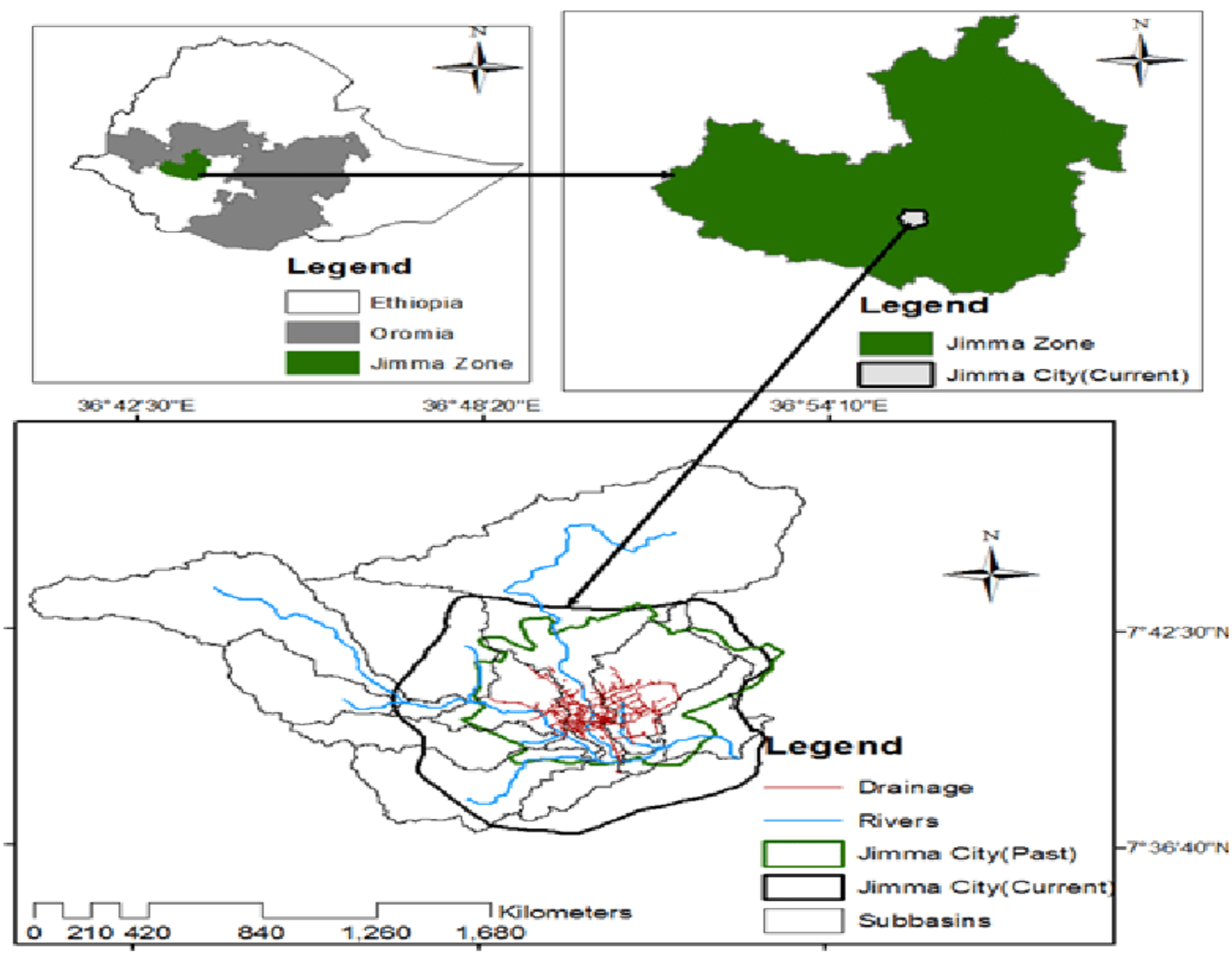
[In a 2006 survey of state and local agencies], the most frequently mentioned operational bottleneck improvements were ramp metering, auxiliary lanes, and introduction of high occupancy vehicle (HOV) lanes. To what degree these are "low-cost" is for the agency to decide. Certainly, other remediation may serve other bottleneck problem areas.

CHAPTER THREE

RESEARCH AREA AND METHODOLOGY

3.1 Study Area

Jimma is the largest town in the southwestern Oromia Region in Ethiopia. **Jimma** town was 220 miles (**353** km) by road southwest of Addis Ababa. It lies at an elevation of **5,740 feet (1,750** meters) in a forested region known for its coffee plantations. It is a special zone of the Oromia Region and is surrounded by Jimma Zone. It has a latitude and longitude of **7°40′N 36°50′E.** Jimma has a relatively cool tropical monsoon climate with the daily mean Temperatures staying between **20 °C and 25 °C** year-round. It features a long annual wet season from March to October with Average rainfall mm (inches) of 1,766(69.5)[*Source:Chicago:UniversityPress,1974*].

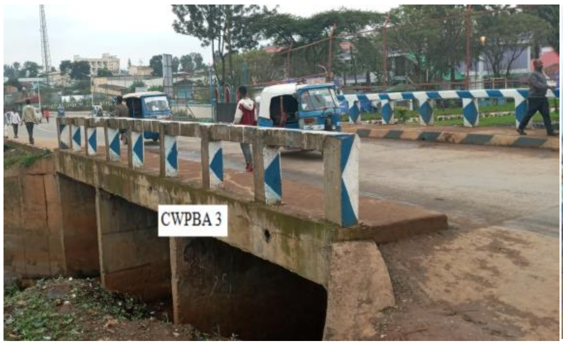


[Source: October 2018 Journal of Sedimentary Environments by wakjira Takala]

Figure 3.1 Map of Jimma Town from Google Map

3.1.1 Study location

There was five constricted width pavement bridge approach within the town. One of them was an arch bridge, one of them was slab Box Bridge and the rest were categorized under Girder Bridge. For the study purpose, it will be best to describe the study location as CWPB1, CWPB2, CWPB3, CWPB4, and CWPB5.



[Source: photo capturing from site]

Figure 3.2 visual image of Nagasa Bridge

Figure 3.3 visual image of Awetu Bridge

[Source: photo capturing from site]

Figure 3.4 visual image of Awetu Manafasha Bridge

Figure 3.5 visual image of Boyye Bridge

[Source: photo capturing from site]

Figure 3.6 visual image of Hikate Bridge

Table 3.1 Name and Location of CWPBA Bridges in Jimma town

No.	Abbreviation	Local name	Location	Types of Bridge	Coordinates
1	CWPBA 1	Awetu Manafasha Bridge	Around Awetu Grand Hotel	Girder Bridge	X= 7.67555 Y= 36.83637
2	CWPBA 2	Awetu Bridge	Around Jimma TOTAL	Girder Bridge	X= 7.66890 Y= 36.83591
3	CWPBA 3	Nagasa Bridge	Around Jimma Stadium	Slab Box Bridge	X= 7.67077 Y= 36.83620
4	CWPBA 4	Boyye Bridge	Around SOS School	Girder Bridge	X= 7.64946 Y= 36.84523
5	CWPBA 5	Hikate Bridge	Around Kella	Arch Bridge	X= 7.66957 Y= 36.86001

Note; CWPBA stands for Constricted Width Pavement Bridge Approach

[Source: data by local questioner, observational and Google map]

3.2 Study Period

The research was taken six months starting on February 16 which lasted to July 15, 2021 GC to be finished the whole study.

3.3 Study Design

The descriptive and observational research methods were used to achieve the ultimate goal and completion of the research. Collecting data from different sources was gathered first. On the other hand, a correlation study was done by using ANOVA and Pearson correlation method. Finally, the "best fit" model relating the effect of constricted bridge approach and traffic flow characteristics has been tested for validation, and the result was interpreted to propose remedial action [Montgomery D.C. and Runger, 2010]**.**

The research design was used by the researcher were descriptive and observational. Here is the research design format, prepared in three stages or process;

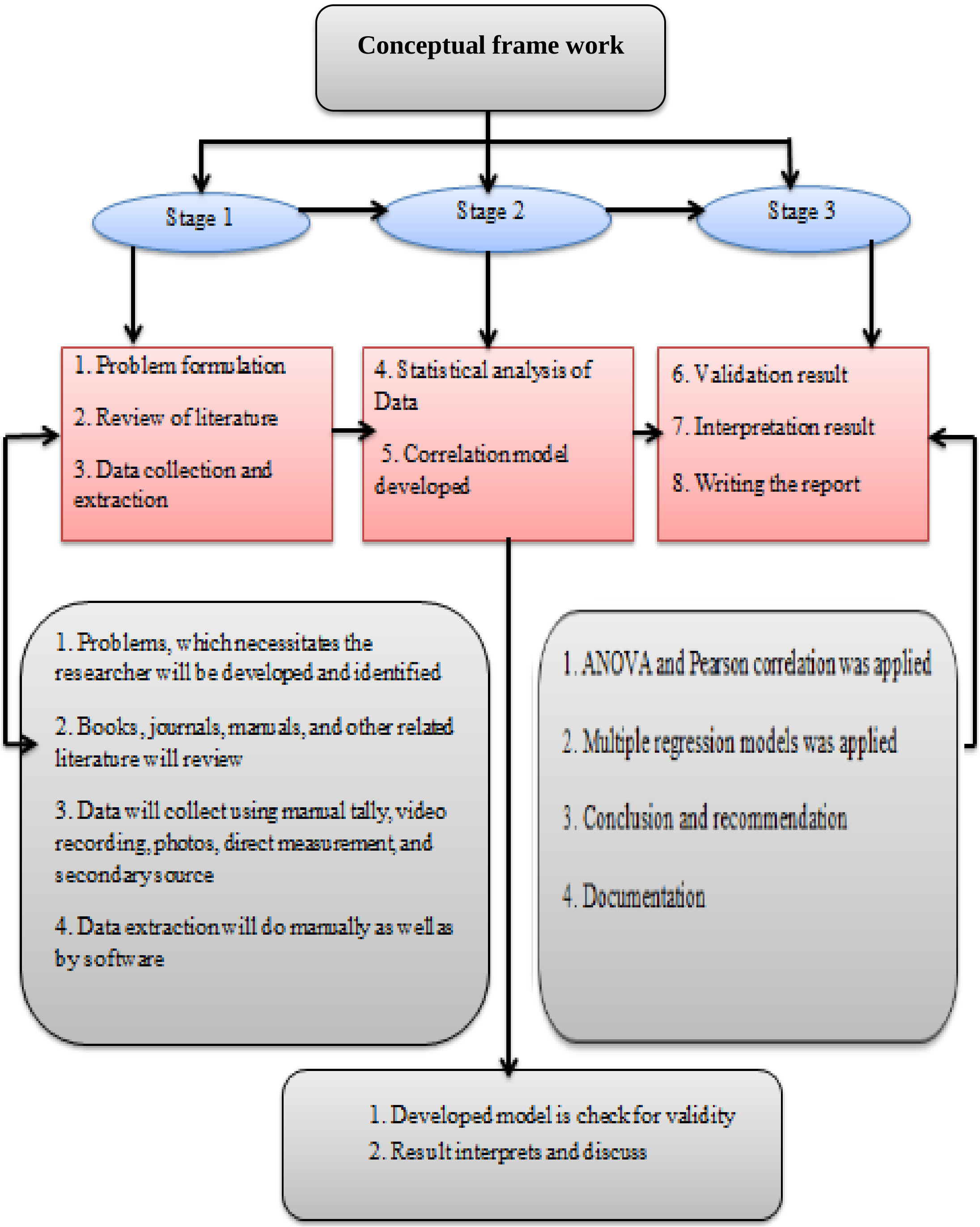


Figure 3.7 Conceptual Frame Work

Table 3. 2 Research Design Procedures

STAGE 1	1. Problem formulation	1.problems, which necessitates the researcher was developed and identified
	2. Review of literature	2. Books, journals, manuals, and other related literature were reviewed
	3. Data collection and extraction	3. Data was collected using manual tally, video recording, photos, direct measurement, and secondary source
		4. Data extraction was done manually as well as by software
STAGE 2	4. Statistical analysis of Data	1. ANOVA and Pearson correlation were applied
	5. Correlation model developed	2. Multiple regression model was applied
STAGE 3	6. Validation result	1. Developed model was checked for validity
	7. Interpretation result	1. Result interprets and discuss 2.conclusion and recommendation
	8. Writing the report	3. Documentation

3.4 Research Data and Equipment

Data required for the research were classified into two categories. They were geometric design and traffic design-related data. And the leading equipment that was used in collecting necessary data for this research is explained under this.

3.4.1 Data Requirement

Data required for the research were classified into two categories. They were geometric design and traffic design-related data.

Geometric Data

- Segment length
- Number of lanes
- Number of links
- The number of conflict points at the bridge segment

Traffic Data

- Traffic
- volume capacity
- Vehicle traffic composition
- Traffic delay
- Travel speed

3.4.2 Equipment's

The leading equipment that was used in collecting necessary data for this research is:

- Videotaping recorder and photo capturing application available on smartphones
- Hand meter, or meter tapes
- Scientific Calculator

Figure 3. 8: Measurement equipment used up during site inspection

3.4.3 Software

Microsoft office word and excel were used for writing, editing, and finalizing the documents. All the data was feed on excel to extract tables and graphs. AutoCAD was used to draw off the geometry of the road section. PTV Vissim Software was used to extract capacity and delay traffic flow at a constricted width pavement bridge approach (vissim). SPSS version 20 software was utilized to analyze the statistical relationship between the dependent and independent variables (IBM SPSS, 2021). In another case, the best-fit regression model was developed by using R-code software.

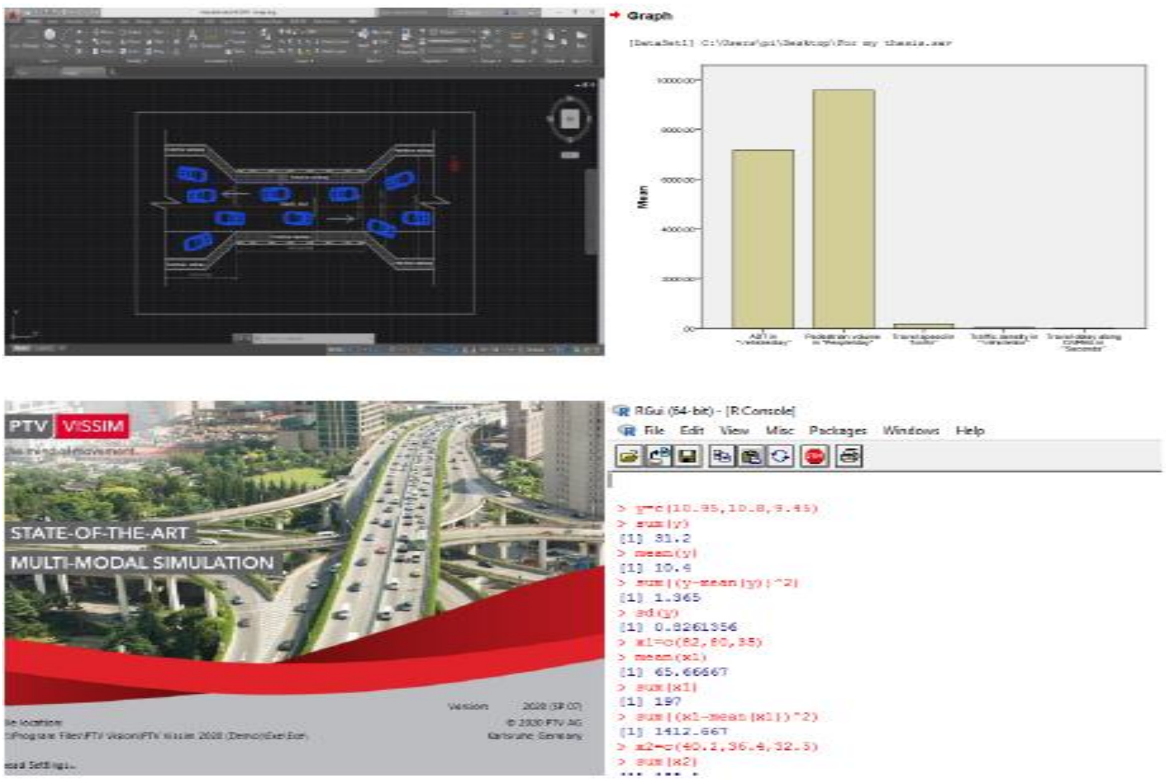


Figure 3. 9: Software's used up for research

3.5 Sample Size

The main objective of this research was conducted by observation; the possible sample size of the constricted width pavement bridge approach was only five within the town. But to know about road user behavior and transport sector ideas towards the effect of constricted width pavement bridge approach on traffic flow, there should be some sort of oral/written interview. With a 95% confidence level and accepted a 5% margin of error in the sample size used for the interview was calculated as follows (Montgomery D.C. and Runger, 2010).

$SS = Z^2 \times (P) \times (1 - P)/d^2$ --Eq (16)

Where; SS- sample size;

Z- Normal distribution value of corresponding confidence level 1.96 at a confidence interval of 95%

P - Proportion expected prevalence of the problem (50%)

d - Degree of accuracy desired (5%)

Hence; from standard normal distribution table, after interpolation for Z-value, Z=0.97764, P=0.5, d=0.05

Sample size (SS) = $0.97764^2 * 0.5 * (1-0.5) / 0.05^2$ = **95.5~95** (population)

Additional numbers of peoples will be added to get a reliable number of interview data. This is because sometimes distributed papers would not return to the researcher. Especially difficult to get drivers permanently b/c they are move from place to place. So that, it's important to add nearly driver's number, about 35 numbers of respondents will be added to get real-time data for analysis. Take SS= **130.**

Table 3. 3: Interview paper distribution among interviewer

Title: Effect of Constricted Width Pavement at Bridge Approach on Traffic Flow: A Case Study In Jimma Town				
sample size distributions among questions				
Driver	Pedestrians	Traffic police	Engineers	Others
40	40	20	20	10
Total				**130**

3.6 Sampling method

There were many bridges in Jimma town. From those five of them were selected using non probability sampling techniques of purposive sampling methods. It involves researcher to select a sample that was most useful to the purposes of the research to gain detailed knowledge about a specific phenomenon. The population was selected by using probability sampling techniques of stratified sampling methods. It entails separating the population units into non-overlapping groups and taking a sample from each other. Groups like a pedestrian, the driver (including motorist), traffic police, professional engineers, and others were taken part proportionally in the interview. Distributions of respondents were applied according to the population density of drivers, pedestrians, engineers, traffic police, and others relative to each other. A non-probability sampling technique was also used where a specific plan in mind (purposive sampling) is needed. The expected number of the interviewer was only 95 in number. Additional numbers of peoples were added to get a reliable number of interview data. This is because sometimes distributed papers would not return to the researcher. Hence about 35 numbers of respondents were added to get real-time data for analysis.

Table 3. 4: Summarized interview data

Average agree or disagree of respondents towards the questions										
Title: Effect of Constricted Width Pavement at Bridge Approach on Traffic Flow: A Case Study In Jimma Town										
Location; Jimma Town										
Part I			Respondents profile							
No	Respondents	Interviewed	Work expirence(%)			Knowing bridges (%)			Observing effects	
			0-5	6~10	>10	know	don't know		observed	Not bsv.
1	Pedestrian(P)	40	65	32	3	100	0		92	8
2	Drivers(D)	40	72	22	6	100	0		93	7
3	Engineers(E)	20	57	38	5	100	0		85	15
4	Traffic police	20	41	55	4	100	0		92	8
5	Others(O)	10	27	56	17	87	13		79	21
Average		**130**	**59.308**	**35.23**	**5.46**	**99**	**1**		**90.23**	**9.77**
part II			Traffic characteristic along constricted width PBA affect							
No	Respondents	Interviewed	Travel speed (%)		Traffic capacity (%)		Site distance (%)		Driving discomfort (%)	
			agree(A)	disagree(B)	agree	disagre	agree	disagre	agree	Disagree
1	Pedestrian(P)	40	56	42	72	23	51	49	42	58
2	Drivers(D)	40	82	18	87	13	92	8	85	15
3	Engineers(E)	20	100	0	100	0	91	9	86	14
4	Traffic police	20	83	17	87	13	91	9	82	18
5	Others(O)	10	92	8	65	32	71	15	55	41
Average		**130**	**77.69**	**21.69**		**15.538**	**77.46**	**21.46**	**69.15**	**30.85**
part III			Observed traffic conflict caused due to in %							
No	Respondents	Interviewed	Vehicle size		Geometric effect		Sudden constriction		Sides wiping	
			agree	disagre	agree	disagre	agree	disagre	agree	Disagree
1	Pedestrian(P)	40	61	37	14	82	76	23	71	21
2	Drivers(D)	40	77	33	22	78	78	22	27	73
3	Engineers(E)	20	83	17	16	84	86	14	87	13

4	Traffic police	20	79	21	44	56	81	18	75	25
5	Others(O)	10	41	52	15	79	36	58	56	44
Average		**130**	**70.54**	**31.38**	**21.46**	**76.846**	**76**	**23.23**	**59.38**	**40.62**
part IV			Possible remedial action to minimize the effect in %							
No	Respondents	Interviewed	New bridge		Pedestrian walkway		a Guide sign		smooth transmission	
			agree	disagree	agree	disagree	agree	disagree	agree	Disagree
1	Pedestrian(P)	40	79	21	91	9	87	13	76	24
2	Drivers(D)	40	85	15	81	19	79	21	82	18
3	Engineers(E)	20	72	28	88	12	84	16	91	9
4	Traffic police	20	76	24	75	25	88	12	76	24
5	Others(O)	10	64	36	68	29	73	27	72	28
Average		**130**	**78.15**	**21.85**	**83.23**	**16.538**	**83.15**	**16.85**	**79.85**	**20.15**
Note		A,% agree; B, % disagree; C, % neutral								
		C=100-A-B								

3.7 Method of data collection

Stage 1; Data collection

Multiple data sources were used to study the effect of constricted width pavement bridge approach on traffic flow in the case of Jimma town. Data were categorized under primary and secondary data.

3.7.1 Primary data

The major primary data collected for this study was from;

- ❖ Geometric measurement of the CWPBA

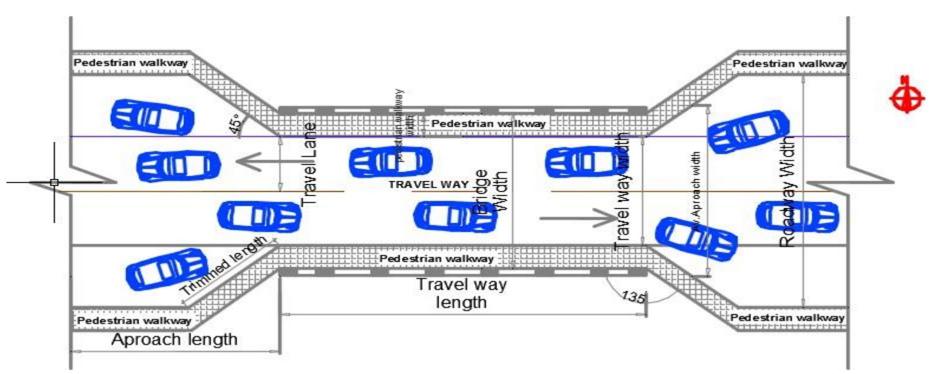


Figure 3. 10: AutoCAD print used for site measurement [source: From auto CAD]

- Once the constricted width pavement bridge approach is measured, it was been organized and tabulated for analysis purposes.

Table 3. 5: Inspection of the bridge and its approach dimensions

Constricted Pavement Bridge Approach Width Inspection checklist									
Type	No of lane	No of links	Bridge Approach	Bridge length(m)	Pedestrian walkway width(m)	Clear Bridge width (m)(A)	Slanted (bottle neck) length(m)	Road way width (m)(B)	Average constricted width (m)
CW1	2	1	(Upstream)	30.4	2.85	16.9	10	20.9	18.9
	2	1	(Downstream)		2.85	16.9	10	20.9	18.9
CW2	1	1	(Upstream)	31.2	1.8	4.3	16	15.5	9.9
	1	1	(Downstream)		1.8	4.3	16	15.5	9.9
CW3	1	1	(Upstream)	23.7	1.25	7	10	9.5	8.25
	1	1	(Downstream)		1.25	7	10	9.5	8.25
CW4	1	1	(Upstream)	32	1.6	7.4	4.6	10.6	9
	1	1	(Downstream)		1.6	7.4	4.6	10.6	9
CW5	1	1	(Upstream)	23.5	1	7	8.5	10	8.5
	1	1	(Downstream)		1	7	8.5	10	8.5
C= (A+B)/2									
(Source; Site Inspection)									

- Collection of traffic composition along CWPBA

  - This was done by selecting five-station points along with the constricted width pavement bridge approach. Using traffic count tally and video recording technology, the data was collected. Traffic composition along different pavement bridge approaches were separately collected either downstream or upstream section.

Table 3. 6: Traffic data

Traffic Counting for 12hr per day											
Location: Jimma town								**Interval**			
Duration: From May 5 up to May 9, 2021								**Start time; 7:00 AM - 6:00 PM**			
Location	**Days**	**Types of vehicle per lane**									**Pedestrian**
		Animal carts	**Bicycles**	**Motorist**	**Bajaj**	**Small car**	**Medium car**	**Heavy car**	**Articulated car**	**Total**	
C W P B A 1	Monday	120	701	2772	13320	3862	3212	1540	11	25538	9740
	Tuesday	212	872	3551	12500	3420	3692	1112	25	25384	8010
	Wednesday	103	950	2971	13341	4826	2940	1301	41	26473	7071
	Thursday	158	603	3011	11600	5122	3162	1413	73	25142	8945
	Friday	116	511	2900	12200	4919	3427	1245	91	25409	8234
	Saturday	300	1200	3660	13440	5340	4320	1860	110	30300	10920
	Sunday	59	1121	3572	13226	5212	4215	1793	20	29218	11165
C W P B A 2	Monday	1221	2700	5901	11300	5600	7441	1230	140	35533	16921
	Tuesday	1012	2552	4999	14672	5571	8532	1542	179	39059	15421
	Wednesday	918	2870	5440	14048	6012	8140	1337	239	39004	17940
	Thursday	984	2990	5760	13800	5973	6970	1773	340	38590	17230
	Friday	1001	3011	5470	13996	6450	7858	1978	291	40055	17528
	Saturday	1380	3300	6060	15600	7380	8880	2160	420	45180	18840
	Sunday	1327	3270	6010	15472	7276	8790	2113	413	44671	18721
C W P B A 3	Monday	112	514	2780	12464	2430	1920	460	6	20686	9844
	Tuesday	127	564	2940	11270	2774	1948	491	9	20123	8694
	Wednesday	96	582	3019	10680	2160	2172	452	4	19165	9490
	Thursday	101	644	2840	12946	2331	1839	513	1	21215	9943
	Friday	180	629	3094	11780	2394	2097	479	3	20656	10012
	Saturday	228	732	3300	13236	3060	2580	696	12	23844	10800
	Sunday	78	618	3266	13142	2981	2376	597	4	23062	10200
C W P B A4	Monday	1430	383	1672	5014	1094	902	412	72	10979	2240
	Tuesday	1681	512	1412	5322	992	964	460	79	11422	2694
	Wednesday	1370	564	1102	5842	1240	951	582	112	11763	2714
	Thursday	1636	419	1616	5966	1132	1042	496	142	12449	2673
	Friday	1394	496	1484	5369	1196	1103	684	132	11858	2414
	Saturday	1812	600	1704	6060	1332	1140	720	180	12348	2880
	Sunday	1714	552	1696	5883	1300	1131	696	140	13112	2650
C W P B A 5	Monday	158	194	632	7540	1112	1271	236	33	11176	3114
	Tuesday	112	183	692	7690	1170	1331	293	43	11514	3160
	Wednesday	131	211	789	7260	1151	1136	264	31	10973	3192
	Thursday	162	198	611	7341	1213	1076	270	21	10892	3151
	Friday	170	231	746	7813	1103	1321	286	100	11770	3212
	Saturday	180	240	960	7980	1320	1440	360	120	12600	3240
	Sunday	176	222	892	7962	1273	1421	348	93	12387	3221
Source; manual count and video recording											

- Traffic data was used for the study is not collect only at peak hours but also when traffics are average and null flow. As there were five sites, manual traffic counting should be done at each site separately.

- The purpose of collecting traffic volume is to get the Average Annual Daily Traffic (AADT) of the site. This can be executed as follows. First, the Average Annual Daily Traffic must be estimated at each site as [ERA, 2013]. As there are five sites, manual traffic counting is done for seven days at each site. The results of any manual counting must be enlarged and corrected to be converted into Average Annual Daily Traffic (AADT). This needs three factors as follows:
  - Hourly factor (HF) (100/% volume in counting hours),
  - Daily Factor (DF), and
  - Seasonally Factor (SF).

These factors are constant for each CWPBA and are obtained from the General Authority of Roads, (ERA). Therefore, the calculated AADT is given by Eq. [ERA, 2013].

The values of AADT where: - AADT = counting volume * HF * DF * SF (veh/day)

3.7.2 Secondary Data

Organizing and inputting data was very poor in Jimma town. Most secondary data like statistical growth of vehicles, peoples, and existing traffic conflicts were collected within Jimma town. Published journals and magazines were also referred for this study.

Table 3. 7: Registered traffic volume of Jimma town

Available Traffic Volume Data							
Location; Jimma town							
Year; 2014-2019							
Vehicles						people	
non-motorized		motorized				Population density(@ 2017)	
animal carts	cycles	Motor cycle	Bajaj	Minibus and bus	large vehicles	Male	female
240	611	1812	2779	1694	283	60,824	60,136
#source; Federal population projection of Ethiopia for all region at wereda level from 2014-2017 and JIMMA TOWN transport office							

Table 3. 8: Existing traffic conflict data

Availabe Traffic Conflict Data's Over CWPBA												
Segment	**Year**	**Crash Type**									**Crash notation**	
		Rear end	**Side swipe**	**Right angle**	**Ped**	**Bike**	**Head on**	**Fixed object**	**Other**	**Total**	**vehicle types and crash with each other**	
CPBA 1	2016	1	1	0	1	1	0	0	1	5	a	Animalcart
	2017	0	2	1	2	1	1	0	1	8	b	Bicycles
	2018	0	3	0	1	0	0	0	2	6	c	Motorist
	2019	0	1	1	0	0	0	0	1	3	d	Bajaj
	2020	1	2	0	0	0	2	1	0	6	e	Small car
	2021	0	2	0	0	0	1	0	1	4	f	Medium car
											g	Heavy car
CPBA 2	2016	0	2	0	0	0	1	0	0	3	h	Articulated car
	2017	1	3	0	0	0	2	1	2	9	i	Others
	2018	0	4	1	1	0	1	2	1	10		
	2019	0	1	2	1	1	2	1	1	9		
	2020	2	1	0	2	0	4	0	0	9		
	2021	1	2	1	0	0	0	2	1	7		
CPBA 3	2016	1	1	1	0	0	0	0	1	4		
	2017	0	1	0	0	0	0	0	0	1		
	2018	2	2	1	0	0	1	0	0	6		
	2019	0	1	0	0	1	1	0	0	3		
	2020	1	1	1	1	1	1	1	1	8		
	2021	0	0	1	0	0	0	0	0	1		
CPBA 4	2016	0	0	1	0	0	0	0	1	2		
	2017	1	2	0	1	0	1	0	0	5		
	2018	0	0	1	0	0	1	0	0	2		
	2019	0	0	0	0	1	2	0	0	3		
	2020	1	0	1	1	1	1	1	1	7		
	2021	0	0	1	0	0	0	0	0	1		
CPBA 5	2016	0	1	0	0	0	0	0	1	2		
	2017	0	0	0	0	0	0	0	0	0		
	2018	0	0	1	0	0	1	0	0	2		
	2019	0	0	0	0	1	2	0	0	3		
	2020	1	0	1	1	1	1	1	1	7		
	2021	0	0	1	0	0	0	0	0	1		
Total		**13**	**33**	**17**	**12**	**9**	**26**	**10**	**17**	**137**		

Source: *(Jimma town transportation office and Jimma city police commission)*

Stage 2: Data extraction

After data collection, the next step was to extract the necessary data. Methods of data extraction were as follows;

Table 3. 9. Data collection and extraction method

Variable Data's	Method of Data Extraction
Traffic volume	From daily count at each bridge segment. i.e., 7 days count (5 weekdays and two weekend day) and convert to ADT
The capacity of the constricted pavement width	Was been calculated by PTV Vissim software
Delay at constricted pavement width	Was been calculated by PTV Vissim software
Average speed	By calculation at each segment, v=s/t where s= traveled distance and t= travel time
Travel time	From manual count by the test vehicle
Road pavement length at bridge	Was been measured manually by meters
Number of lanes of pavement at the bridge	From visual inspection and manual
Number of conflict points at the bridge	From the secondary data source
Number of a pedestrian crossing at the bridge	From recorded video

3.8 Data processing and analysis

Procedure used during data processing and analysis looks like as follows;

Step 1; from an oral and written interview, data were edited, coded, classified, and tabulated for analysis.

Step 2; once traffic characteristic and conflict along the bridge approach determined, then the row data was edited, coded, classified, and tabulated to make ready for analysis.

Step 3; Using the ANOVA test and Pearson's correlation coefficient to ascertain the relationship between the dependent and independent variables. PTV Vissim software also used up to simulate traffic flow along with a constricted pavement bridge approach.

Step 4; regression analysis used to develop a "best fit" model between traffic flow characteristic and constricted width pavement bridge approach.

3.9 Description of variables

3.9.1 Dependent variables

- Constricted Width Pavement and Traffic delay

3.9.2 Independent variables (Predictor variables)

- Traffic speed
- Traffic density
- Traffic volume
- Vehicle type
- pedestrian

3.10 Data quality assurance

Most of the data, information, and methodologies that were provided for this research stand on reliable sources and truth. Things stated under literature review and background study was highly rephrased from internet access and different scholars' products. The researcher was been striving to collect reliable and precise data. Though advanced equipment's were not being majorly employed, all the counts, measures, etc. were guaranteed for their quality.

3.11 Ethical Consideration

Before the beginning of the study, a consent letter from Jimma University IOT was written and the local government of Jimma town is informed to conduct this study. The data collected was used only for research purposes to ensure the confidentiality of the data. This was important to ensure the culture of informants being respected. The data was collected honestly and based on the willingness of informants or organizations to give information.

3.12. Expected Outcomes

Upon the completion of the research, the following outcome was expected.

- Possible remedial actions like widening bridge width, smoothening sudden constriction, constructing a cost-efficient pedestrian walkway, and installing traffic guide warning signs were suggested to reduce the negative effect of constricted width PBA on traffic flow.
- The major effect parameters and the factors that affect the performance of the city road traffic flow were improved.
- The research was used as material for the government office, especially for city road authority, and for other researchers as a supporting document.
- Traffic crashes like rear-end, head-on, sideswiping, and others were improved.

CHAPTER FOUR

DATA ANALYSIS, RESULTS, AND DISCUSSION

4.1. Introduction

By using both descriptive and observational research methods, findings have been analyzed and interpreted. Descriptive study of the researcher mainly focused on peoples (road users) knowledge towards the traffic flow problem along road of Jimma town. As stated on previous research methodology, roads user used for this study includes pedestrians, drivers, traffic police, Engineers, and other. For analysis purpose, the interview data was separated into four parts based of their objectives. Again, for analysis purposes, the researcher combined the level of importance of strongly agree and agree as one positive answer towards the question as well as strongly disagree and disagree as a negative response. Harmonic mean (average) of peoples agrees or disagree calculated by using Microsoft Excel as follows. For example, From snipping pictures of excel format, people who agreed with the statement of "traffic characteristic along constricted width PBA affect road traffic capacity" was calculated on E13 of excel.

Table 4. 1: Computation of harmonic mean

SUM =(C8*E8+C9*E9+C10*E10+C11*E11+C12*E12)/C13

	A	B	C	D	E	F	G	H	I	J	K
1	Average agree or disagree of respondents towards the questions										
2–3	Title: Effect of Constricted Width Pavement at Bridge Approach on Traffic Flow: A Case Study In Jimma Town										
4	Location; Jimma Town										
5	Part I			Respondents profile							
6	No	Respondents	Interviewed	Work expirence(%)			Knowing bridges(%)			Observing effects	
7				0-5	6~10	>10	know	don't know		observed	not obsv.
8	1	Pedestrian(P)	40	65	32	3	100	0		92	8
9	2	Drivers(D)	40	72	22	6	100	0		93	7
10	3	Engineers(E)	20	57	38	5	100	0		85	15
11	4	Traffic police	20	41	55	4	100	0		92	8
12	5	Others(O)	10	27	56	17	87	13		79	21
13	Average		130	59.308	=(C8*	5.46	99	1		90.23	9.77
14	part II			Traff	E8+C9*	istic along constricted width PBA affect(obj#1)					
15	No	Respondents	Interviewed	Travel spe	E9+C10*	raffic capacity(%		Site distance(%) Dr		driving discomfort(%	
16				agree(A)	E10+	agree	disagre	agree	disagre	agree	Disagree
17	1	Pedestrian(P)	40	56	C11*	72	23	51	49	42	58
18	2	Drivers(D)	40	82	E11+	87	13	92	8	85	15
19	3	Engineers(E)	20	100	C12*	100	0	91	9	86	14
20	4	Traffic police	20	83	E12)/C13	87	13	91	9	82	18

[Source: From interviewed data]

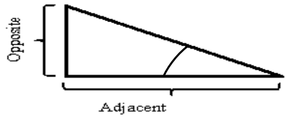
Almost 99% of respondents knew the bridges and observed the problem along constricted width pavement bridge approach. According to those respondents, constricted width PBA highly affects traffic characteristics like travel speed, traffic volume capacity, site distance, and drivers' comfort. It was also possible to observe different traffic conflicts along CWPBA due to geometric effect, vehicle size, and sudden constriction of approach pavement. Sideswiping was the most type of traffic crash observed in those locations according to respondent. Constructing a low-cost pedestrian walkway along the bridge side and providing a traffic guide sign was found to be the best possible remedial action towards the problem according to respondent.

4.2. Traffic flow characteristic along constricted Width PBA

For this research, an observational study was found to be the best method of conducting several traffic flow characteristics, both upper and lower chainage along with a bottleneck structure of bridge approach.

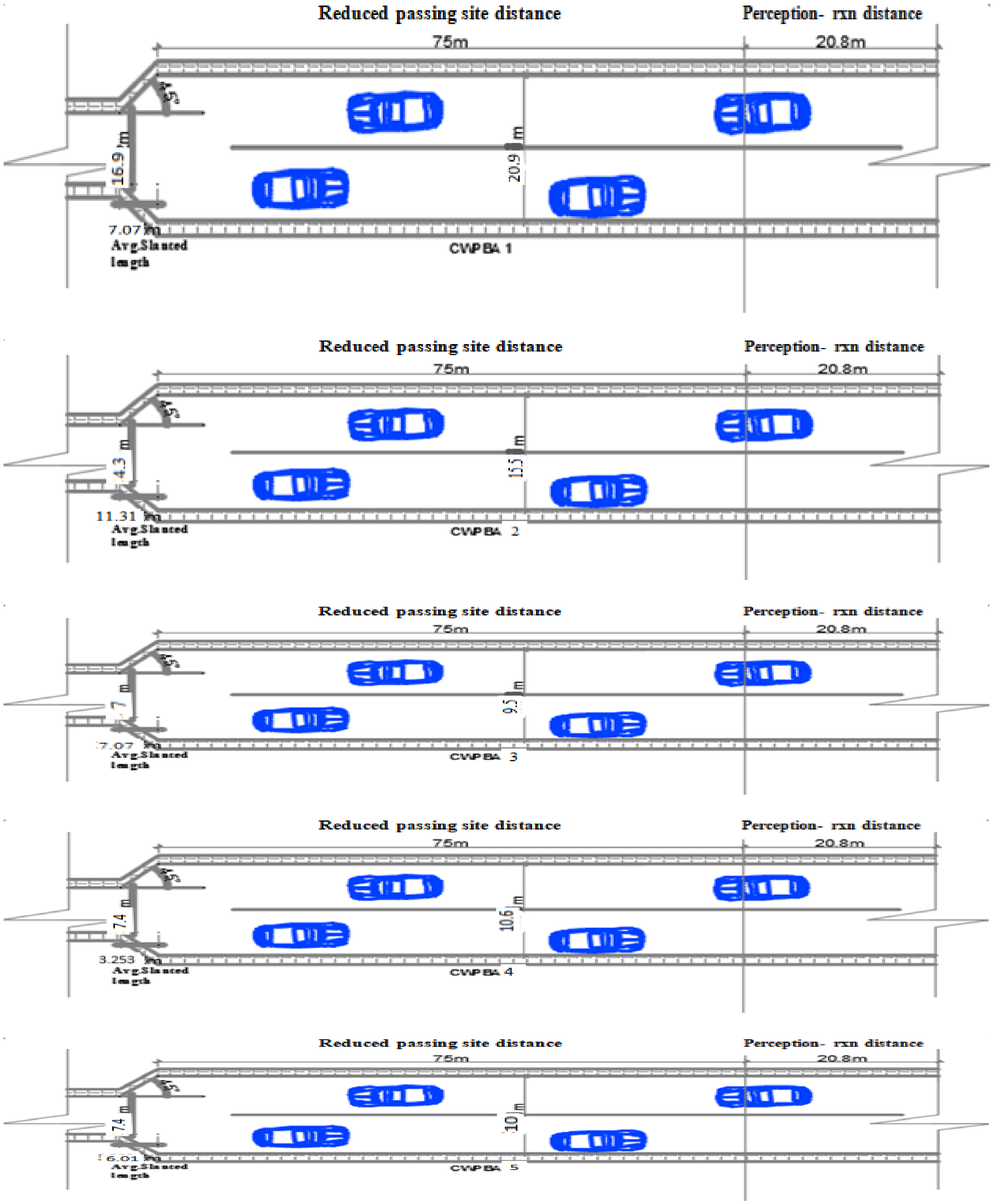
4.2.1. Driver and road characteristic

Constricted Width of pavement bridge approach affects the site distance of the driver to observe and apply reaction. To accommodate mix traffic characteristics, it was essential to know to stop and the passing sight distance of the vehicle before they apply the brake. From ERA design geometric manual, the speed of vehicles limited to 30km/hr in an urban area. Hence it was possible to calculate the stopping and passing sight distance needed when the driver observes the constricted pavement bridge approach. Form table 2.3 of chapter two, the stopping and passing sight distance needed while vehicles move on a specific traffic stream was taken. For 30km/hr and 0.42 coefficient of friction developed between vehicle tire and the road surface, 30m and 75m passing sight distance and reduced passing site distance for the design was required respectively to get smooth traffic flow towards obstacles. Hence stopping site distance required for driver was much smaller than reduced passing distance, 75m length of Approach Bridge was taken for the study. Again for 45 degree slanted length of constricted width pavement bridge approach, adjacent length of Approach Bridge was considered.



$$\text{Adjacent length (m)} = \text{Slanted length (m)} * \text{Cos} \propto^{\circ} -- \text{Eq(17)}$$

For example, for CWPBA 1 Slanted length was recorded to be 10 m connecting one edge of bridge width with pavement approach. Hence, Adjacent length (m) = 10 m * Cos 45 = **7.07m**



[Source: Drawing CWPBA dimensions from AutoCAD]

Figure 4. 1: Upper chain CWPBA dimensions.

Distance traveled during Perception reaction time also a major factor of flow characteristic for the driver. Recommendations made by the American Association of State Highway and Transportation Officials (AASHTO) stipulate 2.5 seconds for stopping-sight distances. This encompasses the decision times for about 90 percent of drivers under most highway conditions. Hence, for vehicle moving 30km/hr,

$$\text{Perception} - \text{reaction distance (m)} = \text{speed in m/ s} * \text{time in s} \ldots\ldots \text{Eq (18)}$$

= 30km/hr*1/3.6*2.5second

= **20.8m**

From the edge of constricted width Pavement Bridge, analysis of PTV Vissim applied 75m (governs) away towards both upper and lower chainage. Hence the total length of the road section analyzed using PTV vissim was found to be (2*75 + 2*adjacent length + bridge length + Reaction-perception distance).

Table 4. 2: Summary of road length used for data collection

Section of Road used for Analysis					
Type	Reduced Passing Site distance	Trimmed length(m)	Perception-reaction disance(m)	Bridge length(m)	Total (m)
CWPBA 1	**75**	**7.07**	**20.8**	**30.4**	**133.27**
CWPBA 2	**75**	**11.31**	**20.8**	**31.2**	**138.31**
CWPBA 3	**75**	**7.07**	**20.8**	**23.7**	**126.57**
CWPBA 4	**75**	**3.3**	**20.8**	**32**	**131.1**
CWPBA 5	**75**	**6.01**	**20.8**	**23.5**	**125.31**
Note: *RP site distance and trimmed length is for both upper and lower stream(x2)m.*					

[Source: From observational analysis]

4.2.2. Vehicle traffic characteristic

4.2.2.1. Speed

The speed of different vehicles was computed by observing and recording the time obtained to cover the test segment of roads. Space mean speed of various vehicles was recorded along constricted width PBA. Five bridge locations were separated to analyze the speed of vehicles according to observational frequency.

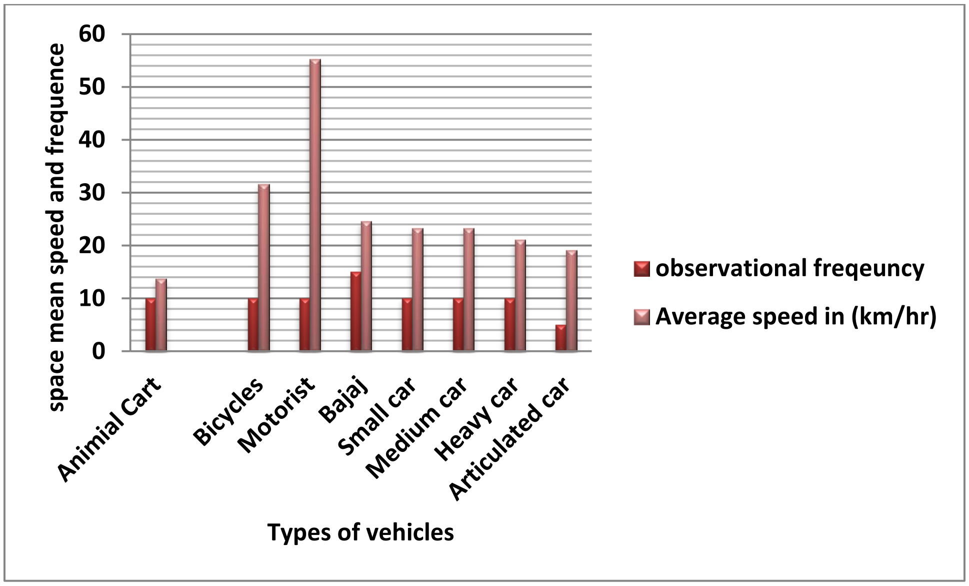


Figure 4. 2: Vehicles speed distribution at CWPBA 1

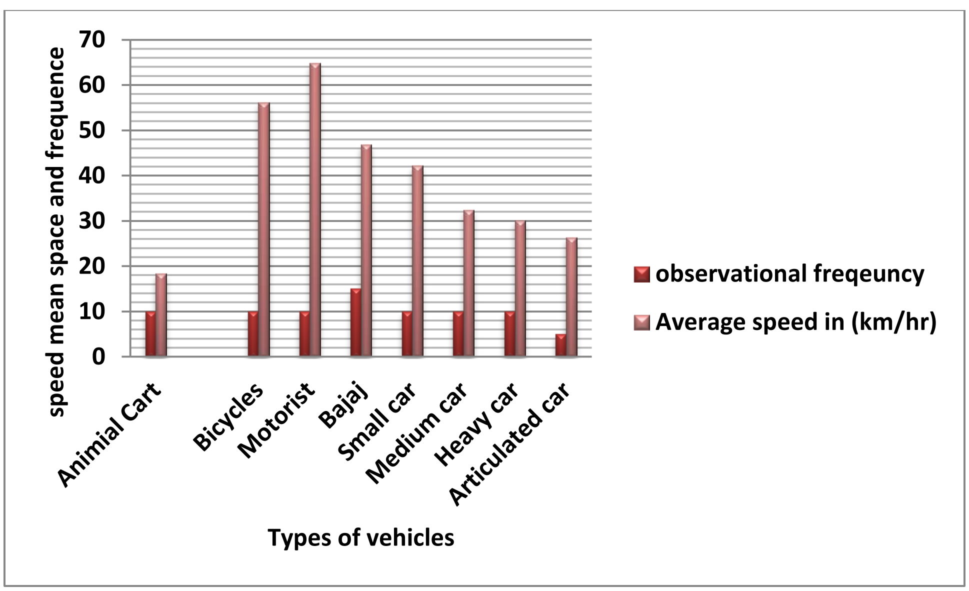


Figure 4. 3: Vehicles speed distribution at CWPBA 2

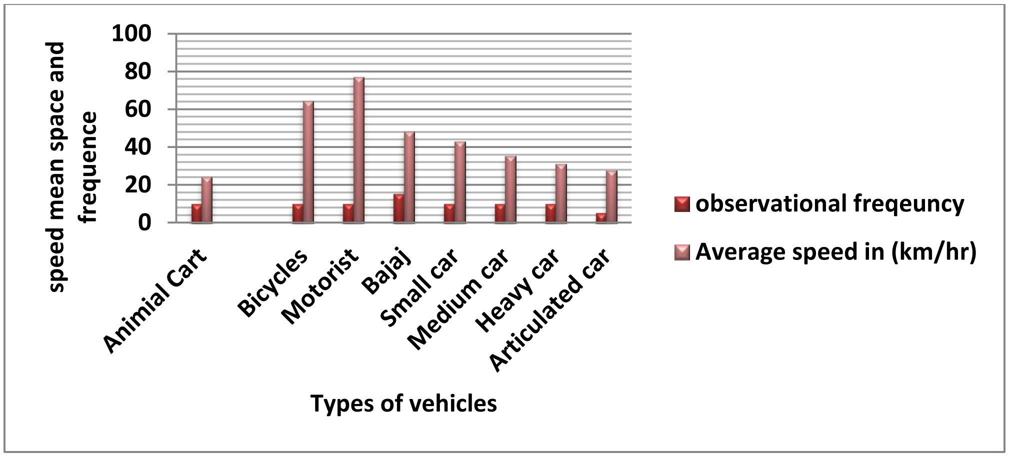


Figure 4. 4: Vehicles speed distribution at CWPBA 3

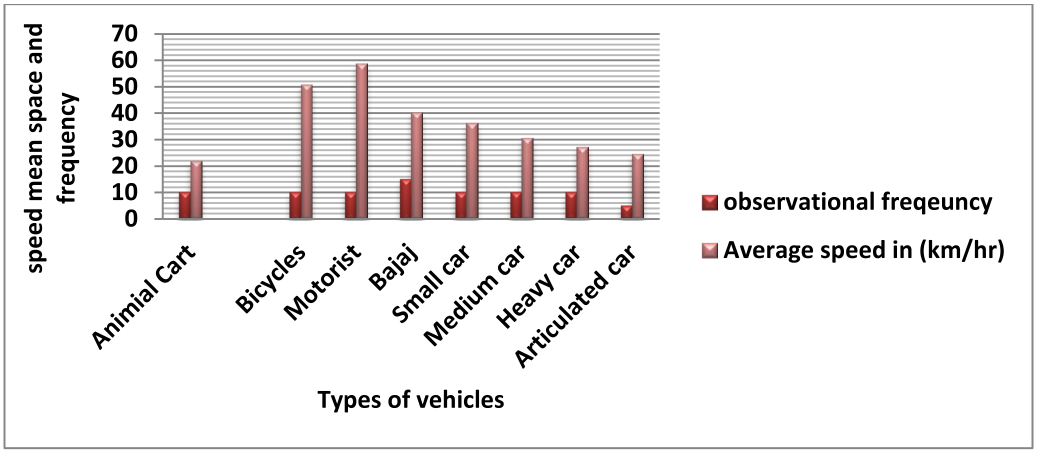
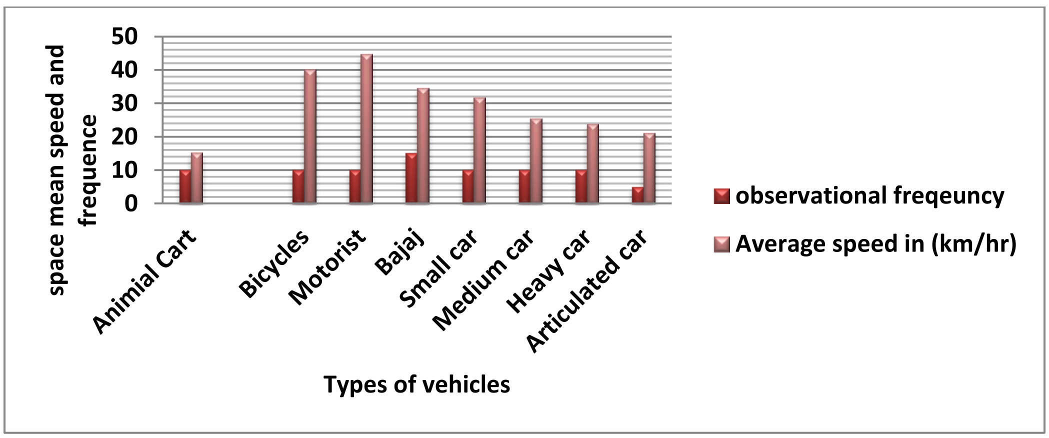


Figure 4. 5: Vehicles speed distribution at CWPBA 4



[Source: from observational analysis of speed by exeel sheet]

Figure 4. 6: Vehicles speed distribution at CWPBA 5

When the front bumper of the vehicles arrived station "A," the time elapsed to departure road section for analysis was registered at point "B." Vehicles were identified according to their size, color, and vehicle type. Test vehicles were also implemented for the study. Only two data collectors were efficiently executed the work.

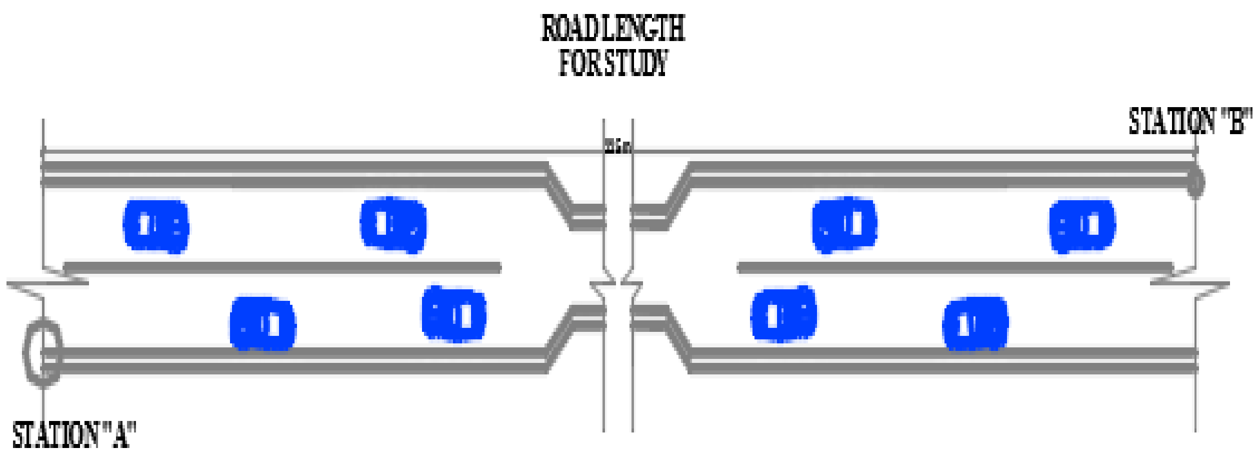


Figure 4. 7: Road length for analysis

Table 4. 3: Average speed along different CWPBA

At CWPBA 1				
Vehicles type	Observation Frequency	Road length (km)	Travel time lapsed in(seconds)	Average speed in (km/hr)
		(A)	(B)	A/B
Animal cart	10	0.1333	58	8.27
Bicycles	10	0.1333	25	19.2
Motorist	10	0.1333	15	32
Bajaj	15	0.1333	32	15
Small car	10	0.1333	34	14.11
Medium car	10	0.1333	34	14.11
Heavy car	10	0.1333	38	12.63
Articulated car	5	0.1333	42	11.43
Harmonic mean speed (km/hr)				**15.84**

At CWPBA 2				
Vehicles type	Observation Frequency	Road length (km)	Travel time lapsed in(seconds)	Average speed in (km/hr)
		(A)	(B)	A/B
Animal cart	10	0.234	57	14.78
Bicycles	10	0.234	25	33.7
Motorist	10	0.234	20	42.12
Bajaj	15	0.234	36	23.4
Small car	10	0.234	42	20.06
Medium car	10	0.234	42	20.06
Heavy car	10	0.234	56	15.043
Articulated car	5	0.234	50	16.85
Harmonic mean speed (km/hr)				**23.25**
At CWPBA 3				
Vehicles type	Observation Frequency	Road length (km)	Travel time lapsed in(seconds)	Average speed in (km/hr)
		(A)	(B)	A/B
Animal cart	10	0.1265	32	14.23
Bicycles	10	0.1265	12	37.95
Motorist	10	0.1265	10	45.54
Bajaj	15	0.1265	16	28.46
Small car	10	0.1265	18	25.3
Medium car	10	0.1265	22	20.7
Heavy car	10	0.1265	25	18.22
Articulated car	5	0.1265	28	16.26
Harmonic mean speed (km/hr)				**25.83**
At CWPBA 4				
Vehicles type	Observation Frequency	Road length (km)	Travel time lapsed in(seconds)	Average speed in (km/hr)
		(A)	(B)	A/B
Animal cart	10	0.1311	35	13.48
Bicycles	10	0.1311	15	31.46
Motorist	10	0.1311	13	36.3
Bajaj	15	0.1311	19	24.84

Small car	10	0.1311	21	22.47
Medium car	10	0.1311	25	18.88
Heavy car	10	0.1311	28	16.85
Articulated car	5	0.1311	31	15.22
		Harmonic mean speed (km/hr)		**22.44**
At CWPBA 5				
Vehicles type	Observation Frequency	Road length (km)	Travel time lapsed in(seconds)	Average speedin(km/hr)
		(A)	(B)	A/B
Animal cart	10	0.1253	50	9.02
Bicycles	10	0.1253	19	23.74
Motorist	10	0.1253	17	26.53
Bajaj	15	0.1253	22	20.5
Small car	10	0.1253	24	18.79
Medium car	10	0.1253	30	15.04
Heavy car	10	0.1253	32	14.1
Articulated car	5	0.1253	36	12.53
		Harmonic mean speed (km/hr)		**17.53**

Harmonic mean speed was used to get a representative average speed of different vehicles. According to the study, vehicle speed varied from one bridge to another. All Harmonic mean speed (km/hr) are less than standard speed (30km/hr). At constricted PBA 3, the speed was relatively high due small constriction of the pavement bridge approach. This influences drivers to use their driving capacity to drive along constricted width pavement bridge approach. In other case, Awetu Bridge experienced low speed due high traffic volume both upper and lower chainage of constricted width pavement bridge approach. Boyye and Hikate brigde do have relatively moderate travel speed recorded as compared to Awetu and Awetu Manafasha Bridge. The harmonic mean speed of both motorized and non-motorized vehicles was calculated by using Microsoft excel. Calculated speed was called spot mean speed. Table 4.3 above gives a clue to calculate harmonic mean speed of different vehicles.

4.2.2.2. Density

By using different digital as well as mobile cameras, the researcher had been collected several photo shoots along with a constricted width pavement bridge approach. Converting the observed camera Width into the actual length of the road section, different traffic segment distance is registered. Taking total of 15 camera shoots, average traffic density at different locations collected and converted into km length. Five stations were identified to execute the work. For constricted width PBA1, the CWPBA was in sag curve. So, the camera man stands at "**Top View Hotel**" to get better shoots. On the other hand, constricted Width PBA 2, and PBA3 on "**Gennu Hotel"** building and on Jimma stadium fence respectively were used. In fact, constricted width PBA4 and PBA5 was found somewhat on the sag curve, and hence, it was easy to get real-time data of traffic density shooting camera from the ground. Summarized observed traffic density was indicated on table 4.4 and 4.5 below. Here were some photos taken.




[Source: photo captured from site]

Figure 4. 8: Observed Camera shoots

Table 4. 4: Traffic density along constricted width PBA

At constricted width PBA 1															
Camera shoots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Road length (m)	152	147	185	148	154	205	185	184	202	194	200	203	206	185	196
Observed number of Vehicles	21	18	26	32	42	29	12	24	6	13	12	19	24	11	10
Density in "Veh/km/lane"	138	122	140	216	273	141	64	130	30	67	60	94	116	60	51
At constricted width PBA 2															
Camera shoots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Road length (m)	170	170	182	198	203	212	205	101	112	118	94	64	86	64	52
Observed number of Vehicles	28	24	13	26	46	34	43	27	32	36	17	14	19	16	13
Density in "Veh/km/lane"	165	141	71	131	227	160	210	267	286	305	180	219	220	250	250

At constricted width PBA 3															
Camera shoots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Road length (m)	152	147	185	148	154	205	185	184	202	194	200	203	206	185	196
Observed number of Vehicles	5	9	12	10	12	6	9	11	6	13	12	7	5	11	10
Density in "Veh/km/lane"	33	61	65	68	78	29	49	60	30	67	60	34	24	59	51
At constricted width PBA 4															
Camera shoots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Road length (m)	116	197	182	110	118	96	57	116	122	73	79	203	206	185	196
Observed number of Vehicles	8	9	8	12	9	5	5	8	5	6	5	7	5	11	10
Density in "Veh/km/lane"	69	46	44	109	76	52	88	69	41	82	63	34	59	59	51
At constricted width PBA 5															
Camera shoots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Road length (m)	79	111	138	156	126	142	157	102	91	63	101	176	196	142	123
Observed number of Vehicles	8	4	6	9	8	9	7	8	6	4	7	10	11	9	8
Density in "Veh/km/lane"	101	36	44	58	63	63	45	78	66	63	69	57	56	63	65

[Source: from analysis of captured photo]

The table above shows that the traffic density observed at Awetu and Awetu Manafasha CWPBA Bridge were higher than that of three CWPBA Bridge. This was due to a closely distribution of vehicles along constricted width PBA. Boyye and Hikate were moderate traffic density. And on Negasa Bridge there was the least traffic density was observed. This indicated that the traffic along the Negasa Bridge was sparsely distributed.

Table 4. 5: Average traffic Density in vehicle/km/lane

Bridges	CWPBA 1	CWPBA 2	CWPBA 3	CWPBA 4	CWPBA 5
Average Traffic density	**113**	**205**	**53**	**63**	**61**

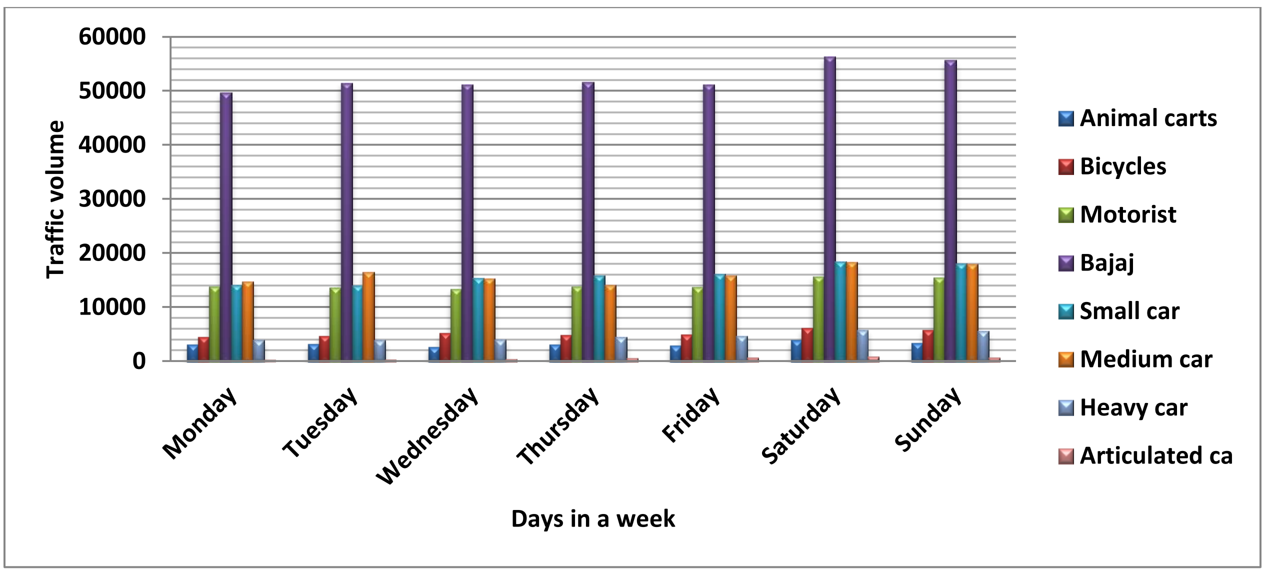
[Source: from analysis of captured photo]

4.2.2.3. Traffic volume

Table 4. 6: Organized Traffic Volume for the Study

Traffic Counting for 12hr per day										
Location	Days	Traffic volume per lane per 12hr								
		Animal carts	Bicycles	Motorist	Bajaj	Small car	Medium car	Heavy car	Articulated ca	Total
CWPBA	Monday	3041	4492	13757	49638	14098	14746	3878	262	**103912**
	Tuesday	3144	4683	13594	51454	13927	16467	3898	335	**107502**
	Wednesday	2618	5177	13321	51171	15389	15339	3936	427	**107378**
	Thursday	3041	4854	13838	51653	15771	14089	4465	577	**108288**
	Friday	2861	4878	13694	51158	16062	15806	4672	617	**109748**
	Saturday	3900	6072	15684	56316	18432	18360	5796	842	**125402**
	Sunday	3354	5783	15436	55685	18042	17933	5547	670	**122450**
	Total	**21959**	**35939**	**99324**	**367075**	**111721**	**112740**	**32192**	**3730**	**784680**

[Source: From manual counting]



[Source: From data manual counting by excel]

Figure 4. 9: Traffic flow bar chart

The above table and bar chart represent the traffic flow of different vehicles constricted width pavement bridge approach. All of them were found in Jimma town. Only the traffic flow of one lane was represented. On the other hand, other side traffic flow was equivalent to the observed lane of a different direction.

From organized traffic volume table 4.6 and the bar chart above, it was quite visible that the number of Bajaj covers nearly half the traffic volume within the town. It was also possible to understand the traffic volume fluctuates within the day. According to this research, Saturday was found to be the most crowdies day. On the other hand, Monday was also found to be the day of lesser traffic volume (registered) along with the constricted width pavement bridge approach. Standard ADT from ERA design manual for Jimma paved road was 300-10,000. This implies all calculated traffic flow in the table 4.7 are above standard ATD. Traffic flow characteristic along constricted Width pavement bridge approach varies from bridges to bridges. Average daily traffic flow along this bottleneck structure was calculated below using a 95% confidence interval of 24hr traffic flow. See chapter 2 of equation 7 and 8.

Table 4. 7: ADT used for analysis

Bridge type	**Total 12hr Traffic count for 7days**	**Confidence Interval**	**7 days 24hr traffic Flow**	**ADT in Vehicle/day**
	(A)	***(B)***	***C= A/B***	***(D) = C/7***
CWPBA 1	187,464	0.95	197330.5	28190.07
CWPBA 2	282,092	0.95	296938.9	42419.84
CWPBA 3	148751	0.95	156580	22368.57
CWPBA 4	83931	0.95	88348.42	12621.2
CWPBA 5	81312	0.95	85591.58	12227.37
Note; *All motorized and non-motorized vehicles were summed to be traffic flow along CWPBA*				

[Source: From analysis of surveyed traffic data]

4.2.2.4. Traffic Flow

For analysis purpose, observed traffic flow of vehicles at different five constricted pavement bridge section was calculated from Eq (5) of chapter two above: (Q) = K*Vav

Where, K = observed Traffic density in "Vehicle/Km/lane."

Vav = Average speed in “km/hr”

Q = Traffic flow (Volume) in “vehicle/hr/lane

For example, for **CWPBA 1** observed traffic density was **113.5 vehicles per kilometer per lane** and recorded harmonic mean speed was about **26.5 km per lane**. Hence by multiplying traffic density with that of traffic speed, it was possible to get traffic flow of **3007.75 vehicle/hour/lane**. The same principle was applied to get traffic flow volume of CWPBA 2, CWPBA 3, CWPBA 4 and CWPBA 5 in general. Table 4.8 below shows computed traffic flow along with independent variables.

Table 4. 8: Traffic data used for analysis

Traffic data Used for Analysis								
No	Available CWPBA	Avg. Approach width(m)	ADT (veh/day)	Avg. Number of pedestrian/ day	Av.traffic Density(veh/km)	Avg.Travel speed(km/hr)	Traffic volume(veh/hr)	Traffic delay(sec)
1	Awetu Manafasha	18.9	28190.1	9155	113	15.84	3008	18.34
2	Awetu	9.9	42419.8	17515	205	23.25	4778	38
3	Negasa	8.25	22368.6	9855	53	25.83	2243	10
4	Boyye	9	12621.2	2610	63	22.44	2286	7
5	Hikate	8.5	12227.4	3185	61	17.57	1834	8
Source; All row data were collected and manipulated from primary data of Traffic survey								

4.2.3. Pedestrian characteristic

Different peoples were using the road to travel from one part of the bridge to another for their own purpose. Childers, youngsters, adults, and olds were using the road. It was observed that some peoples didn’t use their left side regulation along constricted width Pavement Bridge approach. On the other hand, the available pedestrian walkway width was not enough for the flows of peoples across the road. Here were some photos taken during observational studies.

[Source: Photo captured from site]

Figure 4. 10: Pedestrian movement

For analysis purposes, pedestrian volumes were counted all along with the constricted width pavement bridge approach separately. Table 4.9 below shows number of pedestrian volume crossing the bridge per lane on existing pedestrian walkway width.

Table 4. 9: pedestrian volume

Bridges locations	Existing pedestrian width in "m"	Number of pedestrian per lane
CWPBA 1	2.85	9155
CWPBA 2	1.8	17515
CWPBA 3	1.25	9855
CWPBA 4	1.6	2610
CWPBA 5	1	3185

[Source: From site observation]

About 0.214m2 area was needed to stand in general. For sidewalks or other pedestrian corridors dynamic spatial requirements for avoiding collisions with other pedestrians needed. Allow space of 2.30 m2 / pedestrian for walking freely. Average distance preferred between two pedestrians following each other 244 cm = 2.40m, time spacing of 2 seconds. According to the study, pedestrian volume using constricted width pavement approach was affected by narrowness of walkway width. Table 4.10 below shows, maximum number of pedestrian that must use constricted pavement bridge approach according to AASHTO recommendations. Here was the analysis;

Table 4. 10: Pedestrian characteristic along CWPBA

Bridges locations	Free walking area (m2) per pedestrian	Existing pedestrian width in (m)	Length of existing constricted width PBA in (m)	Existing walking area (m2)	Number of pedestrian per lane	Existing Pedestrians Per Lane
CWPBA 1	2.3	2.85	10	28.5	12	17
CWPBA 2	2.3	1.8	16	28.8	12	20
CWPBA 3	2.3	1.25	10	12.5	5	8
CWPBA 4	2.3	1.6	4.6	7.36	3	6
CWPBA 5	2.3	1	8.5	8.5	3	6

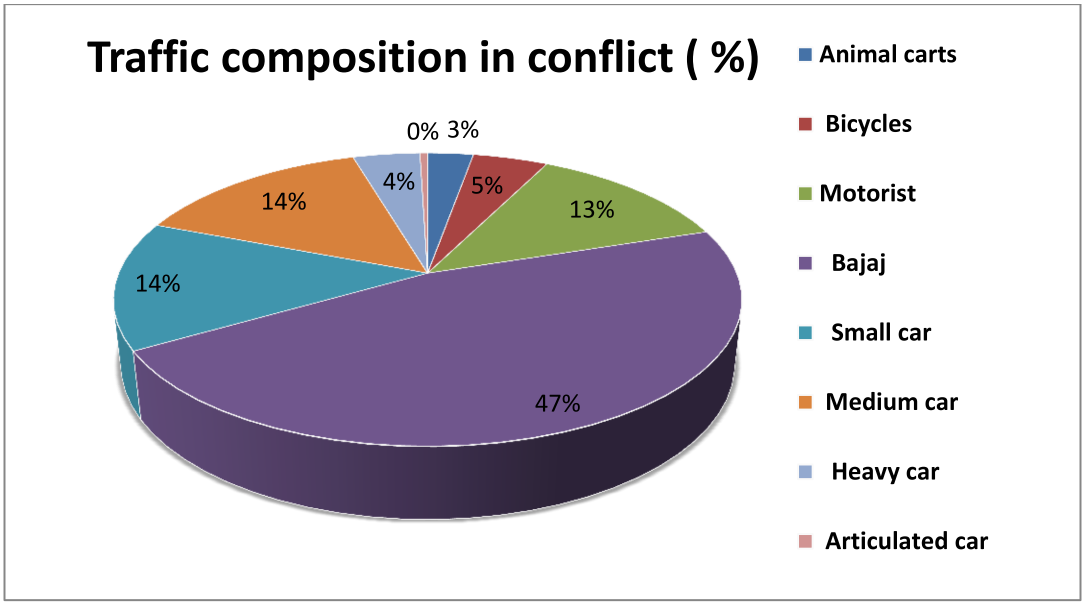
[Source : From observational analysis]

From picture 4.10 above, the number of a pedestrian using the constricted width pavement bridge approach was much higher than the calculated pedestrian volume per lane along a bottleneck structure. The gap observed between two pedestrians following each other was most of the time less than 2.4m away from each other. Hence, it was possible to say that existing pedestrian walkway was not enough to accommodate the current movement of people from place to place.

4.3. Traffic conflict along constricted Width PBA

4.3.1. Traffic composition in conflict

According to different interview respondents, the majority of conflict around the bottleneck structure has occurred between Bajaj's and other vehicles. About 47 % of vehicles around constricted width pavement were three tire vehicles. At least a 5014-15600 numbers of Bajaj were pass the bridge per day. It was also indicted that motorized and non-motorized vehicles like animal cart, bicycle, motorist, pickups, buses, minibuses, Sino, articulated car and other were observed along the five constricted width pavement bridge approaches.

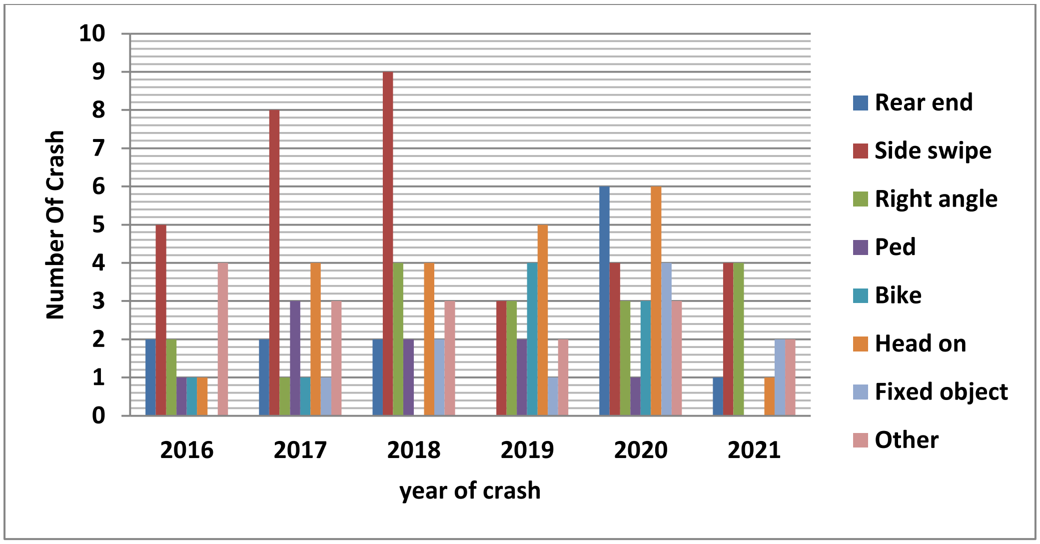


[Source: from traffic survey]

Figure 4.11: Pie chart of traffic composition in conflict

4.3.2. Traffic crashes along CWPBA

Due to road constriction and PBA, sideswiping types of traffic crashes were mostly observed during the past six years of traffic data. This was due vehicle right to get the middle lane of approach lane. In another case, a traffic crash with Bike and Ped occurred rarely. The bar chart below indicates a number of traffic conflict occurred along with a constricted width pavement bridge approach versus data collected years.



[Source: From Jimma town Transport Office and Police Commision]

Figure 4. 12: Bar chart of traffic crashes along CWPBA

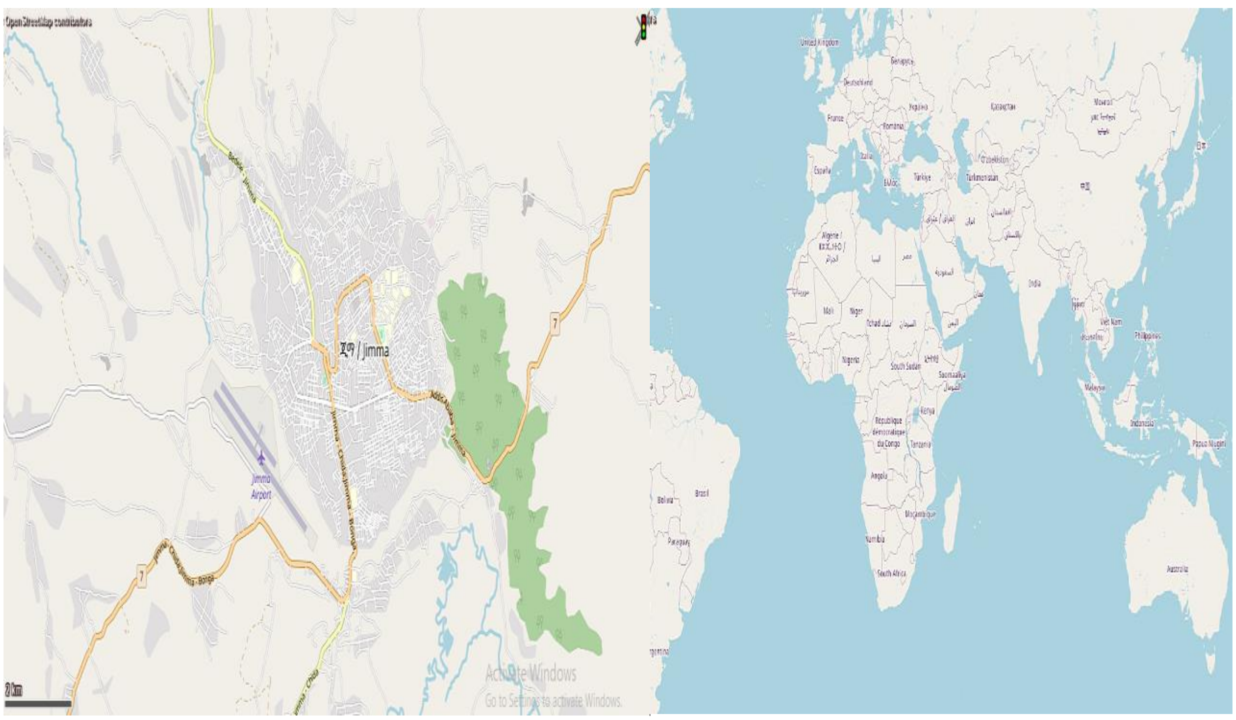
From above cylindrical bar chart, Y- axis indicates the number of conflicts observed along CWPBA while X- axis shows observed years of different crash types. In 2017 and 2018, GC, more than 49 number of traffic crashes occurred along five constricted width pavement bridge approaches. From this, more than 34.7% of the traffic crash was sideswiping in type. On other hand, year 2016 and 2021 was recorded small number of traffic crash following 2019. Although the high volume of traffic flow along with the constricted width pavement approach, a relatively small amount of Bike and Ped traffic crashes observed during the past six years. Contribution of non-motorized vehicles like animal cart over constricted width pavement bridge approach was visible. According to the travel speed analysis above, the time elapsed for one non-motorized vehicle to pass across the bridge was about 40 seconds. Hence non-motorized vehicles occupied the middle lane for a long period of time, making traffic congestion over constricted width pavement bridge approach. Most of the right angle types of traffic accidents occurred along Awetu manafasha and Awetu Bridge. This was due to the attribute traffic road along the constriction. Vehicles inter and exist from constriction directly from the main road. This caused the right angle type of traffic crash to occur frequently.

4.4. Model Development

To develop a best fit model, which describes the effect of constricted width pavement bridge approach over traffic flow in case of Jimma town roads, different software was applied.

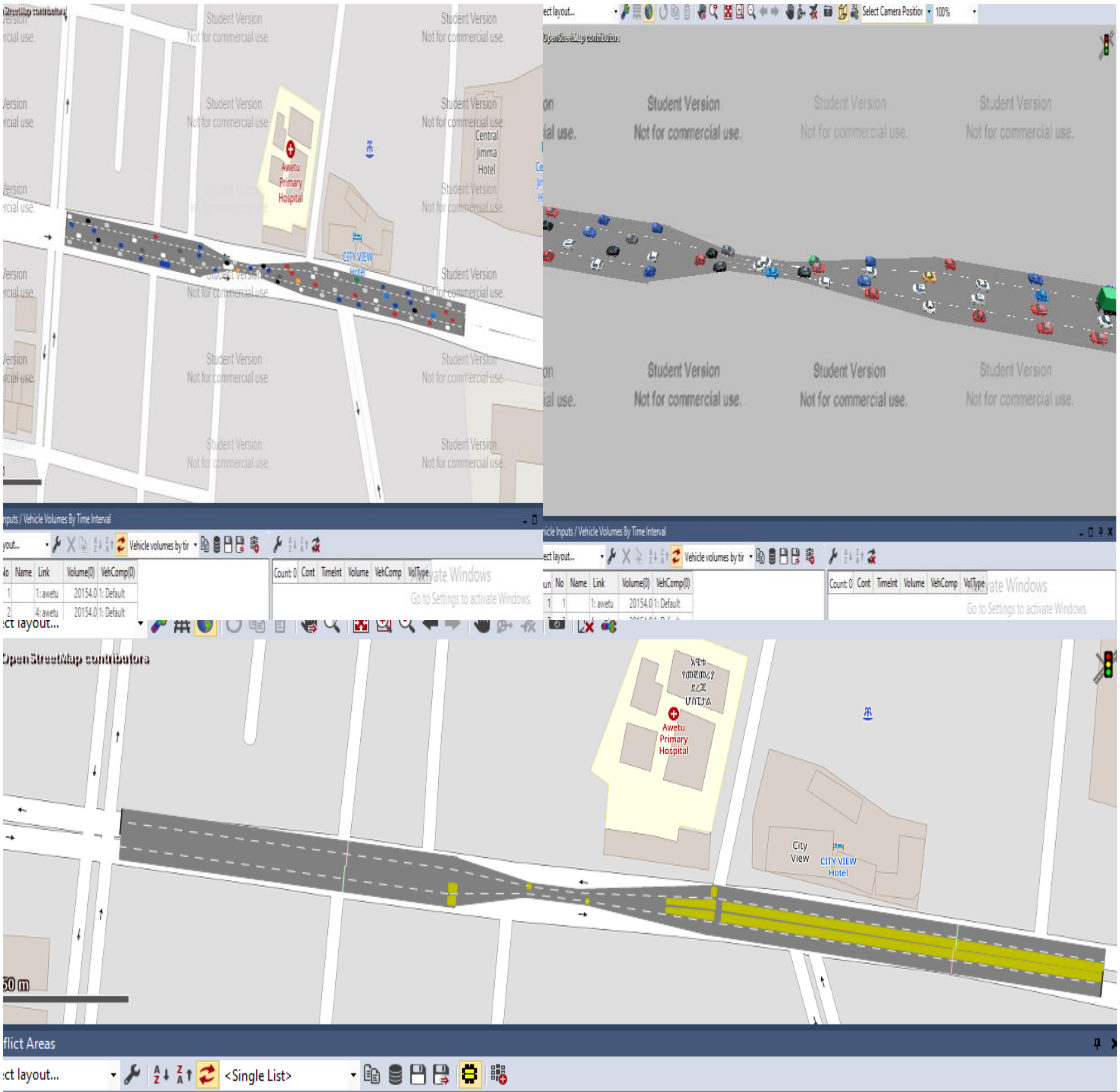
4.4.1. PTV Vissim software

PTV Vissim is the worlds most advanced and flexible traffic simulation software which simulates complex vehicle interaction. They do have wide applications in transportation demand modeling. Hence, From PTV Vissim traffic simulation software, it was possible to determine traffic delay along with the constricted width pavement bridge approach by generating traffic volume. The software also specified traffic conflict zones. By generating different traffic flow, the possible current and future traffic capacity of the constricted road was determined.



[Source: From PTV Vissim software]

Figure 4. 13: PTV Vissim opens street network area



un	Link1	VisibLink1	Link2	VisibLink2	Status	FrontGapDef	RearGapDef	MesoCritGap	SafDistFactDef	AddStopDist	ObsAdjLns	AnticipRout	AvoidBlockMinor
1	5: awetu	100.0	10000: 1-5	100.0	Passive	0.5	0.5	3.5	1.5	0.0	☐	0.0 %	100.0 %
2	3: awetu manafasha	100.0	10001: 5-3	100.0	Passive	0.5	0.5	3.5	1.5	0.0	☐	0.0 %	100.0 %
3	6: awetu	100.0	10002: 4-6	100.0	Passive	0.5	0.5	3.5	1.5	0.0	☐	0.0 %	100.0 %
4	2: awetu	100.0	10003: 6-2	100.0	Passive	0.5	0.5	3.5	1.5	0.0	☐	0.0 %	100.0 %
5	3: awetu manafasha	100.0	4: awetu manafasha	100.0	Passive	0.5	0.5	3.5	1.5	0.0	☐	0.0 %	100.0 %
6	4: awetu manafasha	100.0	10001: 5-3	100.0	Passive	0.5	0.5	3.5	1.5	0.0	☐	0.0 %	100.0 %
7	10001: 5-3	100.0	10002: 4-6	100.0	Passive	0.5	0.5	3.5	1.5	0.0	☐	0.0 %	100.0 %

[Source: PTV Vissim output]

Figure 4. 14: 2D and 3D PTV traffic simulation and conflict area

PTV Vissim analysis applied on five constricted width bridges approaches. Roadway projected 75m away, starting from the point of road constriction to both upper and lower chainage. Constricted or slanted Width of roadway constructed by using a smooth curve projected from several points beginning from the two approach lanes.

The Width of the travel lane applied to the software was half of the geometric Width of the existing road. Shoulders width also calculated from existing data. Flow directions across the bridge were nominated for analysis purposes were north to south and east to west.

Total delay due to insufficient capacity of the constricted width pavement bridge approach (the area was in a state of saturated flow) obtained from the software was highly depends on traffic volume. For delay analyses using PTV Vissim software, draw the link using observational data of table 3.5 for each CWPBA. Then adjust observed traffic data into the drawn link for opposite direction traffic flow. Finally generate the traffic data into drawn link for simulation. The output of PTV Vissim for the researcher was traffic delay per vehicle and area of conflict. The yellow colours in figure 4.14 above indicate the area of conflict along the CWPBA.

From software analysis, delay of vehicles highly observed along the Awetu bridge. Most of the time, an average of 38 seconds was elapsed for vehicles to pass the constricted width pavement bridge approach. Awetu manafasha Bridge also experienced an average 18.34 seconds of traffic delay to pass obstacles. A due small amount of roadway constriction, usage of shoulder-width was not observed along Boyye and Hikate Bridge. Even if constricted Width didn't observe, about 725 and765 vehicles passed the bridge per hour respectively.

Hence only 7 and 8 seconds of traffic delay experienced along this bridge respectively. The table below summarized inputs of raw data and output of traffic delay when obtained traffic flow volume applied to it.

Table 4. 11: Input and outputs of PTV simulation

Bridge location	No of links	Flow direction	Observed roadway length(m)	Applied traffic Volume	Simulated traffic delay(sec)
CWPBA 1	1	south to north (middle lane)	75	10045	7
	2	south to north (shoulder lane)	85	3349	21
	3	south to north(@ bridge width)	30.4	13394	27
	4	north to south (middle lane)	75	10045	7
	5	north to south (shoulder lane)	85	3349	21
	6	north to south(@ bridge lane)	30.4	13394	27
CWPBA 2	7	West to east (middle lane)	75	15115	14
	8	west to east (shoulder lane)	91	5039	44
	9	west to east (@ bridge width)	31.2	20154	56
	10	East to West (middle lane)	75	15115	14
	11	East to West (shoulder lane)	91	5039	44
	12	East to West (@ bridge lane)	31.2	20154	56
CWPBA 3	13	West to east (middle lane)	75	7974	4
	14	west to east (shoulder lane)	80	2658	11
	15	west to east (@ bridge width)	23.7	10632	15
	16	East to West (middle lane)	75	7974	4
	17	East to West (shoulder lane)	80	2658	11
	18	East to West (@ bridge lane)	23.7	10632	15
CWPBA 4	19	south to north (middle lane)	75	6000	11
	20	south to north (shoulder lane)	79.6	0	0
	21	south to north(@ bridge width)	32	6000	11
	22	north to south (middle lane)	75	6000	11
	23	north to south (shoulder lane)	79.6	0	0
	24	north to south (@ bridge lane)	32	6000	11
CWPBA 5	25	West to east (middle lane)	75	5808	12
	26	west to east (shoulder lane)	83.5	0	0
	27	west to east (@ bridge width)	23.5	5808	12
	28	East to West (middle lane)	75	5808	12
	29	East to West (shoulder lane)	83.5	0	0
	30	East to West (@ bridge lane)	23.5	5808	12

[Source: From output of PTV Vissim software]

4.4.2. Data analysis using SPSS software

SPSS Statistics, the world's leading statistical software, is designed to solve business and research problems through hoc analysis, hypothesis testing, and geospatial analysis, and predictive analytics. Many natural science researchers used this software to analyze, correlate, regression, and other mathematical applications in recent times. Using this software was relatively easy to understand and interpret data. The snipping photo below indicates variable and data view of SPSS software feed in table format.

Table 4. 12: Variable and Data view of SPSS software

	Name	Type	Width	Decimals	Label
1	Bridge	Numeric	8	2	Average constricted width PBA in "m"
2	ADT	Numeric	8	2	ADT in "vehicle/day"
3	People	Numeric	8	2	Pedestrian volume in "people/day"
4	Speed	Numeric	8	2	Travel speed in " km/day"
5	Density	Numeric	8	2	Traffic density in "vehicle/hr"
6	volume	Numeric	8	2	Traffic volume in "vehicle/hr"
7	delay	Numeric	8	2	Travel delay along CWPBA in "second"

	Bridge	ADT	People	Speed	Density	volume	delay
1	18.90	28190.10	9155.00	15.84	113.00	3008.00	18.34
2	9.90	42419.80	17515.00	23.25	205.00	4778.00	38.00
3	8.25	22368.60	9855.00	25.83	53.00	2243.00	10.00
4	9.00	12621.20	2610.00	22.44	63.00	2286.00	7.00
5	8.50	12227.40	3185.00	17.57	61.00	1834.00	8.00

[Source: From SPSS software inter lay out]

From a descriptive analysis of SPSS software, a different value of mean, median, variance, standard deviations and Skewness was observed. Using 95 % of the confidence interval, positive and negatives Skewness of dependent and independent data were determined. From the analysis, it was found that the degree of symmetry between variables was somewhat flat. This was due to a small number of constricted width pavement bridge approaches available in Jimma town. But from a correlation study of variables, the observed correlation of variables between dependent and independent variable was strong. This made the statement of the effect of constricted width pavement bridge approach on traffic flow strong and valid. Descriptive and correlation analysis of input data of dependent and independent variables was shown in summarized below;

Table 4. 13: Correlation analysis

Correlation value between dependent and independent variable (Using Pearson correlation method)					
	Average constricted width PBA in "m"	Travel speed in "km/hr"	traffic density in "vehicle/km"	Traffic volume in "vehicle/hr"	travel delay along CWPBA in "seconds"
Average constricted width PBA in "m"	1	-0.970	0.981	0.987	0.988
Travel speed in "km/hr"	-0.970	1	-0.942	-0.963	-0.983
traffic density in "vehicle/km"	0.981	-0.942	1	0.984	0.919
Traffic volume in "vehicle/hr"	0.987	-0.963	0.984	1	0.907
travel delay along CWPBA in "seconds"	0.988	-0.983	0.919	0.907	1

[Source: From SPSS software inter lay out]

From correlation analysis of SPSS, dependent and independent variables were highly correlated. Traffic density and traffic volume was found to highly correlate with respect to constricted width pavement bridge approach. If travel speed along constricted width pavement bridge approach is small, then traffic delay experienced would be high.

While analyzing and interpreting the data using SPSS software, the following variables like driver comfort, geometric condition, roadside environment, and critical length development were kept constant for simplicity purposes.

Table 4. 14: Descriptive statistics

Descriptive Statistics					
		statistic	Std, Error	95% Confidence Interval	
				Lower	Upper
Average constricted width PBA in "m"	N	5		5	5
	Range	10.65			
	Minimum	8.25			
	Maximum	18.90			
	Mean	10.9100	2.01732	8.5500	15.0200
	Std.deviation	4.51088		.22361	5.76546
	Variance	20.348		.050	33.241
	Skewness	2.130	.913	-.928[b]	2.233[b]
Travel speed in " km/day"	N	5		5	5
	Range	9.99			
	Minimum	15.84			
	Maximum	25.83			
	Mean	20.9860	1.85546	17.6723	24.1200
	Std.deviation	4.14893		1.15381	5.11043
	Variance	17.214		1.331	26.116
	Skewness	-.279	.913	-2.173[b]	2.081[b]
Traffic density in "vehicle/hr"	N	5		5	5
	Range	152.00			
	Minimum	53.00			
	Maximum	205.00			
	Mean	99.0000	28.53769	58.6000	149.8000
	Std.ddeviation	63.81222		3.89872	81.53036
	Variance	4072.000		15.200	6647.200
	Skewness	1.595	.913	-1.944[b]	2.235[b]
Traffic volume in "vehicle/hr"	N	5		5	5
	Range	2944.00			
	Minimum	1834.00			
	Maximum	4778.00			
	Mean	2829.8000	522.44181	2016.1719	3781.2000
	Std.deviation	1168.21539		193.72222	1507.17913
	Variance	1364727.200		37528.300	2271591.491
	Skewness	1.581	.913	-2.168[b]	2.235[b]
Travel delay along CWPBA in "second"	N	5		5	5
	Range	31.00			
	Minimum	7.00			
	Maximum	38.00			
	Mean	16.2680	5.78842	8.0000	26.8000
	Std. eviation	12.94330		1.09545	16.70928
	Variance	167.529		1.200	279.200
	Skewness	1.665	.913	-.884[b]	2.236[b]
Source: (SPSS software output)					

4.4.3. "Best fit" Model using R-code software.

R (programming language) R is a programming language and free software environment used for statistical computing and graphics supported by the R Foundation for Statistical Computing purposes. The R language is widely used among other statisticians and data miners for developing statistical software and data analysis. Most engineers used this software for analysis purposes. On the other hand, R-code develops the "Best fit" model, which relates to the effect of constricted width PBA on travel speed and traffic density. Data on traffic density, travel speed, and average constricted width PBA where taken from table 4.8 above.

```
> y=c(18.9,9.9,9,8.5,8.25)
> sum(y)
[1] 54.55
> mean(y)
[1] 10.91
> sum((y-mean(y))^2)
[1] 81.392
> sd(y)
[1] 4.510876
> x1=c(31,22,19,12,10)
> sum(x1)
[1] 94
> mean(x1)
[1] 18.8
> sum((x1-mean(x1))^2)
[1] 282.8
> sd(x1)
[1] 8.408329
> x2=c(13.1,11.8,9.6,9.5,8)
> sum(x2)
[1] 52
> mean(x2)
[1] 10.4
> sum((x2-mean(x2))^2)
[1] 16.46
> sd(x2)
[1] 2.028546
> sum((y-mean(y))*(x1-mean(x1)))
[1] 133.66
> sum((y-mean(y))*(x2-mean(x2)))
[1] 30.24
> cor(x1,y)
[1] 0.9609898
> cor(x2,y)
[1] 0.9261825
> pairs(data.frame(y,x1,x2),main="pairwise  correlation")
> lm(formula=y~x1+x2)
Call:
lm(formula = y ~ x1 + x2)
Coefficients:
(Intercept)        x1        x2
   2.8796     0.05045     0.01399
```

Figure 4. 15: R-code analysis

Table 4.15 R-code output

Coefficients		
intercept	x_1	x_2
2.879	0.05045	0.01399
source: R-code software outputs		

$Y = 2.879 + 0.05045x_1 + 0.01399x_2$ --Eq (19)

Where; Y= Average constricted width PBA in "m"

X1= Traffic density unit

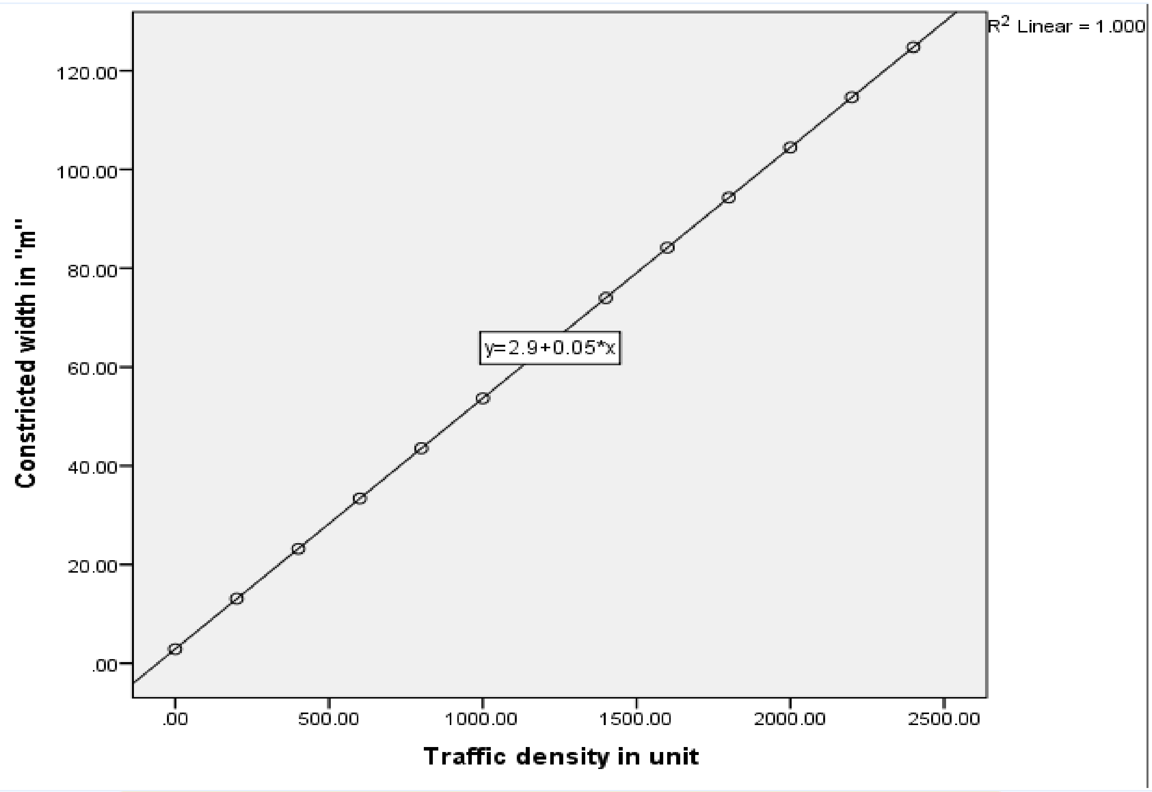
X2 = Travel speed unit

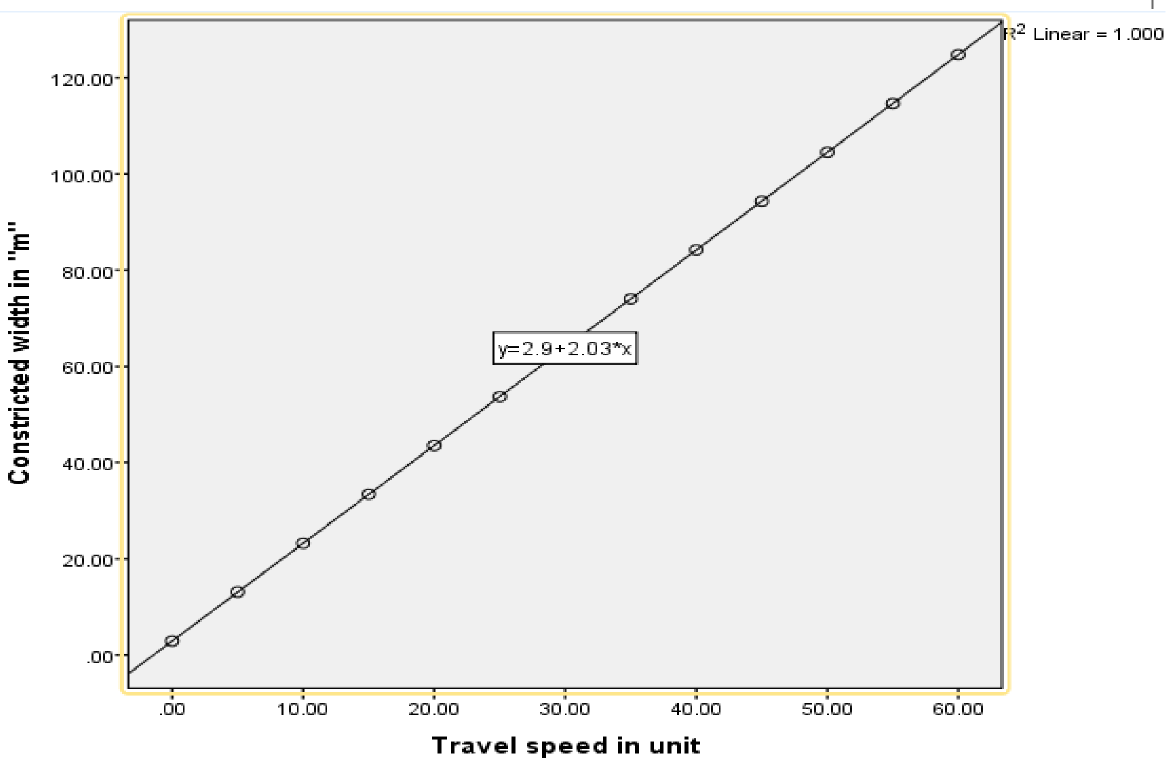
Table 4. 16: Output of the best fit model

Traffic density in unit	0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400
Travel speed in unit	0	5	10	15	20	25	30	35	40	45	50	55	60
Constricted width in "m"	2.879	13.08	23.2	33.4	43.5	53.7	63.8	74.0	84.2	94.3	104.5	114.6	124.8

[Source: R-code software outputs]

Using SPSS software, the graph which represents constricted width pavement bridge approach with that of traffic speed and density was drawn. The dots points indicate corresponding value of CWPBA with traffic density and speed. From below graph if you extend the regression line downwards until you reach the point where it crosses the y-axis, you'll find that the y-intercept value is positive! In fact, the regression equation shows us that the positive intercept is 2.879. Using the traditional definition for the regression constant, if speed and density is zero, the expected mean constricted width is 2.879 m! Neither a zero speed and density nor a constricted width makes any sense at all! The y-intercept for zero density and speed regression model has no real meaning, and the researcher should not try attributing one to it.





[Source: From SPSS output]

Figure 4. 16: Graphical presentation of best fit model output

From multi-linear regression equation (19) above, it was known that there was a positive increasing graph between the constricted width pavement bridge approach and travel speed. The same is true for constricted width pavement bridge approach and traffic density. As Width of constricted PBA increase, traffic density and travel speed also increased in decimal points. This intern increases traffic flow as it was a function of traffic volume and travel speed. The minimum value of constricted width pavement bridge approach shall not be less than 13.08m to safely accommodate traffic density of 200 vehicles/km and travel speed of 5km/hr.

4.5. Possible remedial actions

This study didn't only talk about the effect of the constricted width pavement bridge approach on traffic flow but also suggested a possible option to minimize the impact. According to collected interview data, more than 75% of traffic conflict occurred due to sudden constriction of the pavement bridge approach. Also, 83.7% of peoples agreed to construct a new lightweight pedestrian walkway along bridge span to avoid conflict between pedestrians and vehicles.

Table 4. 17: Respondents possible remedial action

part III			Observed traffic conflict caused due to in %							
No	Respondents	Interviewed	Vehicle size		Geometric effect		Sudden constriction		Sideswipping	
			agree	disagre	agree	disagre	agree	disagre	agree	disagre
1	Pedestrian(P)	75	61	37	14	82	76	23	71	21
2	Drivers(D)	75	77	33	22	78	78	22	27	73
3	Engineers(E)	25	83	17	16	84	86	14	87	13
4	Traffic police	25	79	21	44	56	81	18	75	25
5	Others(O)	15	41	52	15	79	36	58	56	44
Average		**215**	**69.84**	**32.47**	**20.58**	**77.605**	**76**	**23.47**	**56.93**	**43.07**
part IV			Possible remedial action to minimize the effect in %							
No	Respondents	Interviewed	New bridge		edestrian walkwa		Guidesign		smooth transmission	
			agree	disagre	agree	disagre	agree	disagre	agree	disagre
1	Pedestrian(P)	75	79	21	91	9	87	13	76	24
2	Drivers(D)	75	85	15	81	19	79	21	82	18
3	Engineers(E)	25	72	28	88	12	84	16	91	9
4	Traffic police	25	76	24	75	25	88	12	76	24
5	Others(O)	15	64	36	68	29	73	27	72	28
Average		**215**	**78.88**	**21.12**	**83.70**	**16.093**	**83**	**17**	**79.56**	**20.44**

As a researcher, the following remedial action believed to decreases effect of constricted width pavement bridge approach on traffic flow along road of Jimma town;

- Constructing a new wide enough bridge along Awetu manafasha and Awetu Bridge for long term traffic plan to solve the problem.
- Making smooth transmission of vehicles towards constricted width pavement bridge approach both upper and lower chainage. This intern decreases the sideswiping crash effect of vehicles while moving towards the constricted approach width. Also, 80% of peoples agreed on this idea.
- Providing and installing traffic guide and warning signs to give drivers due attention ahead as a short term plan. Also, 83% of peoples agreed on this idea.
- Constructing a new pedestrian walkway bridge on both sides of the road to avoid contact between pedestrians and vehicles. Also, 84% of peoples agreed on this idea.

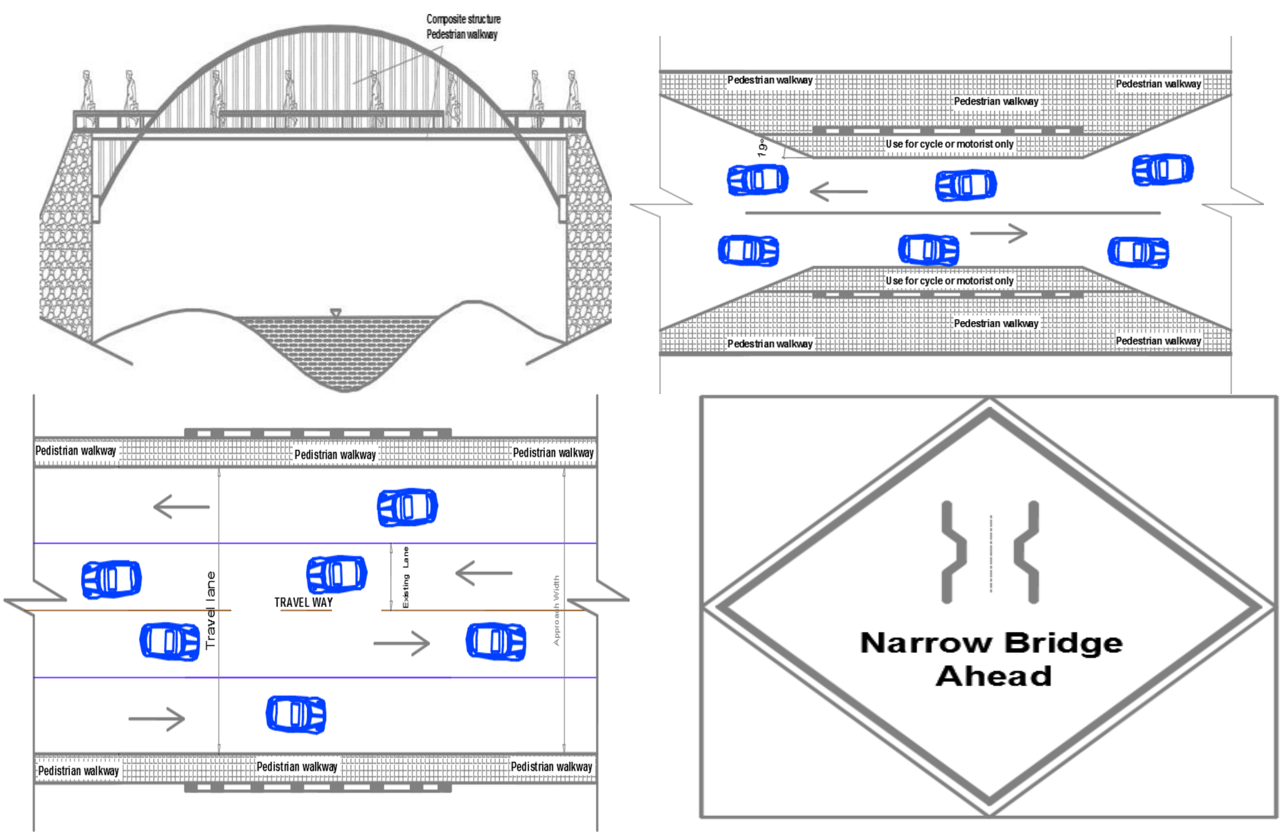


Figure 4.17. Remedial action for CWPBA

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Both from a descriptive and observational study of the research, different traffic characteristic were observed. Standing on sight distance and driver's reaction-perception distance, a range of 120 to 140m road sections had been used for analysis. The average speed of 21.5km/hr was recorded along with five constricted width pavement bridge approach. Per 1km length of road section, about 50-205 vehicles were observed along those bridges. On the other hand, ADT about 12,000 – 40,000 vehicles was passing along CWPBA within a day. Pedestrian of more than 2500 to 17,000 volume passed along constricted width pavement bridge approach per day. Hence, constricted width pavement bridge approaches found to be busy within 24hours.

Different traffic compositions of motorized and non-motorized vehicles were observed along with the lower and upper chainage of road of Jimma town. From animal cart to large articulated cars were observed across the bridge. Collected observational and interview data stated that the number of Bajaj volume induced increased from day to day, bringing high tension on the capacity of the road to volume ratio. During the past five consecutive years, about 137 number of traffic conflict cases were registered only at constricted width PBA. According to the research, about 24 percent of the traffic crash had been happened was sideswiping in type.

Despite the real-time scarcity data and a small number of existing constricted width pavement bridge approaches of road of Jimma town, dependent and independent variables were found to be highly correlated. There was a strong positive and negative correlation between constricted Width of PBA and travel speed, traffic density, and travel delay. As the Width of approach pavement decrease, it also decreases travel speed, increases travel density and increase traffic delay. PTV Vissim, SPSS, and R-code were implemented to develop the best fit model, which relates to the effect of constricted width pavement bridge approach on traffic flow. Developed multi-linear regression indicate that as traffic volume and travel speed increases, constricted width pavement bridge tends to be widened to accommodate current as well as future traffic flow conditions.

Finally, constructing a new wide bridge, providing traffic sign and smoothening bridge approach constriction were proposed as a possible remedial action to minimize the negative effect of constricted width pavement bridge approach on traffic flow.

5.2. Recommendation

Standing on research findings, the researcher believed that the constricted width pavement bridge approach defiantly affects traffic flow. The following recommendation shall be taken to address the effect of constricted width pavement bridge approach on traffic flow. Those were ranked below, depending on their essentiality to solve the problem.

1. The current capacity of the constricted width pavement bridge approach was insufficient to carry 1200-40000 vehicles per day. The researcher recommend that constructing new wide enough bridge width compatible with approach lane to overcome the current traffic flow along constructed width pavement bridge approach was important.

2. Different traffic compositions of motorized and non-motorized vehicle were observed along constricted width pavement at bridge approach. During the past five consecutive years, about 137 numbers of traffic conflict cases were registered only at constricted width PBA. According to the researcher about 24% traffic crash was sideswiping in type. The researcher recommend to eliminate this traffic crash, must be imposing restriction on some vehicle not to use CWPBA by providing other transportation service like large bus and train to reduce traffic volume on the section. For example, Bajaj was found to be the main transportation facilities within the town covering about 50% of traffic volume along CWPBA.

3. Width of bridge approach pavement decrease travel speed, increase density and increase traffic delay were occurred. In order to reduce this problem best fit model was developed by researcher for current and future traffic. For future traffic design in Jimma town, engineers could have used this research as reference.

4. Pedestrian of more than 2500 to17000 volume passed along CWPBA. Hence pedestrian width pavement walkway along CWPBA was not enough for freely movement of people. The researcher recommends that constructing new wide enough bridge for pedestrians walkway along bridge side was short term planned.

REFERENCES

[1] Admasu Shiferaw, (2012). Road Infrastructure and Enterprise Development In Ethiopia, (35-37).

[2] Agent, (May 1975). Accidents Associated With Highway Bridges. Department Of Transportation, Frankfurt.

[3] American Association of State Highway and Transportation Officials (Aashto). (1998). Usa.

[4] Banks, J. (2003). Two Capacity Phenomenons at Freeway Bottlenecks. Transportation Research Record 1320, Usa.

[5] Beckmann, A. Z. (2006). Study And Calibration Of Procedures Fur Current Estimation Of The Duration And Length Of Traffic Jams As A Result Of Single-Day And Long-Term Construction Sites On Motorways. Forschung Straßenbau And Straßenverkehrstechnik , 78-79.

[6] Canada, T. A. (2006). Performance Measures for Road Networks. Canada.

[7] Cirillo. (Jan. 1981). Accident Study at Bridge Width. New York: Journal Of Transportation Engineering.

[8] Conference, T. 2. (August 23-24, 2018). Safer Roads for Sustainable Economic Development. Jimma University, Jimma.

[9] Dewen Kong, X. G. (1997). Traffic Sream Proprerty. Volume 15-18.

[10] ERA. (1997-2007). Road Sector Development. Ethiopia: Ethiopian Road Authority.

[11] ERA, B. M. (June 2017). Short Study on Ethiopian Arch Bridge. Ethiopian Road Authority.

[12] Feldges, C. S. (2016). International Symposium on Enhancing Highway Performance. Christoph Schwietering And Michael Feldges2 , Pages 267–282.

[13] Galeta Chala, P. E. (November 2017). Effects Of Human Behaviors And Geometric Factors In Road Traffic Accidents: A Case Study Along Sululta – Fiche Road, Ethiopia. Galeta Chala , Prof. Emer Tucay Quezon , Tarekegn Kumela , Page 164-165.

[14] Gudisa, M. (2008). Addis Ababa Traffic Flow Problem . Muluken Gudisa , 1-2.

[15] Gunnerson, H. E. (July 1961). Narrow Bridge Accident Study. Iowa.

[16] Ibm Spss, V. 2. (2016). Spss Software. Usa, Usa.

[17] Ivey Et Al, N. H. (2002). Discussion on Influencing Factors Of Free-Flow Travel Time In Road Traffic Impedance Function. Bejing: Bejing Express.

[18] Kenneth And Xuehao Chu, S. (1997). "Hypercongestion". (Department Of Economics), Working Paper No.96-9711.

[19] Lytton, R. B. (Aug. 1983). An Improved Bridge Safety Index For Narrow Bridges. Texas Transportation Institute, Texas A&M University; College Station.

[20] Map, E. D. (2008). Google. Retrieved Nov 25, 2012, From Www.Ethiopian Map.Com/Jimma Location.

[21] Ministry Of Transport. (1995). Guideline For Safeguarding Work Zones On Roads. Kirschbaum Verlag .

[22] Montgomery D.C. And Runger, G. (June 2010). Statistical Analysis And Model Model.

[23] Nico Vandaele*, T. V. (Jan2000). A Queuing Based Traffic Flow Model1. In A Queuing Based Traffic Flow Model1 (Vol. Vol.5, Pp. 47-48).

[24] Nk, J. (1999). Road Safety Audit . In J. Nk, Road Safety Audit (Pp. Page 41-42). Iceland.

[25] P.G.Madisson. (2001). Newyork City Transportation Expansion. Newyork.

[26] R. B. V. Gandhi, R. L. (August 1983). An Improved Bridge Safety Index. Texas Transportation Institute Texas A&M University College Station, Texas , Texas.

APPENDIX A

<table>
<tr><th colspan="9">TRAFFIC COUNT TALLY SHEET</th></tr>
<tr><td colspan="4">Name of Bridge:</td><td colspan="5">Direction:from-----------------to-------------------</td></tr>
<tr><td colspan="4">Station name:</td><td colspan="5">Station number:</td></tr>
<tr><td colspan="4">Data collector:</td><td colspan="5">Supervisor:</td></tr>
<tr><td rowspan="3">HOURS COUNTED</td><td colspan="2">Nonmotorized</td><td colspan="6">Motorized</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td></tr>
<tr><td>Animal cart</td><td>Bycycle</td><td>Motorist</td><td>Bajaj</td><td>Small car</td><td>Medium car</td><td>Large car</td><td>Articulated vehicle</td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Date; --</td><td colspan="4">sheet:-------- of -------</td></tr>
</table>

APPENDIX B

<table>
<tr><th colspan="10">PEDISTRIAN COUNT TALLY</th></tr>
<tr><td colspan="3">Name of Road:</td><td colspan="4">Direction:from------------to-----------</td><td colspan="3">Weather</td></tr>
<tr><td colspan="3">Station name:</td><td colspan="4">Station number:</td><td colspan="3" rowspan="2"></td></tr>
<tr><td colspan="3">Data collector:</td><td colspan="4">Supervisor:</td></tr>
<tr><td rowspan="3">HOURS COUNTED</td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="2">Going</td><td rowspan="2">Total</td><td colspan="2">Going</td><td rowspan="2">Total</td><td colspan="2">Going</td><td rowspan="2">Total</td></tr>
<tr><td>West</td><td>East</td><td>North</td><td>South</td><td>West</td><td>East</td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>To</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Date; ---</td><td colspan="5">sheet:-------- of -------</td></tr>
<tr><td colspan="10">#note; The value of one tally would be equivalent to 100 number person.</td></tr>
</table>

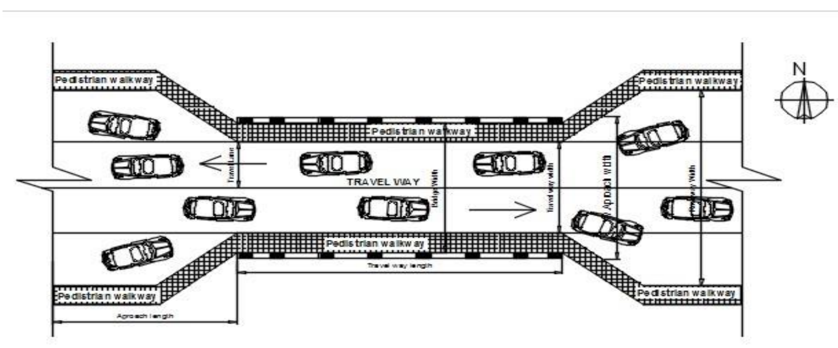
APPENDIX C

Jimma University

School of Post Graduate Studies

Jimma Institute of Technology, Faculty of Civil and Environmental Engineering, Department of Civil Engineering

Title: Effect of Constricted Width Pavement at Bridge Approach on Traffic Flow: A Case Study In Jimma Town



Questionnaire survey will be collected

By:

WAKJIRA DINSA NEMERA

RESEARCH QUESTIONNAIRE

Introduction

The purpose of this questionnaire and formats is to obtain information and data for the specified research will be conducted as a partial fulfillment of the requirements for a master's degree in Civil Engineering (highway Engineering) at Jimma University.

Research Topic

Effect of Constricted Width Pavement at Bridge Approach on Traffic Flow: A Case Study in Jimma Town

Definitions

For the purpose of this research, constriction refers to the narrowness of outer lane or shoulder width of approach Pavement Bridge. Whereas traffic flow refers to the characteristic of pedestrian, vehicle, driver and road along bridge approach.

Objective

The main objective of the study is to determine the traffic characteristics within the identified segment to toward the bridge approaches (upper and lower chainage) in the study areas as well as to ascertain traffic conflict as a result of constricted width pavement at bridge approaches.

Confidentiality

The data collected and the information to be answered in this questionnaire will be used for academic research purpose only. All specific companies and interviewee information will be kept confidential at all times. Only a generalized analysis of the information contained within this completed questionnaire will be utilized in the research process.

Instructions

Please answer, rate and thick (✓) the questionnaire by choosing the appropriate choices, the questionnaire and data collection contains four (4) parts:

Part I: It contains Company and Respondents' General information.

Part II: It contains a generalized interview questionnaire on Basic information about the traffic characteristics along bottleneck structure of bridge approach.

Part III: It contains traffic conflict behavior along bottle neck structure of bridge approach

Part IV: It contains possible remedial action towards the problem

Note: CPBA abbreviation stands for constricted pavement bridge approach

Lastly but not the least, your response in this regard, is highly valuable & contributory to the outcome of my research.

I sincerely thank you for your invaluable time and cooperation in advance.

Regards,

Wakjira Dinsa Nemera

Post Graduate Student, M.Sc. in highway engineering

Jimma University, Institute of Technology

Tel: +251 917443642

Email: wako2007dinsa@gmail.com

P.O. Box:

Jimma, Ethiopia

PART I: General information

General Profile of the Respondent

1.1 Name (optional) ____

1.2 Name of the organization (optional) ____________________________________

1.3 Position (optional) ____

1.4 Type and ownership of your organization: please, tick [✓] one box and specify if you select others.

☐ Engineer ☐ Pedestrian ☐ Driver

☐ Traffic police ☐ Roadside user ☐ others

1.5 Your work experience in your organization:

☐ 0 – 5 years ☐ 6 – 10 years

☐ 11 – 15 years ☐ more than 15 years

1.6 Which of the following bridge do you know in Jimma Town?

☐ **Awetu1 Bridge** (Around Awetu Grand Hotel)

☐ **Awetu2 Bridge (**Around Awetu Hospital**)**

☐ **Boyye Bridge** (Around SOS School)

☐ **Digate Bridge** (Around Kella)

☐ **Nagasa Bridge** (Around Jimma Stadium)

1.7 Have you observed any problem along the above mentioned bridge in number (1.6) question regarding traffic flow?

☐ Yes ☐ No

1.8 If yes, please answer the following questions.

1.9 What type of problems did you observed along **Awetu1 Bridge** (Around Awetu Grand Hotel)?

☐ Rear-End, ☐ Head-On

☐ Sides Wiping ☐ Other

1.10 What type of problems did you observed along **Awetu2 Bridge (**Around Awetu Hospital**)?**

☐ Rear-End, ☐ Head-On

☐ Sides Wiping ☐ Other

1.11 What type of problems did you observed along **Boyye Bridge** (Around SOS School)?

☐ Rear-End, ☐ Head-On

☐ Sides Wiping ☐ Other

1.12 What type of problems did you observed along **Digate Bridge** (Around Kella)?

☐ Rear-End, ☐ Head-On

☐ Sides Wiping ☐ Other

1.13 What type of problems did you observed along **Digate Bridge** (Around Kella)?

☐ Rear-End, ☐ Head-On

☐ Sides Wiping ☐ Other

1.14 What type of problems did you observed along **Nagasa Bridge** (Around Jimma Stadium)?

☐ Rear-End, ☐ Head-On

☐ Sides Wiping ☐ Other

PART II: Basic information on traffic characteristics along bottleneck structure of bridge approach

Basic information on traffic flow characteristics along a bottle neck of pavement bridge approach of Jimma Town						
Codes	1- Strongly disagree; 2- Disagree; 3- Neutral; 4- Agree; 5- Strongly agree					
S/N	Effect of constricted width pavement bridge approach on traffic flow behavior in Jimma Town (e.g: along Awetu bridge)	Level of Importance				
		1	2	3	4	5
1	Traffic delay is common where the approach pavement bridge is constricted					
2	Traffic congestion is common near up/down stream of bridge approach					
3	It has high effect on smoothness of traffic flow in general					
4	It has high effect on traffic speed					
5	It has high effect on traffic capacity					
6	The stopping site distance will be highly affected by approach constriction					
7	The passing site distance will be highly affected by approach constriction					
8	Pedestrian and driver comfort is highly affected by the constriction					
9	The effect of size of vehicle along the constricted bridge approach					
10	Traffic congestion is common during night (off-peak hrs.) than day (peak hrs.) time over constricted width bridge approach.					

PART III: It contains traffic conflict behavior along bottleneck structure of bridge approach

Basic information on traffic conflict behavior along bottleneck structure of bridge approach						
Codes	1- Strongly disagree; 2- Disagree; 3- Neutral; 4- Agree; 5- Strongly agree					
S/N	Traffic conflict due to constricted width pavement bridge approach, in Jimma Town (e.g: along Awetu bridge)	Level of Importance				
		1	2	3	4	5
1	Constriction was contributing factors for the problem traffic conflict around CPBA in Jimma Town.					
2	Three wheelers, motor cycles, bicycles, truck, bus, heavy vehicles, and pedestrians sharing the vehicle lane plays major in aggravating traffic conflict around bottleneck structure.					
3	The cause of conflict around CPBA will be the used of the middle lane of bridge approach by most of the drivers.					
4	The cause of conflict around CPBA will be the gradual narrowness of approach lane.					
5	The cause of conflict around CPBA will be due to geometric alignment of approach bridge.					
6	Rear-End, Head-On, and Sideswiping traffic crash is the commonly observed crash type over CPBA.					

PART IV: Possible remedial action to mitigate effect of constricted width pavement bridge approach

Possible remedial action to mitigate effect of constricted width pavement bridge approach						
Codes	1- Strongly disagree; 2- Disagree; 3- Neutral; 4- Agree; 5- Strongly agree					
S/N	Possible remedial action to mitigate effect of constricted width pavement bridge approach on traffic flow (e.g: along Awetu bridge)	Level of Importance				
		1	2	3	4	5
1	Totally changing the route along constricted width shall be applied					
2	Constructing a new low cost pedestrian walk way bridge along the side of existing bridge will be good remedial action.					
3	Providing guide/regulatory/ warning sign post along the side of existing bridge will be good remedial action.					
4	Providing lighting chips over asphalt surface to create smooth gradual change of approach width.					
5	Removing existing bridge and constructing a new bridge along the river will be excellent solution to provide smooth traffic flow.					
6	Generally, improvement shall be furnished quickly to accommodate future traffic flow demands.					

APPENDIX D

SPSS OUTPUTS

Descriptive Statistics

				Bootstrap[a]			
						95% Confidence Interval	
		Statistic	Std. Error	Bias	Std. Error	Lower	Upper
Average constricted width PBA in "m"	N	5		0	0	5	5
	Range	10.65					
	Minimum	8.25					
	Maximum	18.90					
	Sum	54.55					
	Mean	10.9100	2.01732	.0176	1.7987	8.5013	14.9700
	Std. Deviation	4.51088		-1.02340	2.05336	.30619	5.76488
	Variance	20.348		-3.973	11.941	.094	33.234
	Skewness	2.130	.913	-.969	1.026	-.661	2.232
ADT in "vehicle/day"	N	5		0	0	5	5
	Range	30192.40					
	Minimum	12227.40					
	Maximum	42419.80					
	Sum	117827.10					
	Mean	23565.4200	5597.47415	149.2503	4994.8001	14592.2555	33881.9800
	Std. Deviation	12516.33270		-1716.86725	3282.86223	4451.58288	16321.36540
	Variance	156658584.332		-29263723.085	66166617.237	19816590.108	266386968.588
	Skewness	.857	.913	-.342	.961	-1.334	2.235
Pedestrian volume in "people/day"	N	5		0	0	5	5
	Range	14905.00					
	Minimum	2610.00					
	Maximum	17515.00					
	Sum	42320.00					
	Mean	8464.0000	2706.19770	68.2160	2415.4041	4149.6351	13117.0000
	Std. Deviation	6051.24202		-839.15403	1591.46590	2745.46535	7954.55264
	Variance	36617530.000		-6921437.860	15681189.806	7537580.000	63275198.803
	Skewness	.746	.913	-.360	1.053	-2.178	2.228
Travel speed in "km/hr"	N	5		0	0	5	5
	Range	16.60					
	Minimum	15.84					
	Maximum	32.44					
	Sum	114.93					
	Mean	22.9860	2.98274	-.0914	2.6177	18.0140	27.9580
	Std. Deviation	6.66960		-.96641	1.68131	1.41312	8.48992
	Variance	44.484		-9.133	18.225	1.997	72.079
	Skewness	.483	.913	-.214	.952	-1.770	2.168
traffic density in "vehicle/km"	N	5		0	0	5	5
	Range	152.00					
	Minimum	53.00					
	Maximum	205.00					
	Sum	495.00					
	Mean	99.0000	28.53769	.8512	25.0716	58.2000	156.2000
	Std. Deviation	63.81222		-10.37543	22.22703	4.33706	81.53036
	Variance	4072.000		-722.962	2032.164	18.810	6647.200
	Skewness	1.595	.913	-.590	1.049	-1.918	2.235
Traffic volume in "vehicle/hr"	N	5		0	0	5	5
	Range	2944.00					
	Minimum	1834.00					
	Maximum	4778.00					
	Sum	14149.00					
	Mean	2829.8000	522.44181	13.1866	464.0173	2088.0000	3835.2000
	Std. Deviation	1168.21539		-187.43992	399.19733	198.30935	1507.43763
	Variance	1364727.200		-243607.535	687341.434	39326.983	2272368.200
	Skewness	1.581	.913	-.684	1.014	-2.168	2.234
travel delay along CWPBA in "seconds"	N	5		0	0	5	5
	Range	31.00					
	Minimum	7.00					
	Maximum	38.00					
	Sum	81.34					
	Mean	16.2680	5.78842	.1748	5.1010	8.2051	27.8680
	Std. Deviation	12.94330		-2.14826	4.59196	1.22474	16.61566
	Variance	167.529		-29.931	85.096	1.500	276.081
	Skewness	1.665	.913	-.592	.957	-.884	2.230
Valid N (listwise)	N	5		0	0	5	5

a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Correlations

			average consricted PBA in"m"	traffic density in "vehicle/km"	traffic volume in "vehicle/hr"	travel speed in "km/hr"	travel delay along CWPBA in "seconds"
average consricted PBA in"m"	Pearson Correlation		1	-.470	.211	.250	.519
	Sig. (2-tailed)			.424	.733	.685	.370
	N		5	5	5	5	5
	Bootstrap[d]	Bias	0[e]	-.108[e]	.294[e]	.341[e]	.159[e]
		Std. Error	0[e]	.350[e]	.508[e]	.473[e]	.393[e]
		95% Confidence Interval	1[e]	-1.000[e]	-1.000[e]	-.291[e]	-1.000[e]
			1[e]	.110[e]	1.000[e]	1.000[e]	1.000[e]
traffic density in "vehicle/km"	Pearson Correlation		-.470	1	-.642	-.763	-.683
	Sig. (2-tailed)		.424		.243	.133	.204
	N		5	5	5	5	5
	Bootstrap[d]	Bias	-.108[e]	0[e]	.039[e]	-.053[e]	.025[e]
		Std. Error	.350[e]	0[e]	.464[e]	.212[e]	.419[e]
		95% Confidence Interval	-1.000[e]	1[e]	-1.000[e]	-1.000[e]	-1.000[e]
			.110[e]	1[e]	.897[e]	-.605[e]	.579[e]
traffic volume in "vehicle/hr"	Pearson Correlation		.211	-.642	1	.984[**]	.919[*]
	Sig. (2-tailed)		.733	.243		.002	.027
	N		5	5	5	5	5
	Bootstrap[d]	Bias	.294[e]	.039[e]	0[e]	-.094[e]	.025[e]
		Std. Error	.508[e]	.464[e]	0[e]	.343[e]	.050[e]
		95% Confidence Interval	-1.000[e]	-1.000[e]	1[e]	-.362[e]	.845[e]
			1.000[e]	.897[e]	1[e]	1.000[e]	1.000[e]
travel speed in "km/hr"	Pearson Correlation		.250	-.763	.984[**]	1	.907[*]
	Sig. (2-tailed)		.685	.133	.002		.034
	N		5	5	5	5	5
	Bootstrap[d]	Bias	.341[e]	-.053[e]	-.094[e]	0[e]	-.024[e]
		Std. Error	.473[e]	.212[e]	.343[e]	0[e]	.261[e]
		95% Confidence Interval	-.291[e]	-1.000[e]	-.362[e]	1[e]	.168[e]
			1.000[e]	-.605[e]	1.000[e]	1[e]	1.000[e]
travel delay along CWPBA in "seconds"	Pearson Correlation		.519	-.683	.919[*]	.907[*]	1
	Sig. (2-tailed)		.370	.204	.027	.034	
	N		5	5	5	5	5
	Bootstrap[d]	Bias	.159[e]	.025[e]	.025[e]	-.024[e]	0[e]
		Std. Error	.393[e]	.419[e]	.050[e]	.261[e]	0[e]
		95% Confidence Interval	-1.000[e]	-1.000[e]	.845[e]	.168[e]	1[e]
			1.000[e]	.579[e]	1.000[e]	1.000[e]	1[e]

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

d. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

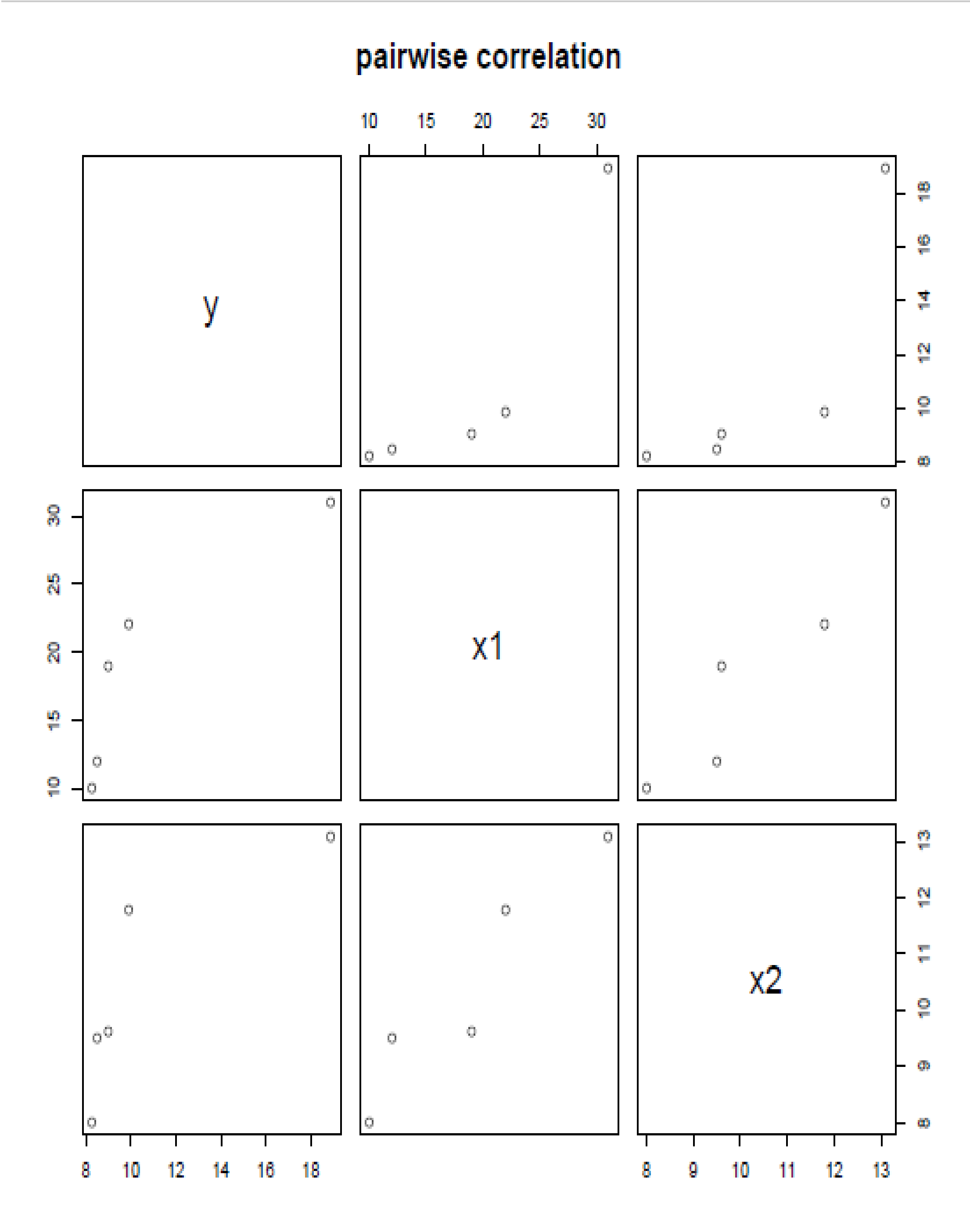
e. Based on 997 samples

APPENDIX E

R-CODE SOFTWARE

```
> y=c(18.9,9.9,9,8.5,8.25)
> sum(y)
[1] 54.55
> mean(y)
[1] 10.91
> sum((y-mean(y))^2)
[1] 81.392
> sd(y)
[1] 4.510876
> x1=c(31,22,19,12,10)
> sum(x1)
[1] 94
> mean(x1)
[1] 18.8
> sum((x1-mean(x1))^2)
[1] 282.8
> sd(x1)
[1] 8.408329
> x2=c(13.1,11.8,9.6,9.5,8)
> sum(x2)
[1] 52
> mean(x2)
[1] 10.4
> sum((x2-mean(x2))^2)
[1] 16.46
> sd(x2)
[1] 2.028546
> sum((y-mean(y))*(x1-mean(x1)))
[1] 133.66
> sum((y-mean(y))*(x2-mean(x2)))
[1] 30.24
> cor(x1,y)
[1] 0.9609898
> cor(x2,y)
[1] 0.9261825
> pairs(data.frame(y,x1,x2),main="pairwise  correlation")
> lm(formula=y~x1+x2)
Call:
lm(formula = y ~ x1 + x2)
Coefficients:
(Intercept)        x1        x2
     2.8796     0.05045     0.01399
```

APPENDIX F


pairwise correlation
y
x1
x2
10
15
20
25
30
8
10
12
14
16
18
8
9
10
11
12
13

APPENDIX G

NORMAL DISTRIBUTION VALUES

$$\Phi(z) = P(Z \leq z) = \int_{-\infty}^{z} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2} du$$

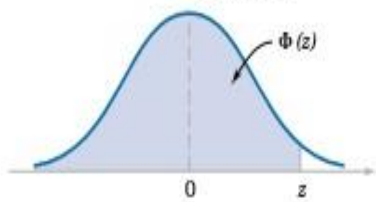
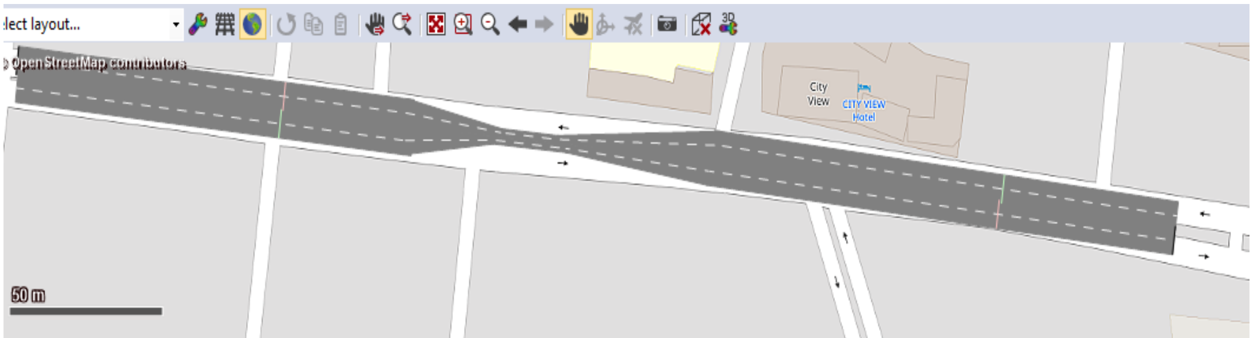


Table II Cumulative Standard Normal Distribution (*continued*)

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.500000	0.503989	0.507978	0.511967	0.515953	0.519939	0.532922	0.527903	0.531881	0.535856
0.1	0.539828	0.543795	0.547758	0.551717	0.555760	0.559618	0.563559	0.567495	0.571424	0.575345
0.2	0.579260	0.583166	0.587064	0.590954	0.594835	0.598706	0.602568	0.606420	0.610261	0.614092
0.3	0.617911	0.621719	0.625516	0.629300	0.633072	0.636831	0.640576	0.644309	0.648027	0.651732
0.4	0.655422	0.659097	0.662757	0.666402	0.670031	0.673645	0.677242	0.680822	0.684386	0.687933
0.5	0.691462	0.694974	0.698468	0.701944	0.705401	0.708840	0.712260	0.715661	0.719043	0.722405
0.6	0.725747	0.729069	0.732371	0.735653	0.738914	0.742154	0.745373	0.748571	0.751748	0.754903
0.7	0.758036	0.761148	0.764238	0.767305	0.770350	0.773373	0.776373	0.779350	0.782305	0.785236
0.8	0.788145	0.791030	0.793892	0.796731	0.799546	0.802338	0.805106	0.807850	0.810570	0.813267
0.9	0.815940	0.818589	0.821214	0.823815	0.826391	0.828944	0.831472	0.833977	0.836457	0.838913
1.0	0.841345	0.843752	0.846136	0.848495	0.850830	0.853141	0.855428	0.857690	0.859929	0.862143
1.1	0.864334	0.866500	0.868643	0.870762	0.872857	0.874928	0.876976	0.878999	0.881000	0.882977
1.2	0.884930	0.886860	0.888767	0.890651	0.892512	0.894350	0.896165	0.897958	0.899727	0.901475
1.3	0.903199	0.904902	0.906582	0.908241	0.909877	0.911492	0.913085	0.914657	0.916207	0.917736
1.4	0.919243	0.920730	0.922196	0.923641	0.925066	0.926471	0.927855	0.929219	0.930563	0.931888
1.5	0.933193	0.934478	0.935744	0.936992	0.938220	0.939429	0.940620	0.941792	0.942947	0.944083
1.6	0.945201	0.946301	0.947384	0.948449	0.949497	0.950529	0.951543	0.952540	0.953521	0.954486
1.7	0.955435	0.956367	0.957284	0.958185	0.959071	0.959941	0.960796	0.961636	0.962462	0.963273
1.8	0.964070	0.964852	0.965621	0.966375	0.967116	0.967843	0.968557	0.969258	0.969946	0.970621
1.9	0.971283	0.971933	0.972571	0.973197	0.973810	0.974412	0.975002	0.975581	0.976148	0.976705
2.0	0.977250	0.977784	0.978308	0.978822	0.979325	0.979818	0.980301	0.980774	0.981237	0.981691
2.1	0.982136	0.982571	0.982997	0.983414	0.983823	0.984222	0.984614	0.984997	0.985371	0.985738
2.2	0.986097	0.986447	0.986791	0.987126	0.987455	0.987776	0.988089	0.988396	0.988696	0.988989
2.3	0.989276	0.989556	0.989830	0.990097	0.990358	0.990613	0.990863	0.991106	0.991344	0.991576
2.4	0.991802	0.992024	0.992240	0.992451	0.992656	0.992857	0.993053	0.993244	0.993431	0.993613
2.5	0.993790	0.993963	0.994132	0.994297	0.994457	0.994614	0.994766	0.994915	0.995060	0.995201
2.6	0.995339	0.995473	0.995604	0.995731	0.995855	0.995975	0.996093	0.996207	0.996319	0.996427
2.7	0.996533	0.996636	0.996736	0.996833	0.996928	0.997020	0.997110	0.997197	0.997282	0.997365
2.8	0.997445	0.997523	0.997599	0.997673	0.997744	0.997814	0.997882	0.997948	0.998012	0.998074
2.9	0.998134	0.998193	0.998250	0.998305	0.998359	0.998411	0.998462	0.998511	0.998559	0.998605

APPENDIX H

PTV VISSIM OUT PUT

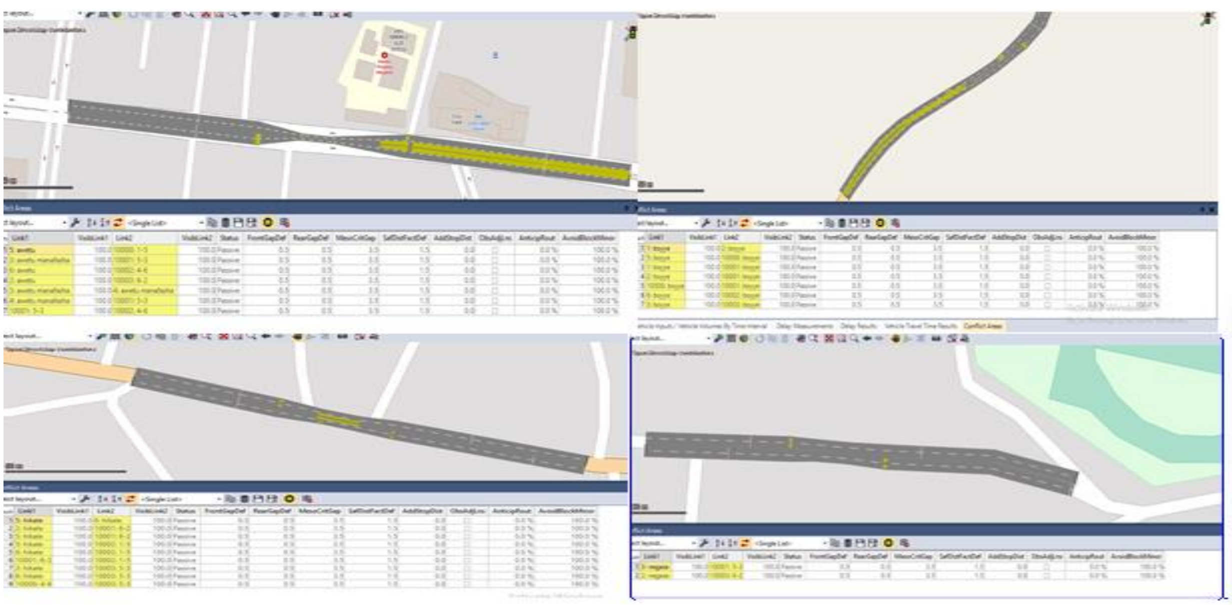


lay Results

lect layout...

oun	SimRun	TimeInt	DelayMeasurement	StopDelay(All)	Stops(All)	VehDelay(All)	Vehs(All)	PersDelay(All)	Pers(All)
1	8	0-3600	1	0.00	0.00	2.63	696	2.63	696
2	8	0-3600	2	0.00	0.00	2.05	739	2.05	739
3	9	0-3600	1	0.00	0.00	2.63	696	2.63	696
4	9	0-3600	2	0.00	0.00	2.05	739	2.05	739
5	12	0-3600	1	0.00	0.00	3.35	225	3.35	225
6	12	0-3600	2	0.00	0.00	2.21	234	2.21	234
7	Average	0-3600	1	0.00	0.00	2.87	539	2.87	539
8	Average	0-3600	2	0.00	0.00	2.10	571	2.10	571
9	Standard deviation	0-3600	1	0.00	0.00	0.41	272	0.41	272
10	Standard deviation	0-3600	2	0.00	0.00	0.09	292	0.09	292
11	Minimum	0-3600	1	0.00	0.00	2.63	225	2.63	225
12	Minimum	0-3600	2	0.00	0.00	2.05	234	2.05	234
13	Maximum	0-3600	1	0.00	0.00	3.35	696	3.35	696
14	Maximum	0-3600	2	0.00	0.00	2.21	739	2.21	739

Vehicle Inputs / Vehicle Volumes By Time Interval | Data Collection Points / Data Collection Measurements | Delay Results



APPENDIX I

T/L	Bara	Gosa Balaa Qaqqabee				Tilm. Qar
		Du'a	Balaa cimaa	Balaa salphaa	Miidhaa Qabeenyaa	
1	2008	22	14	12	17	1,309,000
2	2009	20	27	19	20	496,080
3	2010	18	16	9	40	486,785
4	2011	10	31	11	42	1,740,700
5	2012	17	8	5	32	1,222,940
6	2013	9	5	3	20	686,400
2008-2013	6	96	101	59	171	5,941,905

Available Traffic Volume Data					
Location; Jimma town					
Year; 2016-2021					
Vehicles				people	
non-motorized		motorized			
animal carts	cycles	Motor cycles	Bajaj	Minibus and bus	large vehicles
240	611	1812	2779	1694	283
#source; Federal population projection of Ethiopia for all region at wereda level from 2014-2017 and JIMMA TOWN transport office					

APPENDIX J

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Average constricted width PBA in "m' is normal with mean 10.40 and standard deviation 0.83.	One-Sample Kolmogorov-Smirnov Test	.850	Retain the null hypothesis.
2	The distribution of ADT in "Vehicle/day" is normal with mean 7,170.33 and standard deviation 3,071.79.	One-Sample Kolmogorov-Smirnov Test	.814	Retain the null hypothesis.
3	The distribution of Pedestrian volume in "People/day" is normal with mean 9,573.67 and standard deviation 5,461.94.	One-Sample Kolmogorov-Smirnov Test	.804	Retain the null hypothesis.
4	The distribution of Travel speed in "km/hr" is normal with mean 32.73 and standard deviation 5.92.	One-Sample Kolmogorov-Smirnov Test	1.000	Retain the null hypothesis.
5	The distribution of Traffic density in "Vehicle/km" is normal with mean 38.67 and standard deviation 14.29.	One-Sample Kolmogorov-Smirnov Test	.988	Retain the null hypothesis.
6	The distribution of Traffic volume in "vehicle/hr" is normal with mean 1,588.33 and standard deviation 691.47.	One-Sample Kolmogorov-Smirnov Test	.993	Retain the null hypothesis.
7	The distribution of Travel delay along CWPBA in "Seconds" is normal with mean 15.33 and standard deviation 5.03.	One-Sample Kolmogorov-Smirnov Test	.999	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Model Summary

Target	Average constricted width PBA in "m'
Automatic Data Preparation	On
Model Selection Method	Forward Stepwise
Information Criterion	.

The information criterion is used to compare to models. Models with smaller information criterion values fit better.

The information criterion and accuracy chart cannot be computed because the model has perfect fit.