Jimma University

Jimma Institute of Technology

School of Post Graduate Studies

Faculty of Civil and Environmental Engineering

Highway Engineering Stream

Investigation of Pavement Distresses Condition and Its Influence on Macro Traffic Parameters: A Case of Harar to Dhangago Road Segment.

A Final MSc Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirement for the Degree of Master of Science in Highway Engineering

By:

Jufare Getachew

November 2018

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Advisor: Prof. Emer T. Quezon, P.Eng.

Co-advisor: Engr. Tarekegn Kumela, MSc

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DECLARATION

I, the undersigned, declare that this thesis entitled: “Investigation of Pavement Distresses Condition and Its Influence on Macro Traffic Parameters: A Case of Harar to Dhangago Road Segment.” 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 used in this thesis have been duly acknowledged.

Candidate:

Jufare Getachew

Signature____________________________

As Master’s Research Advisors, we hereby certify that we have read and evaluated this MSc Thesis prepared under our guidance by Jufare Getachew entitled: “Investigation of Pavement Distress Condition and Its Influence on Macro Traffic Parameters: A Case of Harar to Dhangago Road Segment.”

We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

Prof. Emer T. Quezon, P.Eng	_____________	22/11/2018
Advisor	Signature	Date
Engr. Tarekegn Kumela, MSc	_____________	_________
Co- Advisor	Signature	Date

ACKNOWLEDGMENT

First and for most, I would like to thank and praise my Almighty God for his guidance and success achieved in my life.

Next I would like to express my deepest gratitude to my advisor, Professor Emer T. Quezon, P.Eng for his close supervision, and constructive suggestion during my research work. He has been devoting his time and providing all necessary relevant information to carry out the research.

I would like to express my sincere gratitude to my co-advisor Engr. Tarekegn Kumela (M.Sc.) for his valuable comments on the development of this research

I would like to thank Harari regional transportation agency, Oromia regional transportation agency and Ethiopian Road Authority by helping me in doing the field measurement and traffic data recording.

My heartfelt gratitude also goes to Jimma University Institute of technology, school of graduate studies for the arrangements and the creation of opportunity to develop this research.

Also I would like to take this opportunity to thank the Ethiopian Road Authority (ERA) and Ministry of education for sponsoring me to study this M.Sc. Degree.

I would like to extend my deepest thanks to my instructors who shared me their knowledge and skills on subject matter and capacitate me to do this research.

Finally, I would like to thank all my friends and my Family for their helpful encouragement.

ABSTRACT

Pavements are designed for desired speed limits and traffic capacity over time without considering the effects of more distinct pavement distresses parameters. However, various forms of pavement characteristics, causes an impact on the traffic stream, particularly free-flow speed, roadway capacity and density. The target of this research was to identify the distresses condition and its influence on macro traffic parameters such as speed, capacity and density of the road segment along Harar to Dhangago segment. In order to achieve the objective of this research, the necessary data were collected at the study site. The data collection process included field visual inspection, field measurements and traffic data video recording. Typical data required for the assessment of pavement impact on traffic flow were processed and analyzed based on direct-empirical method. The observed traffic volumes and speeds were used to derive densities- flow equation. In addition, the least square regression method was used for estimation of the model coefficients. The results of the research showed that the PCI value ranges from 10 to 84, which indicated a section of the road had all most all types of pavement condition Rating. From the pavement condition survey analysis, it was identified that; good, fair, poor, and serious covers equal 20% in each case, While, the remaining percent is covered by Very poor and failed section. Based on the pavement condition rating, traffic data for four study sections, a section rated 'good', free flow speed estimated of about 73.37km/hr, and the optimum speed is 37km/hr. However, once the pavement distress impact is factored in, optimum speed dropped to 29.6km/hr in 'poor' section. As pavement condition rated 'very poor', the analysis indicated that the impact of distress on optimum speed reduced by 34.23% when compared to the section rated 'Good', dropped to 24.33km/hr. On the other hand, the Optimum speed of 'serious' section reduced by 52% when compared to the section rated 'Good'. It is therefore concluded that there is a strong influence of pavement distresses condition on the traffic flow parameters. Hence, for varying PCI and PCR values, the road sections rated 'Good', it is recommended to provide crack sealing and minor patching. Likewise, for sections rated 'Fair', seal coating or thin nonstructural overlay of 50mm or more, is one of the best options to restore as-is service condition of the pavement. While sections rated 'Poor' and failed sections, should have to be corrected by in-depth patching and repair with major overlay and reconstruction with an extensive base repair, respectively.

Keywords: *Pavement distress, Macro traffic parameters, Space mean speed, Density, PCI Value, Optimum speed*

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ACRONYMS

AC	Asphalt Concrete
ASTM	American Society for Testing and Material
CDV	Corrective Deduct Value
DV	Deduct Value
ERA	Ethiopian Road Authority
HCM	Highway Capacity Manual
HGVs	Heavy Goods Vehicle
JU	Jimma University
JiT	Jimma institute of Technology
Km/hr.	Kilometer per hour
LOS	Level of Service
PCE	Passenger car equivalence
PCI	Pavement Condition Index
PCR	Pavement Condition Rating
PMMS	Pavement Maintenance and Management System
Qmax	Maximum flow
R-Sq.	Residual Square
SMS	Space Mean Speed
TDV	Total Deduct Value

CHAPTER ONE

INRODUCTION

1.1. Background of the study

Rural road connectivity is a key component of rural development in one country since it promotes access to economic and social services and thereby increases agricultural income and productive employment opportunities. As a result, it is also a key ingredient in ensuring sustainable poverty reduction [1].

A highway is a major and widely used mode of transportation. It is classified as flexible and rigid pavement. Flexible pavements are asphalt concrete that used to support traffic load. It is constructed of several layers of natural granular material covered with one or more waterproof bituminous surface layers, and as the name implies, is considered to be flexible. Flexible Pavement design is the process of developing the most economical combination of pavement layers (in relation to both thickness and type of materials) to suit the soil foundation and the cumulative traffic to be carried during the design life. It is designed and constructed to satisfy acceptable riding quality and good performance under applied load within the design period [2].

The primary functions of a pavement are to provide a reasonably smooth riding surface which implies a smooth riding surface (Low Roughness) is essential for riding comfort, and over the years it has become the measure of how road users perceive a road. Roughness can arise from a number of causes, most often however it is from pavement distress due to structural deformation. Also provide adequate surface friction (skid resistance). In addition to a riding comfort, the other road user requirement is that of safety. Safety, especially during wet conditions can be linked to a loss of surface friction between the tire and the pavement surface. A pavement must therefore provide sufficient surface friction and texture to ensure road user safety under all conditions. Pavement can protect the subgrade. The supporting soil beneath the pavement is commonly referred to as the subgrade, if it be over-stressed by the applied axle loads it will deform and lose its ability to properly support these axle loads. Therefore, the pavement must have sufficient structural capacity (strength and thickness) to adequately reduce the actual stresses so that they do not exceed the strength of the subgrade. The strength and thickness requirements of a pavement can vary greatly depending on the combination of subgrade type and loading condition (magnitude and number of axle loads). It also Provide waterproofing for entire layers of pavement. The pavement surfacing acts as a water proofing surface that prevent the under laying support layers including the subgrade from becoming saturated through moisture ingress. When saturated, soil loses its ability to adequately support the applied axle loads, which will lead to premature failure of the pavement [2].

The asphalt road is exposed to many distresses due to of the high stress on the pavement. So it causes cracks and a lot of defects. These defects cause a lot of problems for road users such as discomfort and the road will not be safe. All kinds of pavement needs proper maintenance as a result of affected overload, temperature change rate, Impact of climate (rains) and other factor [3].

Different factors that are taken into account in the design and construction of asphalt concrete pavements includes: the characteristics of the traffic, climatic conditions, material as well as structural properties and other elements which have significant impact on the overall performance of the road segment. Generally, to give satisfactory service, a flexible pavement must therefore resist the distress caused by the various deterioration mechanisms that are at work [4].

According to ERA2013 manual, the principal structural requirements are as follows (1) the subgrade should be able to sustain traffic loading without excessive deformation; this is controlled by the vertical compressive stress or strain at this level. (2) Bituminous materials and cement-bound materials used in the road base design should not crack under the influence of traffic; this is controlled by the horizontal tensile stress or strain at the bottom of the boundary layer. (3) The road base is often the main structural layer of the pavement, required to distribute the applied traffic loading so that the underlying materials are not overstressed. It must be able to sustain the stress and strain generated within itself without excessive or rapid deterioration of any kind. (4) In pavements containing bituminous materials, the internal deformation of these materials must be limited. (5) The load spreading ability of granular sub-base and capping layers must be adequate to provide a satisfactory construction platform. The manual also identifies that, when some of the above criteria are not satisfied, distress or failure will occur. For instance, rutting may be the result of excessive internal deformation within bituminous materials, or excessive deformation at the subgrade level (or within granular layers above) [4].

Pavement distresses are classified into two different categories. The first is known as functional failure. In this case, the pavement does not carry out its intended function without either causing discomfort to passengers or high stresses to vehicles. The second, known as structure failure, includes a collapse of pavement structure or the breakdown of one or more components of the pavement with such magnitude that the pavement becomes incapable of sustaining the loads imposed upon its surface [5].

1.2. Statement of the Problem

The road surface should be free from physical defects such as rutting, potholes and cracking in order to provide a smooth traffic condition. Pavements are designed for desired speed limits and traffic capacity over time without considering the effects of more distinct pavement distresses parameters. But various forms of pavement characteristics and distress condition cause an impact on the traffic stream, particularly on free-flow speed and roadway capacity [6].

This study was conducted to identify and investigate the distresses condition and its influence on macro traffic parameters such as speed, capacity and density of the road segment from Harar – Dhangago. Currently, this road segment faced several distresses such as potholes; different cracks, corrugation of road surface, raveling, shoulder thickness loss and other similar problems. The extent and types of cracks and other deterioration are increasing from time to time on this section.

The distressed condition of this road is now becoming the main causes of speed reduction, decrement of capacity, density change, road users' discomfort, delays, reduction of safety and high maintenance cost of vehicles. The extent and effect of pavement distresses on this road segment was identified in this study. For future planning and modification of service condition this segment, this research investigated type, severity and impact of pavement of distresses on speed, density and capacity of the selected road segment.

Operating speed, density of the stream and capacity level are the fundamental parameters that affected by the deterioration of highway. The analysis done on flow rate contraction due to pavement distresses reveals that, there is a significant change in vehicle speed between the 'with' and 'without' pavement distress sections. The operating speed of the site is dropped from 55 Km/hr. to 24 Km/hr. due to the existence of potholes and road hump on the study spot. Estimated roadway capacity attributed to the existence of the pothole is falling from 1555pcu/hr. to 1204pcu/hr, and Density of the distressed section was increased by following speed and capacity reduction [7]. From those foregoing issues and problems, it can be seen that there is a strong relationship between pavement distresses and free flow speed based on the macro point of view. Also, it is foreseen a pavement characteristics have a major influence on the free-flow speed of vehicles.

At some points, the previous studies summarized above explored the relationship between pavement conditions and traffic parameters; however, the effect of poor pavement conditions on individual macro traffic flow parameters' has not been addressed, particularly using a model such as the linear regression. As a prerequisite for the development of a safety-incorporated pavement management system, an investigation on how the pavement condition affects traffic flow was carried out in this study. It emphasized the evaluation of the relationship between poor pavement conditions and traffic flow using a linear regression model. It is expected that the findings of this study can assist transportation agencies at the federal state, and local levels to select appropriate the pavement maintenance and rehabilitation strategies to reduce influence of pavement distress on traffic flow condition.

1.3. Research Questions

1. What are the distress types, severity level, pavement condition indexes (PCI) and pavement condition rating (PCR) for the different distress types?
2. What are the macro traffic flow parameters for Poor, Very Poor, Seriously affected and Good road section?
3. What are the impacts of the severely distressed pavement rated as poor, very poor and seriously affected section of road on macro traffic flow parameters.

4. What are the possible remedial measures to correct the pavement defects in order to provide smooth traffic movement?

1.4. Objectives of the Study

1.4.1. General Objective

The general objective of the study was to investigate the pavement distress condition and its influence on macro traffic parameters, specifically along Harar- Dhangago road segment.

1.4.2. Specific Objectives

1. To determine and discuss the distress type, severity level, pavement condition index (PCI) and pavement condition rating (PCR) for the different distress types.

2. To determine macro traffic flow parameters for Poor, Very Poor, Seriously affected and Good road section.

3. To asses and discuss the influence of the pavement distressed rated as poor, very poor and seriously affected section of road on macro traffic flow parameters.
4. To suggest remedial measures to correct the pavement defects in order to get smooth traffic movement.

1.5. Scope of the Study

This research was focused on Harar to Dhangago road segment, and it was targeted to evaluate the existing road condition and impact of pavement of distresses on speed, density and capacity. It also aims to identify the distresses stage through field inspection and traffic data collection concerning the above parameters. After the basic distresses stage, it was identified, and came up with a possible analysis to be done in order to know the effect of distresses on traffic parameters. To meet this objective, the road segment conditions and traffic data were analyzed by using Microsoft excel and Minitab16 software.

1.6. Operational Definition

Pavement structure: - is a layer structure which supports the vehicle load on its surface and transfers and spreads the load to the subgrade without exceeding either the strength of the subgrade or the internal strength of the pavement itself [4].

Pavement distress: - external indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or a combination therefore. Typical distresses are cracks, rutting, and weathering of the pavement surface [8].

Pavement condition rating: - a verbal description of pavement condition as a function of the PCI value that varies from ―failed to ―excellent [8].

Pavement condition index: - a numerical rating of the pavement condition that ranges from 0 to 100 with 0 is being the worst possible condition and 100 being the best possible condition [8].

Speed: - Speed is the second macroscopic parameter describing the state of a traffic stream. Speed is defined as a rate of motion in distance per unit time. Travel time is the time taken to traverse a defined section of roadway [9].

Density: Density, the third primary measure of traffic stream characteristics, is defined as the number of vehicles occupying a given length of highway or lane, generally expressed as vehicles per mile or vehicles per mile per lane [9].

Capacity: - The maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway [10].

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1. General

Identification and evaluation of the distresses extent of severity play great role in pavement management to modify the service condition of the highway. Because the current status of the road influence service performance of the road by influencing the day to day traffic movement. As the research conducted on an uneven and texture of road implies, it is important to be able to determine or measure the geometric condition of road surface in order to accurately develop the design and construction activities as well as to plan and realize the most appropriate pavement management programs, when the infrastructure are subjected to wearing due to traffic and environmental action [11].

2.2. Asphalt Concrete Deterioration

Highway pavements, once constructed, will not last forever. After a time, signs of wear will appear. These signs include cracking, cutting and polishing of the road's surface are some of it. A point will arrive where the wear and tear is at such an advanced stage that the integrity of the pavement and hence the standard of service provided by it has diminished. The most serious distresses associated with flexible pavement are cracking, which occurs at intermediate and low temperatures, and permanent deformation, which occurs at high temperatures [12].

The functional deterioration is indicated by the changes in the surface condition of the pavement in the form of deterioration in the riding quality, which can be measured by simple methods; it is also possible to restore the surface to the original condition of the pavement by providing a profile correction course and a resurfacing layer [13]. The pavement deterioration process starts very slowly so that it may not be noticeable, and over time it accelerates at faster rates. There should be implementation of the proper maintenance and repair work in suitable time; which will maintain the pavement in a safe and acceptable operational condition and helps to save cost of maintenance [14]. In the design of asphalt pavements, it is necessary to determine the minimum pavement thickness required to withstand the expected traffic such that fatigue and rutting strains are within the allowable minimum [15]. Because traffic flow increase with growth rate of one country.

2.3. Types of asphalt concrete deterioration

Various types of distresses are observed on the road surface. Potholes, cracks, edge failure, raveling, rutting are some of harmful distress which reduces the whole pavement performance and increases travel time [16]. Disintegrations and deformations are repeatedly seen a distress feature on the road. Surface deformation occurs usually due to failure or weakness in one of the layers of the pavement due to traffic movement after construction [17]. It was confirmed that parameters such as layer thickness and load repetitions have a significant impact on the amount of permanent deformation of flexible pavements and it is likely to follow a powerful trend over time, achieving an asymptotic behavior (lower rate of deformation) and lower deformations in pavements with higher structural capacity [18].

'Some Observations Interpretation clearly puts, single longitudinal crack indicates the onset of structural failure in the wheel path pavement greater than 200mm thick. This does not heal and deterioration will be progressive. Multiple wheel path cracking Narrow cracks imply condition is not near failure. Wider and crazing cracks imply advanced failure of a thicker structure. Longitudinal cracking outside in all likelihood the location of a construction joint the wheel path. Short transverse cracks unlikely to be structurally significant. It has probably started at the surface and will progress slowly long transverse cracks indicate a discontinuity in a lower layer, possibly a construction joint in a bituminous material' [12]. According ASTM D6433 here is type of distress and severity level measurement for field investigation [25]

1. Alligator cracking (Fatigue)

A. Description

Alligator or fatigue cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface under repeated traffic loading. Cracking begins at the bottom of the asphalt surface, or stabilized base, where tensile stress and strain are highest under a wheel load. The cracks propagate to the surface initially as a series of parallel longitudinal cracks. After repeated traffic loading, the cracks connect, forming many sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are generally less than 0.5 m (1.5 ft) on the longest side. Alligator cracking occurs only in areas subjected to repeated traffic loading, such as wheel paths. Pattern-type cracking that occurs over an entire area not subjected to loading is called ―block cracking, ‖ which is not a load- associated distress [25].

B. Severity Levels:

Low level of severity (L):-Fine, longitudinal hairline cracks running parallel to each other with no, or only a few interconnecting cracks. The cracks are not spalled.

- **Moderate level of severity (M):-**Further development of light alligator cracks into a pattern or network of cracks that may be lightly spalled.

- **Higher level of severity (H):-** Network or pattern cracking has progressed so that the pieces are well defined and spalled at the edges. Some of the pieces may rock under traffic.

C. How to Measure

Alligator cracking is measured in square meters (square feet) of surface area. The major difficulty in measuring this type of distress is that two or three levels of severity often exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately; however, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity present. If alligator cracking and rutting occur in the same area, each is recorded separately as its respective severity level [25].

2. Bleeding

A. Description

Bleeding is a film of bituminous material on the pavement surface that creates a shiny, glasslike, reflecting surface that usually becomes quite sticky. Bleeding is caused by excessive amounts of asphaltic cement or tars in the mix, excess application of a bituminous sealant, or low air void content, or a combination thereof. It occurs when asphalt fills the voids of the mix during hot weather and then expands onto the pavement surface. Since the bleeding process in not reversible during cold weather, asphalt or tar will accumulate on the surface [25].

B. Severity Levels:

- **Low level of severity (L):-**Bleeding only has occurred to a very slight degree and is noticeable only during a few days of the year. Asphalt does not stick to shoes or vehicles
- **Moderate level of severity (M):-**Bleeding has occurred to the extent that asphalt sticks to shoes and vehicles during only a few weeks of the year.
- **Higher level of severity (H):-** Bleeding has occurred extensively and considerable asphalt sticks to shoes and vehicles during at least several weeks of the year.

C. How to Measure

Bleeding is measured in square meters (square feet) of surface area. If bleeding is counted, polished aggregate should not be counted.

3. Block cracking

A. Description

Block cracks are interconnected cracks that divide the pavement into approximately rectangular pieces. The blocks may range in size from approximately 0.3 by 0.3 m (1 by 1 ft) to 3 by 3 m (10 by 10 ft). Block cracking is caused mainly by shrinkage of the asphalt concrete and daily temperature cycling, which results in daily stress/strain cycling. It is not load-associated. Block cracking usually indicates that the asphalt has hardened significantly. Block cracking normally occurs over a large portion of the pavement area, but sometimes will occur only in non-traffic areas. This type of distress differs from alligator cracking in that alligator cracks form smaller, many-sided pieces with sharp angles. Also, unlike block, alligator cracks are caused by repeated traffic loadings, and therefore, are found only in traffic areas, that is, wheel paths [25].

B. Severity Levels:

- **Low level of severity (L):-**Blocks are defined by low-severity cracks
- **Moderate level of severity (M):-**Blocks are defined by medium-severity cracks
- **Higher level of severity (H):-** Blocks are defined by high-severity cracks

C. How to Measure

Block cracking is measured in m^2 given pavement section; however, if areas of different severity levels can be distinguished easily from one another, they should be measured and recorded separately.

4. Bumps and sags

A. Description:

Bumps are small, localized, upward displacements of the pavement surface. They are different from shoves in that shoves are caused by unstable pavement. Bumps, on the other hand, can be caused by several factors, including:

- Buckling or bulging of underlying PCC slabs in AC overlay over PCC pavement.
- Frost heaves (ice, lens growth).
- Infiltration and build-up of material in a crack in combination with traffic loading (sometimes called ―tenting‖). Sags are small, abrupt, downward displacements of the pavement surface. If bumps appear in a pattern perpendicular to traffic flow and are spaced at less than 3 m (10 ft), the distress is called corrugation [25].

B. Severity Levels:

- **Low level of severity (L):-**Bump or sag causes low-severity ride quality.
- **Moderate level of severity (M):-**Bump or sag causes medium-severity ride quality.
- **Higher level of severity (H):-** Bump or sag causes high-severity ride quality.

C. **How to Measure**

Bumps or sags are measured in linear meters (feet). If the bump occurs in combination with a crack, the crack also is recorded.

5. Corrugation

A. Description

Corrugation, also known as ―wash-boarding‖, is a series of closely spaced ridges and valleys (ripples) occurring at fairly regular intervals, usually less than 3 m (10ft) along the pavement. The ridges are perpendicular to the traffic direction. This type of distress usually is caused by traffic action combined with an unstable pavement surface or base [25].

B. Severity Levels:

- **Low level of severity (L):-**Corrugation produces low-severity ride quality.

- **Moderate level of severity (M):-**Corrugation produces medium-severity ride quality.
- **Higher level of severity (H):-** Corrugation produces high-severity ride quality.

C. How to Measure

Corrugation is measured in square meters (square feet) of surface area.

6. Depression

A. Description

Depressions are localized pavement surface areas with elevations slightly lower than those of the surrounding pavement. In many instances, light depressions are not noticeable until after a rain, when ponding water creates a ―birdbath‖ area; on dry pavement, depressions can be spotted by looking for stains caused by ponding water. Depressions are created by settlement of the foundation soil or are a result of improper construction. Depressions cause some roughness, and when deep enough or filled with water, can cause hydroplaning [25].

B. Severity Levels (Maximum Depth of Depression):

- **Low level of severity (L):-**13 to 25 mm (1⁄2 to 1 in.)
- **Moderate level of severity (M):-**25 to 50 mm (1 to 2 in.)
- **Higher level of severity (H):-** More than 50 mm (2 in.)

C. How to Measure

Depressions are measured in square meters (square feet) of surface area.

7. Edge cracking

A. Description

Edge cracks are parallel to and usually within 0.3 to 0.5 m (1 to 1.5 ft) of the outer edge of the pavement. This distress is accelerated by traffic loading and can be caused by frost-weakened base or subgrade near the edge of the pavement. The area between the crack and pavement edge is classified as raveled if it is broken up (sometimes to the extent that pieces are removed).

B. Severity Levels:

- **Low level of severity (L):-**Low or medium cracking with no breakup or raveling.
- **Moderate level of severity (M):-**Medium cracks with some breakup and raveling.
- **Higher level of severity (H):-** Considerable breakup or raveling along the edge.

C. How to Measure

Edge cracking is measure in linear meters (feet).

8. Reflection cracking

A. Description

This distress occurs only on asphalt-surfaced pavements that have been laid over a PCC slab. It does not include reflection cracks from any other type of base, that is, cement- or lime-stabilized; these cracks are caused mainly by thermal- or moisture-induced movement of the PCC slab beneath the AC surface. This distress is not load-related; however, traffic loading may cause a breakdown of the AC surface near the crack. If the pavement is fragmented along a crack, the crack is said to be spalled. Knowledge of slab dimension beneath the AC surface will help to identify these distresses [25].

B. Severity Levels [25]**:**

- **Low level of severity (L):-**One of the following conditions exists. Non filled crack width is less than 10 mm (3⁄8 in.), or filled crack of any width (filler in satisfactory condition).

- **Moderate level of severity (M):-**One of the following conditions exists: None filled crack width is greater than or equal to 10 mm (3⁄8 in.) and less than 75 mm (3 in.); none filled crack less than or equal to 75 mm (3 in.) surrounded by light secondary cracking; or, filled crack of any width surrounded by light secondary cracking.

- **Higher level of severity (H):-** One of the following conditions exists.

Any crack filled or no filled surrounded by medium or high-severity secondary cracking; no filled cracks greater than 75 mm (3 in.); or, a crack of any width where approximately 100 mm (4 in.) of pavement around the crack are severely raveled or broken.

C. How to Measure

Joint reflection cracking is measured in linear meters (feet). The length and severity level of each crack should be identified and recorded separately. For example, a crack that is 15 m (50 ft) long may have 3 m (10ft) of high severity cracks, which are all recorded separately. If a bump occurs at the reflection crack, it is recorded also [25] .

9. Lane shoulder drop

A. Description

Lane/shoulder drop-off is a difference in elevation between the pavement edge and the shoulder. This distress is caused by shoulder erosion, shoulder settlement, or by building up the roadway without adjusting the shoulder level [25].

B. Severity Levels:

- **Low level of severity (L):-**The difference in elevation between the pavement edge and shoulder is > 25 mm (1 in.) and< 50 mm (2 in.).
- **Moderate level of severity (M):-**The difference in elevation is > 50 mm (2in) and < 100 mm (4 in).
- **Higher level of severity (H):-** The difference in elevation is > 100 mm (4in).

How to Measure

Lane/shoulder drop-off is measured in linear meters (feet).

10. Longitudinal & Transverse

A. Description

Longitudinal cracks are parallel to the pavement‘s centerline or laydown direction. They may be caused by [25] :

- A poorly constructed paving lane joint.
- Shrinkage of the AC surface due to low temperatures or hardening of the asphalt, or daily temperature cycling, or both.
- Transverse cracks extend across the pavement at approximately right angles to the pavement center line or direction of laydown. These types of cracks are not usually load-associated.

B. Severity Levels:

- **Low level of severity (L):-**One of the following conditions exists: non-filled crack width is less than 10 mm (3⁄8 in.), or filled crack of any width (filler in satisfactory condition).
- **Moderate level of severity (M):-**One of the following conditions exists: non-filled crack width is greater than or equal to 10 mm and less than 75 mm (3⁄8 to 3 in.); non-filled crack is less than or equal to 75 mm (3 in.) surrounded by light and random cracking; or, filled crack is of any width surrounded by light random cracking.

Higher level of severity (H):- One of the following conditions exists: any crack filled or non-filled surrounded by medium- or high-severity random cracking; non-filled crack greater than 75m (3 in.); or, a crack of any width where approximately 100mm (4 in.) of pavement around the crack is severely broken.

C. How to Measure

Longitudinal and transverse cracks are measured in linear meters (feet). The length and severity of each crack should be recorded. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately [25].

11. Patching &Utility patch

A. Description

A patch is an area of pavement that has been replaced with new material to repair the existing pavement. A patch is considered a defect no matter how well it is performing (a patched area or adjacent area usually does not perform as well as an original pavement section). Generally, some roughness is associated with this distress [25].

B. Severity Levels:

- **Low level of severity (L):-**Patch is in good condition and satisfactory. Ride quality is rated as low severity or better.
- **Moderate level of severity (M):-**Patch is moderately deteriorated, or ride quality is rated as medium severity, or both.
- **Higher level of severity (H):-** Patch is badly deteriorated, or ride quality is rated as high severity, or both; needs replacement soon.

C. How to Measure

Patching is rated in ft2 of surface area; however, if a single patch has areas of differing severity, these areas should be measured and recorded separately. For example, a 2.5 m2 (27.0 ft2) patch may have 1 m2 (11 ft2) of medium severity and 1.5 m2 (16 ft2) of low severity. These areas would be recorded separately. Any distress found in a patched area will not be recorded; however, its effect on the patch will be considered when determining the patch‘s severity level. No other distresses, for example, are recorded within a patch. Even if the patch material is shoving or cracking, the area is rated only as a patch. If a large amount of pavement has been replaced, it should not be recorded as a patch but considered as new pavement, for example, replacement of a complete intersection recorded separately [25].

12. Polished Aggregate

A. Description

This distress is caused by repeated traffic applications. Polished aggregate is present when close examination of a pavement reveals that the portion of aggregate extending above the asphalt is either very small, or there are no rough or angular aggregate particles to provide good skid resistance. When the aggregate in the surface becomes smooth to the touch, adhesion with vehicle tires is considerably reduced. When the portion of aggregate extending above the surface is small, the pavement texture does not significantly contribute to reducing vehicle speed. Polished aggregate should be counted when close examination reveals that the aggregate extending above the asphalt is negligible, and the surface aggregate is smooth to the touch. This type of distress is indicated when the number on a skid resistance test is low or has dropped significantly from a previous rating [25].

B. Severity Levels

No degrees of severity are defined; however, the degree of polishing should be clearly evident in the sample unit in that the aggregate surface should be smooth to the touch

C. How to Measure

Polished aggregate is measured in square meters (square feet) of surface area. If bleeding is counted, polished aggregate should not be counted.

13. Potholes

A. Description

Potholes are small usually less than 750 mm (30 in.) in diameter bowl-shaped depressions in the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. When holes are created by high-severity alligator cracking, they should be identified as potholes, not as weathering [25].

B. Severity Levels:

- The levels of severity for potholes less than 750mm (30 in.) in diameter are based on both the diameter and the depth of the pothole, according to Table 2.2

- If the pothole is more than 750 mm (30 in.) in diameter, the area should be determined in square feet and divided by 0.5 m2 (5.5 ft2) find the equivalent number of holes. If the depth is 25 mm (1 in.) or less, the holes are considered medium-severity. If the depth is more than 25 mm (1 in.), they are considered high-severity [25].

Table2. 1: Levels of severity for potholes [25].

Maximum depth of pothole	Average diameter (mm)(in.)		
100 to 200mm (4 to 8in.)	200 to 450mm (8 to 18in.)	450 to 750mm (18 to 30in.)	
13 to ≤25mm (1/2 to 1in.)	L	L	M
>25 and ≤50mm (1 to 2in.)	L	M	H
>50mm (2in.)	M	M	H

How to Measure

Potholes are measured by counting the number that are low-, medium-, and high-severity and recording them separately.

14. Rutting

A. Description

A rut is a surface depression in the wheel paths. Pavement uplift may occur along the sides of the rut, but, in many instances, ruts are noticeable only after a rainfall when the paths are filled with water [25].

B. Severity Levels (Mean Rut Depth):

- **Low level of severity (L):-**6 to 13 mm (1⁄4 to 1⁄2 in.)
- **Moderate level of severity (M):-**13 to 25 mm (>1⁄2 to 1 in.)
- **Higher level of severity (H):-** >25 mm (>1 in.)

C. How to Measure

Rutting is measured in square meters (square feet) of surface area, and its severity is determined by the mean depth of the rut. The mean rut depth is calculated by laying a straight edge across the rut, measuring its depth, then using measurements taken along the length of the rut to compute its mean depth in millimeters [25].

15. Railroad crossing

A. Description

Railroad crossing defects are depressions or bumps around, or between tracks, or both [25].

B. Severity Levels:

- **Low level of severity (L):-**Railroad crossing causes low-severity ride quality.
- **Moderate level of severity (M):-** Railroad crossing causes medium-severity ride quality.
- **Higher level of severity (H):-** Railroad crossing causes high-severity ride quality.

C. How to Measure

The area of the crossing is measured in square meters (square feet) of surface area. If the crossing does not affect ride quality, it should not be counted. Any large bump created by the tracks should be counted as part of the crossing [25].

16. Shoving

A. Description:

Shoving is a permanent, longitudinal displacement of a localized area of the pavement surface caused by traffic loading. When traffic pushes against the pavement, it produces a short, abrupt wave in the pavement surface. This distress normally occurs only in unstable liquid asphalt mix (cutback or emulsion) pavements. Shoves also occur where asphalt pavements abut PCC pavements. The PCC pavements increase in length and push the asphalt pavement, causing the shoving [25].

Severity Levels:

- **Low level of severity (L):-**Shove causes low-severity ride quality.
- **Moderate level of severity (M):-** Shove causes medium-severity ride quality.
- **Higher level of severity (H):-** Shove causes high-severity ride quality.

C. How to Measure

Shoves are measured in square meters (feet) of surface area. Shoves occurring in patches are considered in rating the patch, not as a separate distress [25].

17. Slippage

A. Description

Slippage cracks are crescent or half-moon shaped cracks, usually transverse to the direction of travel. They are produced when braking or turning wheels cause the pavement surface to slide or deform. This distress usually occurs in overlaps when there is a poor bond between the surface and the next layer of the pavement structure [25].

B. Severity Level:

- **Low level of severity (L):-**Average crack width is < 10 mm (3⁄8 in.).
- **Moderate level of severity (M):-** One of the following conditions exists: average crack width is $ 10 and < 40 mm ($ 3⁄8 and<1-1⁄2 in.); or the area around the crack is moderately spalled, or surrounded with secondary cracks.

Higher level of severity (H):- One of the following conditions exists: the average crack width is > 40 mm (1-1⁄2 in.) or the area around the crack is broken into easily removed pieces.

C. How to Measure

The area associated with a given slippage crack is measured in square meters (square feet) and rated according to the highest level of severity in the area [25].

19. Raveling &Weathering

A. Description

Weathering and raveling are the wearing away of the pavement surface due to a loss of asphalt or tar binder and dislodged aggregate particles. These distresses indicate that either the asphalt binder has hardened appreciably or that a poor-quality mixture is present. In addition, raveling may be caused by certain types of traffic, for example, tracked vehicles. Softening of the surface and dislodging of the aggregates due to oil spillage also are included under raveling [25].

B. Severity Levels:

- **Low level of severity (L):-**Aggregate or binder has started to wear away. In some areas, the surface is starting to pit. In the case of oil spillage, the oil stain can be seen, but the surface is hard and cannot be penetrated with a coin.
- **Moderate level of severity (M):-** Aggregate or binder has worn away. The surface texture is moderately rough and pitted. In the case of oil spillage, the surface is soft and can be penetrated with a coin.
- **Higher level of severity (H):-** Aggregate or binder has been worn away considerably. The surface texture is very rough and severely pitted. The pitted areas are less than 10 mm (4 in.) in diameter and less than 13 mm (1⁄2 in.) deep; pitted areas

larger than this are counted as potholes. In the case of oil spillage, the asphalt binder has lost its binding effect and the aggregate has become loose.

C. How to Measure

Weathering and raveling are measured in square meters (square feet) of surface area [25].

2.4. Pavement Condition Survey

An inventory of highway condition data is updated on a routinely regular basis in order to determine the condition of the pavement and whether its level of deterioration is such that remedial action is necessary [12]. In the road management process, an evaluation of road pavement conditions is one of the most important aspects required to guarantee adequate functional standards and a suitable maintenance program. It is, therefore, fundamental to define a data collection method which makes it possible to acquire a suitable knowledge of the network within limited times and manage [20].

2.4.1. Automated Distress Surveys

An automated distress detection and recognition system must be able to determine all types of surface distress at any level of severity, with a wide range of collection speeds and under different weather conditions. Several attempts have been made to develop an automatic pavement inspection procedure. However, those existing automated distress detection systems commonly require special devices such as lights, lasers, etc., which would dramatically increase the cost and limit the system to certain applications [20].

2.4.2. A Manual Distress Survey

The surveys provide factual information for deciding on the most appropriate structural treatments, and identify sections of highway suitable for remedial treatment. Planning for long-term treatment can thus be undertaken, with performance of the pavements being monitored and priorities for treatment being established on the basis the database compiled [12].

To be economical, manual distress survey techniques was used to collect the necessary data Surveys are conducted visually by foot, which provides the best vantage point for observing the actual condition of the pavement surface. By standing or walking the pavement surface, the pavement rater has the opportunity to closely observe pavement distresses such as cracks, weathering, raveling, and rutting, allowing for a better assessment of the amount of distress in a specific survey location. That occur over large areas of the pavement surface, causing large or long dips, or both, in the pavement should be recorded as ―swelling [19].

2.5. Pavement Performance Evaluation

Distress surveys are carried out to assess the degree of physical pavement deterioration, which is a function of; Type of distress, Severity of distress and Extent of distress (amount or density of distress). Each of the above three characteristics of pavement distress has a significant influence on the determination of the overall pavement deterioration. Because there are many types of distresses and a variety of ways to define severity level and extent measurement, it is important to use or adapt standard procedures for distress identification and measurements of extent at each severity level. For the practical and meaningful performance evaluation of a network, most distress data are combined into an overall condition index [22].

2.6. Pavement condition index (PCI)

Initially PCI was developed by the United States Army Corps of Engineers and is based on a visual survey of the pavement. It is a statistical measure and requires manual survey of the pavement. PCI surveying processes and calculation methods have been standardized by ASTM for both roads and airport pavements. The PCI provides a measure of the present condition of the pavement based on the distress observed on the surface of the pavement, which also indicates the structural integrity and surface operational condition (localized roughness and safety) [23].

The Pavement Condition Index (PCI) was used to identify the overall pavement condition for each section. It is a deduct-value model defined on a scale of 0–100, where at 100 the pavement is assumed to be in perfect condition and 0 represents a completely failed pavement section. The quality of pavement is expressed in terms of Pavement Condition Index (PCI) that has a scale of 0 to100, where index 0 refers that a failed condition and index 100 is the excellent condition [22].

The PCI was calculated by assuming that the pavement was in perfect condition (PCI of 100) and subtracting Deduct Values (DV) for each observed distress, depending on the type, severity and extent of the distress. DV provide relative weights indicating the relative importance of the distresses/severity levels in terms of the pavement performance. The magnitude of the value deducted from the PCI depends on distress type and severity [24]. Pavement Condition Rating (PCR) is a verbal description of pavement condition as a function of the Pavement Condition Index (PCI) value that varies from failed — good. The PCI is a subjective method in terms of quantifying the structural and functional condition of the pavement, as it neither measures the bearing capacity, nor quantities the level of surface characteristics but provides feedback on pavement performance for validation or improvement of current pavement design and maintenance procedures [24].

Table 2. 2: Interpretation of pavement condition index [24]

PCI	(PCR)
100	Excellent
85	Very good
70	Good
55	Fair
40	Poor
25	Very poor
10 and 0	Failed

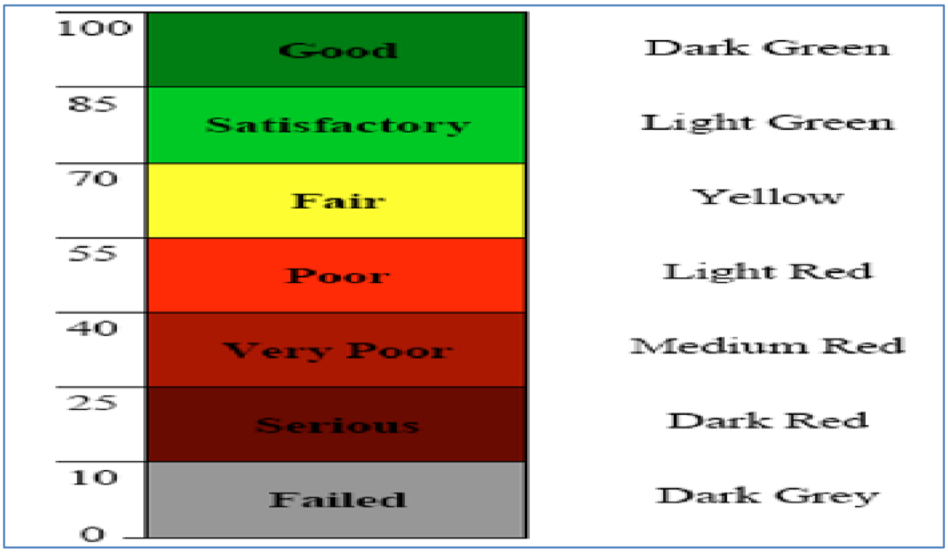


Figure 2. 1 Rating scale and suggested color [25]

The PCI cannot measure structural capacity nor does it provide direct measurement of skid resistance or roughness. Pavement condition is related to several factors, including structural integrity, structural capacity, roughness, skid resistance/hydroplaning potential, and rate of deterioration. Direct measurement of all of these factors requires expensive equipment and highly trained personnel. However, these factors can be assessed by observing and measuring distress in the pavement [26].

2.7. Pavement Maintenance

Maintenance is an essential practice in providing for the long-term performance and the esthetic appearance of an asphalt pavement. The purpose of pavement maintenance is to correct deficiencies caused by distresses and to protect the pavement from further damage. Various degrees or levels of maintenance can be applied to all pavements, regardless of the end use. A condition rating of the pavement will help determine what pavement maintenance technique is necessary [8].

Pavement rehabilitation is defined as a resurfacing or restoration of existing pavement to extend its service life. It can be done by milling and/or overlay of the existing pavement. Pavement rehabilitation can be done after assessing the initial condition of the pavement [27].

Recycling is the process of removing pavement materials for reuse in resurfacing or reconstructing a pavement (or constructing some other pavement). For asphalt pavements, this process may range from in-place recycling of the surface layer, to recycling material from all pavement layers through a hot mix plant. For concrete pavements, recycling involves removal and crushing for reuse as aggregate, either in the reconstruction of the pavement or for surface, base, or sub base layers in other pavement construction. Recycling of asphalt-overlaid concrete pavement may be either surface recycling or removal and recycling of both asphalt and concrete. In this case, the asphalt and concrete layers are removed and recycled separately [28].

Reconstruction is the removal and replacement of all asphalt and concrete layers, and often the base and sub base layers, in combination with remediation of the subgrade and drainage, and possible geometric changes. Due to its high cost, reconstruction is rarely done solely on the basis of pavement condition [28].

Today‘s increasing budget constraints require that state and local agencies perform more work with less money. Historically, the emphasis of local highway departments has been on building new roads, but the new focus is on maintaining and preserving existing pavement surfaces. This shift has resulted in three types of pavement maintenance operations [29]

Maintenance is required at this point to prolong the highway's useful life. Loss of skidding resistance and loss of texture are forms of deterioration eventually suffered by all highway pavements. In order to carry out the maintenance in as cost-effective a manner as possible, a logical coherent procedure must be adopted in order to select the most effective form that the maintenance should take, together with the optimum time at which this work should be undertaken [30].

There is several maintenance techniques, from this Preventive Maintenance is one it. It is performed to improve or extend the functional life of a pavement. It is a strategy of surface treatments and operations intended to retard progressive failures and reduce the need for routine maintenance and service activities [29]. Corrective Maintenance is also one of maintenance technique which is performed after a deficiency occurs in the pavement, such as loss of friction, moderate to severe rutting, or extensive cracking. It may also be referred to as ―reactive‖ maintenance. At the end Emergency Maintenance is performed during an emergency situation, such as a blowout or severe pothole that needs repair immediately. This also describes temporary treatments designed to hold the surface together until more permanent repairs can be performed [29].

The PCI values obtained from visual inspection i.e. distress survey by recording the severity and extent of the various distress namely cracking, rutting and potholes occurred to pavement can be utilized well in prioritizing the maintenance strategies [31]. This method provides cost effective maintenance and rehabilitation measures for planners and decision makers for maintenance of pavement in road network. The PCI provides an objective rational basis for determining the maintenance and rehabilitation needs of highway pavements and for prioritization of the pavement sections for maintenance on priority [32].

This methodology considers the common type of distresses in highway pavements and suggests the maintenance treatment considering the overall health of the pavement section [33]. PCI is meant to provide an objective, rational basis for determining maintenance and rehabilitation needs and priorities and a warning system for early identification or projection of major repair requirements or both.

The PCI can be used as a tool for assessing the condition of the pavement for periodic maintenance work which could be taken up accordingly in order to slow down the deterioration rate of rural roads [34]. The cost effective maintenance and management strategies can be developed by assessing the severity and extent of measured pavement distress values, further which can be used as input to Pavement Maintenance & Management System (PMMS). In developing the maintenance and management strategies PCI plays a major role including type of pavement and other road related information [35].

Table 2.3: Maintenance option depending on PCI value [33]

PCI Range	Rating	Maintenance Measures
86-100	Excellent	No maintenance required
71-85	Very Good	Little or no maintenance
56-70	Good	Routine maintenance, crack sealing and minor patching
41-55	Fairs	Preservative treatments (seal coating or thin nonstructural overlay 2” or more)
26-40	Poor	Needs patching and repair prior to major overlay Milling and removal of deterioration extends the life of overlay.
11-25	Very Poor	Needs reconstruction with extensive base repair
0-10	Failed	Total reconstructions

To avoid the pavement of reaching the state of failure and consequently major rehabilitations, management programs were developed having their basis from regular inspections to the pavements. Those inspections may be by the use of machinery or visual, which is the cheapest and more common method. The visual inspections are done walking over the pavement and its end is to establish the rate of pavement deterioration [33].

2.8. Macro Traffic flow parameters

Poor road surfaces are not only recipes for congestion and road accidents; they are characterized by slower speeds, longer travel times, increased queuing and severe discomfort [8]. Various forms of pavement characteristics cause an impact on the traffic stream particularly Free-Flow Speed and roadway capacity. Flow, speed, and density are macroscopic parameters characterizing the traffic stream as a whole.

Headway, gap, and occupancy are microscopic measures for describing the space between individual vehicles [30].

2.8.1. Capacity

Capacity which is central to traffic analysis can be taken as the maximum traffic flow rate traversing a point or uniform section of road carriageway lane per hour under prevailing conditions. When a highway is oversubscribed, flow rate reduces and capacity loss is recorded. In any case, capacity of any roadway follows a probability distribution depending on headways and speeds between vehicles Traffic, roadway and ambient conditions are known factors that affect highway capacity [8].

2.8.2. Speed

Spot speed studies are conducted to estimate the distribution of speeds of vehicles in a stream of traffic at a particular location on a highway. The speed of a vehicle is defined as the rate of movement of the vehicle; it is usually expressed in miles per hour (mi/h) or kilometers per hour (km/h). A spot speed study is carried out by recording the speeds of a sample of vehicles at a specified location [10].

2.8.2.1. Locations for Spot Speed Studies

The following locations generally are used for the different applications listed: [10]

1. Locations that represent different traffic conditions on a highway or highways are used for basic data collection.
2. Mid-blocks of urban highways and straight, level sections of rural highways are sites for speed trend analyses.
3. Any location may be used for the solution of a specific traffic engineering problem.

2.8.2.2. Time of Day and Duration of Spot Speed Studies

In general, when the purpose of the study is to establish posted speed limits, to observe speed trends, or to collect basic data, it is recommended that the study be conducted when traffic is free-flowing, usually during off-peak hours. The duration of the study should be such that the minimum number of vehicle speeds required for statistical analysis is recorded. Typically, the duration is at least 1 hour and the sample size is at least 30 vehicles [10].

It was observed that pavement characteristics have a major influence on the free-flow speed of vehicles [6]. The desired speed is highly influenced by the road environment.

For example traffic travelling in mountainous and hilly terrain is usually less eager to travel fast than when they travel over flat or rolling roads. The road alignments, width, separation between slow and motorized traffic are also parameters that influence the desired speed [8].

The pavement condition and traffic speed are considered as operative and important factors that affect the efficiency of highway systems. The Traffic speed is an important parameter because it determines safety, time, comfort, convenience, and economics, and is an important indication for predicting pavement condition and surface roughness of roadways [24]. The increase in surface roughness causes considerable irregularities on the pavement surface. This uneven surface along road length enables drivers to clearly feel vibrations in the car body, and so they become worried and uncomfortable during driving. The current study is only related to the free-flow speed, because the interactions among vehicles under non-free-flow conditions can significantly affect speed and make it an inconsistent value for a given set of road conditions. In a non-free-flow condition, a driver’s desire to speed up on a good condition pavement will be impeded by traffic flow and will therefore not be reflected in the actual driving behavior [37].

2.8.3. Density

Density is the most important of the three traffic-stream parameters, since it is the measure most directly related to traffic demand and congestion levels. In fact, traffic is generated from various land uses, bringing trips on a highway segment. Generated trips produce traffic density, which in turn produces flow rate and speeds. Density also gives an indication of the quality of flow on the facilities. It is the measure of proximity of vehicles and is also the basis for LOS on uninterrupted facilities [10].

2.9. Relationship of traffic flow parameters

The functional relationship between the macroscopic parameters, flow, and density is called fundamental diagram, which plays an important role in traffic flow theory and traffic engineering [38]. The flow, density curves are peculiar to highway traffic. It has 4 basic boundary conditions: i, flow equals zero when density is zero; ii, flow equals zero when density is at jam, iii, speed equals zero at jam density, iv, speed equals free flow when density is zero [8]. Fundamental Diagram of Traffic Flow that shows the relationships of parameters are as follows [39].

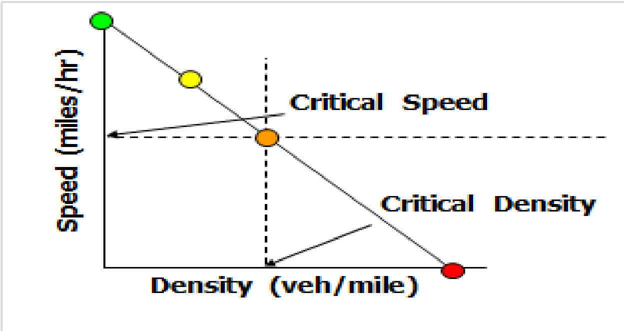
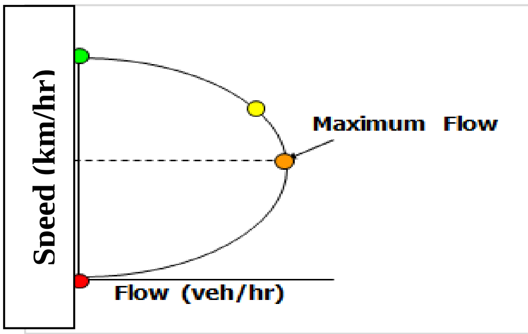


Figure 2. 1: Speed (V) vs. traffic density (D)



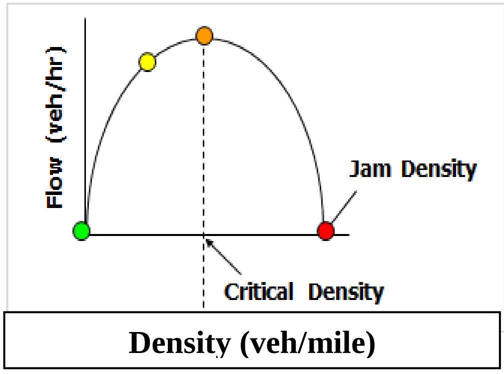


Figure 2. 2: Flow (Q) vs. Speed (V)

Figure 2.3: Flow (Q) Vs. Density (D)

From the above diagram the scholars interpret its relation hereunder:

i. Speed-Density

The speed-density relationship as shown in (figure 2.1) is linear with a negative slope which explains as the density of traffic increases the speed on the roadway decreases. The line crosses the speed axis, y, at the free flow speed, and the line crosses the density axis, x, at the jam density. Here the speed approaches free flow speed as the density approaches zero and speed approaches zero when the density equals the jam density.

ii. Flow-Density

The flow-density diagram as shown in (figure 2.2) is used to determine the traffic state on a roadway. The triangular shaped curve consists of two vectors. The first vector is the free flow side of the curve by placing the free flow velocity vector of a roadway at the origin with rising slope up to apex of curve. The second vector is the congested branch, which is created by placing the vector of the shock wave speed at zero flow and jam density. The congested branch has a negative slope, which implies that the higher the density on the congested branch the lower the flow. The intersection of free flow and congested vectors is the apex of the curve and is considered the capacity (Qmax) of the roadway, which is the traffic condition at which the maximum number of vehicles can pass by a point in a given time period. The flow and capacity at which this point occurs is the optimum flow and optimum density, respectively.

iii. Speed-Flow

Speed flow diagram as shown in (figure 2.3) are used to determine the speed at which the optimum flow occurs. The two branches of the speed-flow curve consisting of the free flow (horizontal line) and congested branches (parabolic shape). The diagram is not a function, allowing the flow variable to exist at two different speeds. The flow variable existing at two different speeds occurs when the speed is higher and the density is lower or when the speed is lower and the density is higher, which allows for the same flow rate. The parabola suggests that the only time there is free flow speed is when the density approaches zero; it also suggests that as the flow increases the speed decreases.

In the fundamental relationship between speed (u), flow (q) and density (k); Green shields Model

Green shields carried out one of the earliest recorded works in which he studied the relationship between speed and density. He hypothesized that a linear relationship existed between speed and density which he expressed as; [35].

$$q = uk, \text{ and } k = \frac{q}{u} \qquad (1)$$

$$u_s = u_s - \frac{u_f}{k_j}k \qquad (2)$$

Since $q = u_s k$, substituting $\frac{q}{u}$ for 'k' in the equation 2

$$u_s^2 = u_s u_f - \frac{u_f}{k_j}q \qquad (3)$$

Again substituting $\frac{q}{k}$ for u_s in the equation 2

$$q = u_f k - \frac{u_f}{k_j}k^2 \qquad (4)$$

Above equation shows that the relationships between flow - density and speed - flow are parabolic.

2.9.1. Calibration of Macroscopic Traffic Flow Models

The most common method of approach is regression analysis. This is done by minimizing the squares of the differences between the observed and expected values of a dependent variable [33].

2.10. Passenger Car Unit (PCU)

Traffic flow conditions in developing country are mixed or heterogeneous. Operating condition on a highway becomes complex when all these vehicles of different sizes move on the same road space without any physical segregation and occupy any lateral position on the roadway depending upon availability of the road space. Analysis of mixed traffic is often simplified by converting the different types of vehicles into equivalent number of passenger cars [36]. From observation at surveyed sites, trucks are less affected by pavement distress than passenger car and it may be argued that the passenger car equivalent values of trucks or Heavy Goods Vehicle (HGVs) are somewhat lower than those of passenger cars on roadways with significant pavement distress [14]. Therefore to minimize this difference converting the mixed traffic flow to passenger car equivalence is the best way, in the analysis of effect of pavement distresses.

Vehicles of different types require different amount of road space because of the various sizes and performance characteristics. For traffic analysis purposes and especially for capacity measurements, all traffic volumes are expressed in terms of passenger car units. The basic unit is the car which is considered as equal to 1 pcu. Equivalent factors for other types of traffic are as follow [41].

Table2.4: Conversion Factor of Vehicle into Equivalent Passenger Car [40]

Vehicle Type	Terrain		
	Flat	Rolling	Hilly/ Mountainous
	Factor		
Passenger cars	1.0	1.0	1.5
Light goods vehicle	1.0	1.5	3.0
Medium goods vehicle*	2.5	5.0	10.0
Heavy goods vehicle	3.5	8.0	20.0
Buses	2.0	4.0	6.0
Motot cycles, Scooters	0.5	1.0	1.5
Pedal cycles	0.5	0.5	NA

2.11. Linear Regression

The stepwise regression analysis is used to select the most statistically significant independent variables with dependent variable in one model, while keeping only the statistically significant terms in the model. The selected model will have the smallest number of independent variables, the minimum infinity norm of error vector (‖δ‖), the root mean square error (RMSE), and the highest R2 value [38].

Following known equation:

$$y = \beta_0 + \sum_{i=1}^{n} \beta_i x_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (5)$$

Where,

y - $Space\ Mean\ Speed$ at each section,

x_i- Explanatory variables (density) from 1 to n,

β_0 - Regression constant,

β_i- Regression coefficient

2.12. Correlation of macro traffic flow parameters and pavement distresses

Correlation coefficient is measures of the direction and strength of the linear relationship between the between a response variable Y and a predictor variable X. Notation for the Data Used in Simple Regression and Correlation is as follow [42].

Table 2.5: Notation for the Data Used in Correlation [42].

Observation number	Response 'Y'	Predictors 'X'
1	y_1	x_1
2	y_2	x_2
.	.	.
.	.	.
N	y_n	x_n

$$cor(y,x) = \frac{\sum(y_i-\bar{y})(x_i-\bar{x})}{\sqrt{\sum(y_i-\bar{y})^2\sum(x_i-\bar{x})^2}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\,.\dots\dots\dots\dots. (5)$$

The closer Cor(Y, X) is to 1 or -1, the stronger is the relationship between Y and *X*. The sign of Cor(Y, *X)* indicates the direction of the relationship between Y and X. That is, Cor(Y, X) > 0 implies that Y and X are positively related. Conversely, Cor(Y, X) < 0, implies that Y and X are negatively related [41]

CHAPTER THREE
RESEARCH METHODOLOGY

3.1. Study area

The study was conducted on the road segment from Harar to Dhangago which is located in the eastern part of Ethiopia. It traverses a business town of Harar, Awaday and Haramaya. This road is used for transporting goods and people, with a large percentage of passenger cars moving on it. It covers a distance of around 28 km road length. It is a two-lane road, with one lane in each direction, and it is an asphalt pavement road, constructed 8 years ago. In this study, an attempt was made to evaluate the effect of surface condition on macro traffic flow parameters and suggest suitable Maintenance and Rehabilitations works for a major road corridor connecting Harar city to Dhangago village.

3.1.1 Location and topography of the study area

Harar city is located in eastern part of Ethiopia and the capital city of Harari Regional state. It is located at coordinate of 8°24'03"N and 39°27''10"E at an elevation of 1417meters, 525 km east of Addis Ababa.

Table 3.1: Location of Harar and Dengego (source Google earth map)

Location	Harar	Dengego
Coordinate	8°24'03"N - 8°04'11"N, 39°27''10"E - 39°37''05"E	9°25'53"N - 9°06'04"N 42°33'11"E - 42°22'11"E
Country	Ethiopia	Ethiopia
Regional	Harari	Oromia
Zone	Hakim woreda	East Hararghe
Elevation	1417meters	1795metres

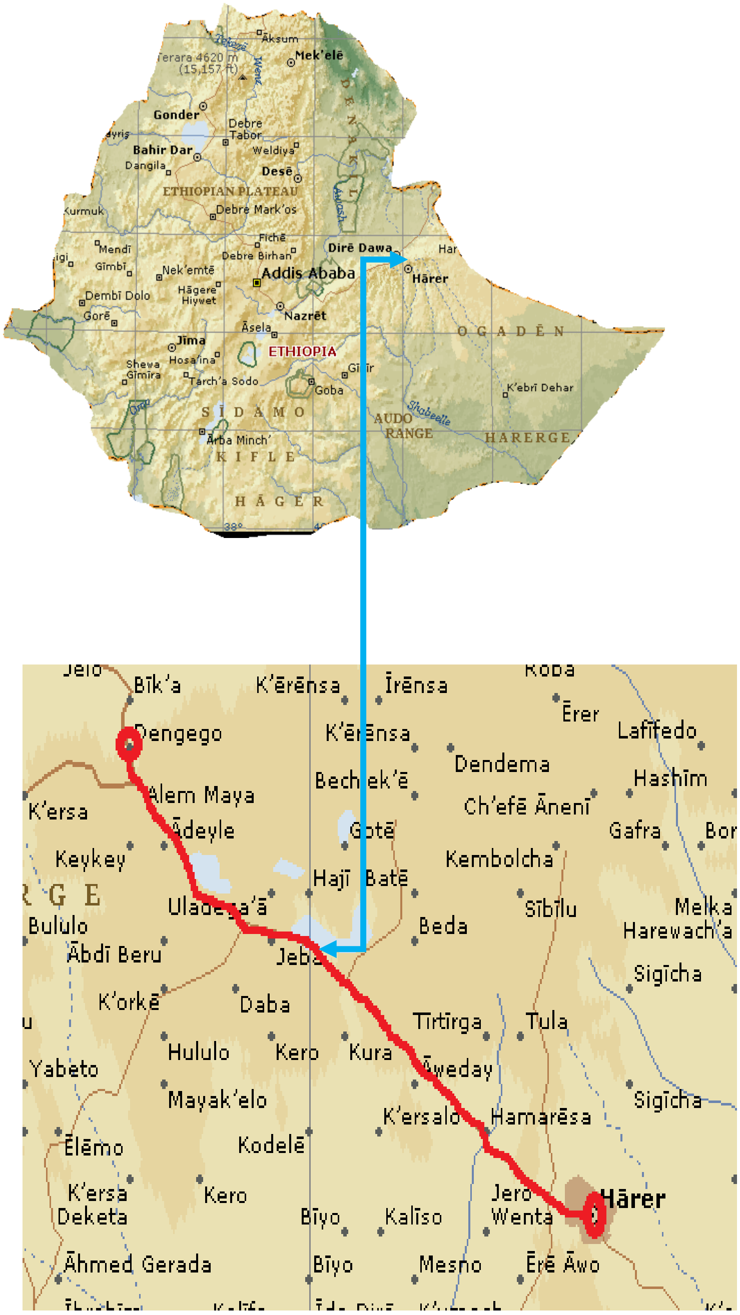


Figure 3. 1: Location of the study area (Source: Microsoft Encarta premium 2009)

3.2. Study period

The study was conducted from May to September, 2018. Within the specific period of time, the required research planning preparation of data collection sampling, evaluation, writing up and finally dissemination will be executed.

3.3. Study design

The study was conducted by using cross sectional comparative study design. It was designed in the way that important and exact information could be obtained to evaluate asphalt concrete damage on the road from Harar to Dhangago road segment. Qualitative and quantitative data were gathered from the study area. Qualitative study is the result based on the field assessment where a quantitative study is used to describe the numerical values of the research findings, based on field investigation. The study was undertaken according to the following flow chart.

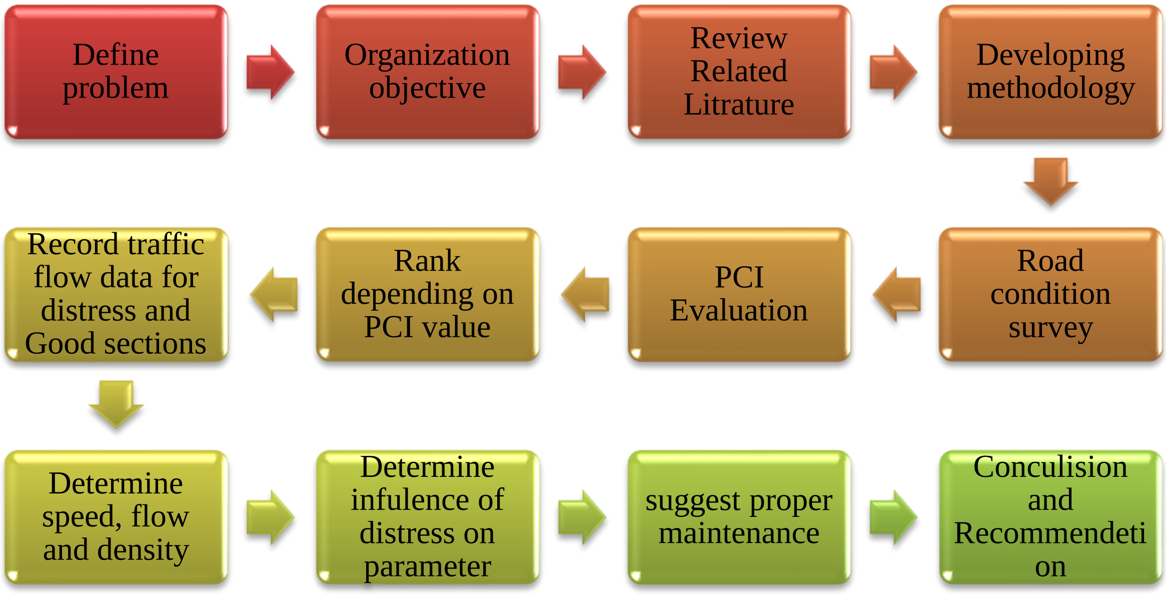


Figure 3. 2: Flow chart of study design activities

3.4. Population

The total length of the road that was considered in the study area covered a distance of about 50kms from Harar to Dhangago along the main trunk road. This road segment was observed with a various types of pavement distresses showing varying extent of defects that influence the traffic.

3.5. Sample size and Sampling Procedures

3.5.1. Sample size for pavement condition evaluation

A pavement sample unit is a subdivision of a pavement section that has standardized area ranges between 225m^2 ±90m^2 for the flexible pavement road as described in the ASTM D6433 standard. In this research, the sample size or a number of sample units (n) that was inspected in each section of the road network is computed using a formula below that provide a statistical adequate estimation of 95% confidence level of the PCI of the section and rounding n to the next whole number [23].

$$n = NS^2 \Big/ \left[\left(\frac{e^2}{4}\right)(N-1) + S^2\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

Where:

e= acceptable error in estimating the section PCI; commonly, = ±5 PCI points

N= total number of sample units in the section.

s = standard deviation of the PCI from one sample unit to another within the section.

When performing the initial inspection the standard deviation is assumed to be ten.

The actual standard deviations (S) were calculated using a formula below until the total number sample units surveyed equal or exceeds a minimum number of sample units (n). Otherwise, additional sample units required to be surveyed [23].

$$S = \left(\sum_{i=1}^{n} (PCI_i - PCI_s)^2/(n-1)\right)^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

Where:

PCI_i= PCI of surveyed sample units i,.

PCI_s= PCI of section or mean PCI of surveyed sample units

Total Number of Sample Units in Section (N) = 28

Minimum Number of Units to be surveyed (n) = 10

Interval (i) = N/n = 28/10 =2.8 take = 2

Random Start (r) = 1

A sampling technique that was adopted for this study is a systematic sampling. Once the number of sample units or sample size for each pavement section have determined, the spacing interval (I) of the sample units was calculated as total sample units (N) in the section divided by n and I, rounded to the next lower whole number. Samples were spaced equally throughout the section with the first sample selected at random and successive increments of the interval I. Each sample was conducted with 1000 m length of pavement sections. The sample with '*'was selected sample for study.

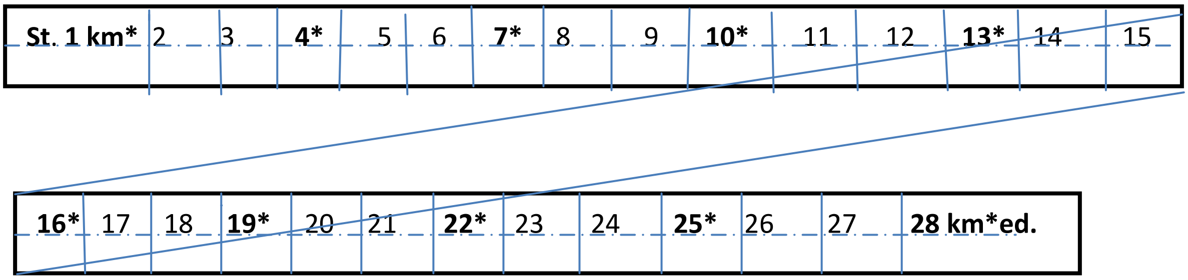


Figure 3. 3: Study segment section and sampling units

3.5.2. Sample Size for Spot Speed and flow Studies

The calculated mean (or average) speed is used to represent the true mean value of all vehicle speeds at that location. The accuracy of this assumption depends on the number of vehicles in the sample. The larger the sample size, the greater the probability that the estimated mean is not significantly different from the true mean. It is therefore necessary to select a sample size that will give an estimated mean within acceptable error limits. Statistical procedures are used to determine this minimum sample size [35]. In case of this research, all vehicles were used for determination of traffic flow parameters except for those entries /exit or both were hidden by another vehicle.

3.5.3. Sampling Procedures

In order to achieve the objective of this research, the necessary data was collected at the study site. Data collection processes include field visual inspection, Field measurements and traffic data video recording. Type and severity levels of distress were recorded on the data sheet for PCI determination. In the section classified as poor, very poor, serious and good condition rating, traffic flow data were collected to identify the impact of pavement distress by comparing the section 'Good' with distressed section. Video recordings were then analyzed for each individual vehicle in the traffic flow and the data on the passing times of the vehicle through the first and the second line of the observed road segment were collected. The digital video recording was stopped on the screen at the moment when each of the vehicles passed the entry/exit line of the observed road segment and the respective frame numbers were recorded. The vehicle passed the observed line at the moment when either the front or the rear axle of the vehicle was aligned with the observed line.

3.6. Study Variables

3.6.1. Dependent Variable

- ✓ Influence of pavement distress on macro traffic flow parameters

3.6.2. Independent Variables

- Pavement Distress Types
- Extent of Defects
- Severity level of defect

3.7. Data Collection Instruments

- Data Sheets
- Digital camera
- Clipboard or binder
- Measuring tape.
- Straightedge or String Line
- Stopwatch
- Distress Identification photos.
- Pencil and remover
- Calculator
- Ruler

3.8. Data Collection Process

Before beginning of data collection, formal letter was obtained from the Jimma Institute of Technology and other concerning body for permission of data collection. Then data collection was started from field inspection to identify the current status of the road segment. After ranking study section according to potential for improvement, the traffic flow data collection was begun by dividing Study sites into entry and exit section. Conventional data collection methodologies adopted for data collection on the macroscopic variables of Heterogeneous traffic stream involves the collection of the video film on the traffic stream being studied. Flow and speed data are collected while replaying the video film. A trap section of 50 m is used to manually collect the spot speeds of the vehicles.

Figure 3. 4: Study segment section for traffic data records

3.9. Data Processing and Analysis

Typical data required for the pavement distresses analysis and identification, impact of pavement distresses on traffic flow was processed and analyzed in required manner. The research was concerned with operational capacity based on direct-empirical method using observed volumes and speeds to derive densities for analysis impact of pavement distress. The methods used for estimation of the model coefficients are linear regressions.

3.9.1. Data Processing

Data processing include, categorizing the data according to its population, category coding and Data entry for both road condition assessment and traffic flow parameters. The field work and traffic flow data was processed and analysis using Microsoft excel and Minitab 16 software.

3.9.1.1. Field work

A manual survey is performed following ASTM D 6433. The pavement was divided into sections. Each section was divided into sample units. The type and severity of sample distress was assessed by visual inspection of the pavement sample units and the quantity of each distress was measured. Typically, this procedure requires a team of at least two engineers (US Army, 2001). Before starting of the detail pavement evaluation, the entire road length was visually assessed and it is attempted to identify the types of failures occurred on the road surface. After all necessary data recorded on pavement condition survey sheet, it was copied on excel sheet for determination of pavement condition index (PCI) , pavement condition and other related assessment. The following images described the major pavement distresses that are found in the study area along the road section from Harar to Dhangago during the field condition surveys:

Figure 3. 5: Medium severity alligator cracking (by Tekalign Morka ,June, 2018)

Figure 3. 6: High severity alligator cracking (June, 2018)

Figure 3. 7: Low severity block crack (June, 2018)

Figure 3. 8: medium severity block crack (June, 2018)

Figure 3. 9: High severity of block cracking (June, 2018)

Figure 3. 10: transverse cracking (June, 2018)

3.9.1.2. Traffic flow parameter

After finishing of the pavement condition survey assessment, four section's traffic data were collected for poor, very poor, failed and serious road condition rating. Using the total travel time and passenger cars volume, space mean speed, were taken as the mean speed of passenger cars measured to denote an average speed based on the average travel time of vehicles to traverse a segment of roadway. Free flow was corresponding to the passenger car taken as the weighing parameters. Free flow densities were estimated based on the average traffic flow composition observed on this road stretch. For each category, approximately 73 passenger cars moving freely were identified for this purpose. Analysis and modeling of the traffic stream behavior are necessary for traffic operations. Using the flow and speed data, and the fundamental relation of macroscopic variables, density has been estimated.

3.9.2. Data Analysis

1. Road Survey condition

Dummy tables were developed that contain all variable need to analysis. PCI and PCR were determined depending on the data collected. All samples surveyed were ranked according to potential for improvement.

The density of the distresses, measured in square meters ($m^{2)}$ or square feet (ft^2), was calculated as follows [5]:

$$Density \ = \frac{density\ amount\ in\ m^2\ (f^2)}{sample\ unit\ area\ in\ m^2\ (f^2)} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (3.3)$$

The density of the distresses, measured in linear feet or meters (bumps, edge cracking, joint reflection cracking, lane/shoulder drop-off as well as longitudinal and transverse cracks) was calculated as follows [5]:

$$Density \ = \frac{density\ amount\ in\ \text{linear m (ft)}}{sample\ unit\ area\ in\ m^2\ (f^2)} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.4)$$

Density of distresses, as measured by the number of potholes, was calculated as follows [5]:

$$Density \ = \frac{number\ of\ potholes}{sample\ unit\ area\ in\ m^2\ (ft^2)} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (3.5)$$

After the density of distresses for each distress type / severity combination is calculated, the deduct values were determined from the appropriate distress deduct value Curve [22]. Then the DVs were determined from the DV curves, then for each distress type and severity Total Deduct Value (TDV) was computed by summing up all the individual DVs then the Corrected Deduct Value (CDV) was determined from CDV curve. Then the PCI was computed [27].

$$PCI = 100 - \text{CDV} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

2. From the Collected traffic data for both control section (very good or no distress section) and highly distressed section;

Step 1: Calculate Passenger Car Equivalent (PCE) from traffic data.

Step 2: Determine flow (q), speed (u) and density (k) without and with pavement distresses using appropriate PCE values [10].

$$space\ mean\ speed\ (SMS) = \frac{d}{\frac{\sum t}{n}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.7)$$

$$where\ d - distance, t - time\ taken\ \ and\ n - number\ of\ vehicle$$

$$flow\ (q) = \frac{\sum n}{T} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.8)$$

$$density\ (k) = \frac{q}{SMS} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.9)$$

Step 3: Determine variances (d) and standard errors (E) [25, 10].

$$variance(d) = \frac{\sum (u_i - u_m)^2}{N-1} \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.10)$$

$$E = \frac{d}{\sqrt{N}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (11)$$

Step 4: Derive flow/density equations from speed density linear equation

$$y = +\sum_{i=1}^{n} \beta_i\, x_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.12)$$

Where, y - SMS at each section,

x_i- Explanatory variables (density) from 1 to n,

β_0 - Regression constant, β_i- Regression coefficient [33]

Step 5: Test model equations for validity.

Step 6: Estimate critical densities by differentiating flow with respect to density.

Step 7: Determine roadway capacities by putting estimated critical densities into model equations.

Step 8: Lastly, determines variation speed, capacity and density due to pavement distress.

3.10. Ethical Consideration

A consent letter obtained from the Jimma University that orders respecting informants were implemented during the data collection process.

3.11. Data Quality Assurance

Double data entry was performed for crosscheck of data. Checking again for completeness and internal consistency has been done. For inconsistency and error occurred, correction and re-entry of data was correct the whole data quality. The quality of data collection was assured without any hesitations. Because primary source of data collection (the first witness of a fact) and secondary source of data collection (books). Therefore; the assurance of those data is highly recognized and those data are true.

3.12. Limitation of the study

Some of limitations addressed during assessment of pavement distress influence on macro traffic flow parameter were as follows;

1. There is no plenty literature on influence of pavement distress on traffic flow parameter.
2. In some place the people around the study area were confused on field measurement and didn't understand the permission letter.
3. The difficulty of safety of data collector around congested area.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. General

The methodology used in the present study for calculating space mean speed was implemented by converting mixed traffic volume to passenger car unit, using an appropriate conversion factor. The procedures used for the determination of optimum speed of good section as well as the distressed were linear regression analysis. This study found out that the linear regression provides a better model when being supported by appropriate predictions for lower space mean speed values. It was observed on the existing pavement that there were several distresses like alligator cracking, longitudinal cracking, transverse cracking, potholes, and patching. The Weightages of pavement distress have been given to various parameters related to the pavements and shoulders. On the other hand, the Pavement Condition Index (PCI) had been calculated based on distress Weightages. The relation has been developed between PCI values with optimum speed and density of traffic volume.

4.2. Pavement distress type and severity level

4.2.1. Pavement distress type

There were more than 10 pavement distresses observed in the study area. The following table shows the types of pavement existed along the study area.

Table 4. 1: Types of pavement exist in the study area

Type of distress	Severity values		
	Low (L)	Medium (M)	High (H)
Alligator cracking (m2)	✓	✓	✓
Bleeding(m2)	✓		
Block cracking (m2)	✓	✓	✓
Bump and Sag			✓
Corrugation (m2)	✓		
Depression (m2)	✓		✓
Edge cracking (m2)		✓	✓
Jt. Reflection cracking (m2)	✓	✓	
Long.& trans cracking (m2)	✓	✓	✓
Patching & utility cut patch (m2)		✓	
Pothole (number)	✓	✓	
Weathering/ raveling (m2)		✓	

4.2.2. Pavement distress severity level

Pavement Condition Survey of all selected samples roads has also been done which consisted of measuring distress type and severity on the Asphalt Pavement Inspection Sheet. The letter L (low), M (medium), or H (high) included along with the distress number code to indicate the severity level of the distress. The dominant types of distresses which covered most of the road sections inspected, more than 75% of which the pavement had a combination of different types of pavement distresses.

i. Low severity level

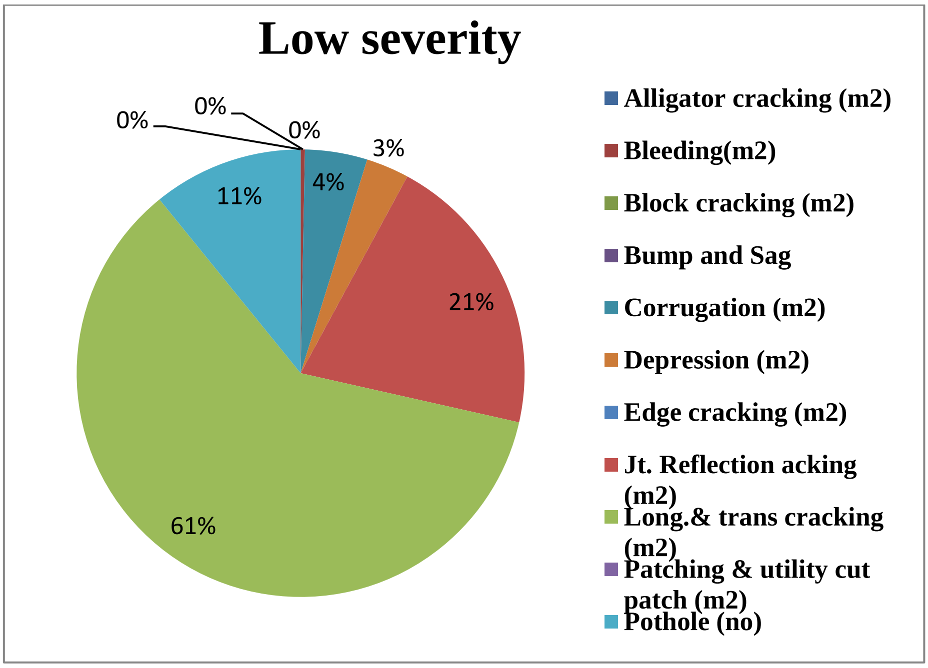


Figure 4. 1: Low severity level distress

The Low severity level group such as alligator cracking, bleeding, block cracking, bump, sag, and corrugation were the recorded distresses. From those distressed, block cracking's dominate large percentage. It covers 61% of the total low severity level. Also bleeding distress covered 21% of the total distress in this severity level. Detailed descriptions of these distresses are listed under chapter two.

ii. Medium severity level

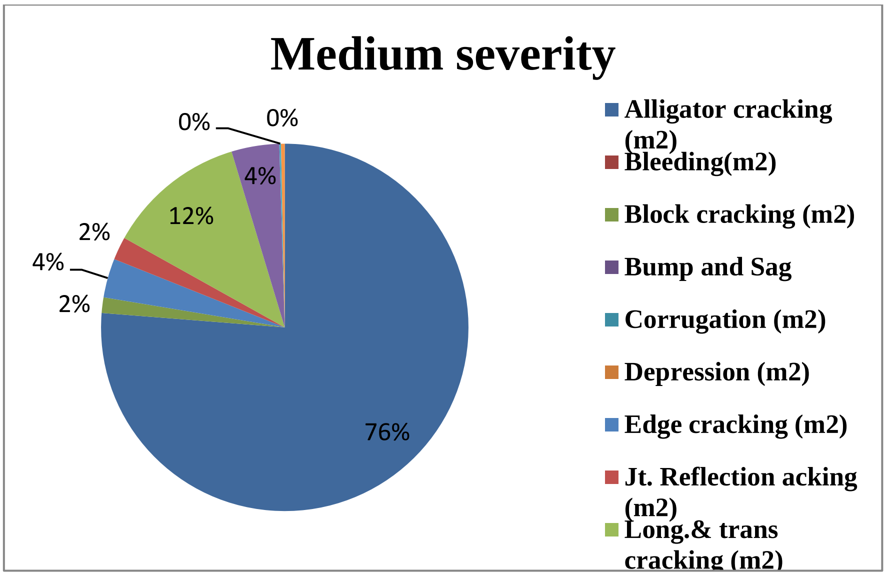


Figure 4. 2: Medium severity level distress

The medium severity level groups of distresses, which affected 76% of the very poor and serious pavement sections, are alligator cracking. Block cracking, Edge cracking, Corrugation, Bump and Sag were also the distresses covered the remaining percentage. The probable causes of these failures may be improper construction or previous maintenance and poor drainage.

iii. High severity level

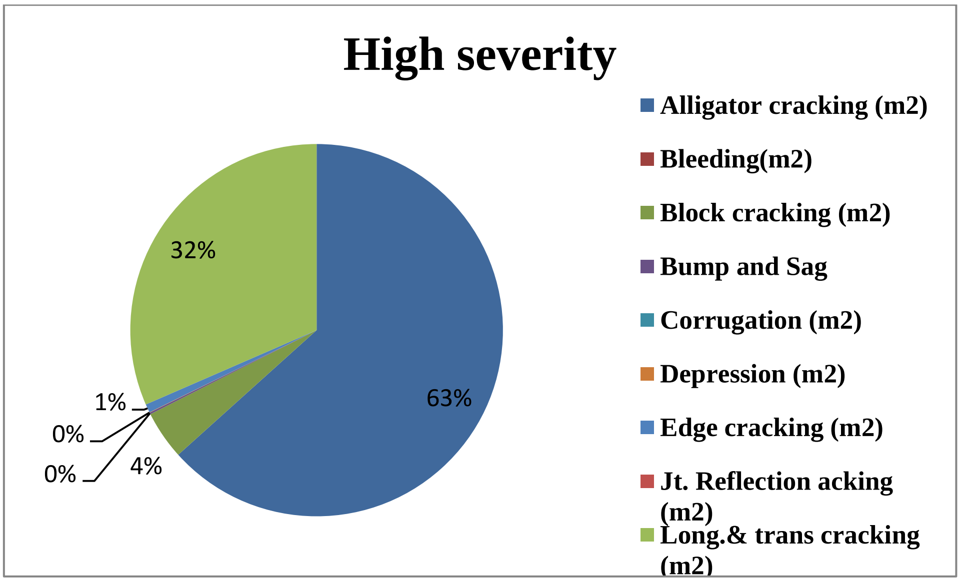


Figure 4. 3: High severity level distress

The High severity level groups of distress categorized were alligator cracking, bleeding, block cracking, bump and sag. From those distress alligator cracking dominate high severity level. It covered 63% of the total high severity level. Also block cracking distress covered 32% of the total distress in this severity level.

4.2.3. Determination of Pavement Condition Index (PCI) and Pavement Condition Rating (PCR)

The quantity, quality and the area covered by each distress were determined. When comparing this area to the total damaged area of pavement sections, the distress percent can be calculated. The results obtained from assessment and calculation of the table above shows, it was observed that virtually all pavement condition rating was recorded to flexible pavements found on the site visited. All the PCIs and rating for the respective section with TDV and CDV are presented in the Table below.

Table 4. 2: Rank of study section depending on PCI and PCR values

Section	Width (m)	Length (m)	TDV	Max. DV	PCI	PCR
Section 10	7.2	1000	15	16	84	GOOD
Section 4	7.2	1000	20.5	20	80	GOOD
Section 7	7.2	1000	40.5	40	60	FAIR
Section 1	7.2	1000	45.7	45	55	FAIR
Section 16	7.2	1000	69.5	52	48	POOR
Section 13	7.2	1000	53.6	54	46	POOR
Section 19	7.2	1000	105.3	74.5	25.5	V.POOR
Section 28	7.2	1000	105.5	76	24	SERIOUS
Section 22	7.2	1000	148.8	84	16	SERIOUS
Section 25	7.2	1000	167	90	10	FAIL

Pavement Condition Rating (PCR) is a verbal description of pavement condition as a function of the Pavement Condition Index (PCI) value that varies from ―failed to very good. Based on the field condition survey, almost all types of pavement condition rating were existed in the study area along the road section from Harar to Dhangago road segment.

The pavement evaluation results from the manual PCI survey revealed that two sections of road were in a good and the other two sections were also in a fair condition while the rest six sections were in a poor to failed rating condition. From the table 4.2 average condition index (PCI) was 44.85. It means the inspected sample road sections were rated poor pavement condition.

4.3. Determination of the Macro Traffic Flow Parameters with Different Rating

A total of 3517 vehicles were observed during the study period, of which 51.5% were passenger cars (PC) and 7.65% were light trucks. Table 4.1 shows the frequency of each vehicle type in the total vehicle observations. Weekday off-peak hours of traffic were observed generally between 9 am to 11am and again from 2pm to 4pm for determination of Space Mean Speed.

According to the HCM 2000, Space Mean Speed is (SMS) is the mean speed of passenger cars measured to denote an average speed based on the average travel time of vehicles to traverse a segment of roadway. It is called a space mean speed because the use of average travel time essentially weights the average, according to the length of time each vehicle spends in the defined roadway segment or space.

This average Passenger Car speed reflects the net effect of all prevailing pavement conditions, such as cracking, depression, pothole, patching, raveling and weathering that influence speed. As the data for this research was collected from a level segment, the SMS was determined by converting mixed traffic stream to passenger car units. To determine the influence of pavement distress, speed data collected from pavement 'Good' section were used as control section.

Statistical analysis and calculation of basic parameters of traffic flow (flow, speed and density); vehicle speed, density, flow, tabular and graphical representation of analyzed values of traffic flow parameters; correlation and regression had performed. The graph below shows space mean speed reduction with respect to pavement condition rating.

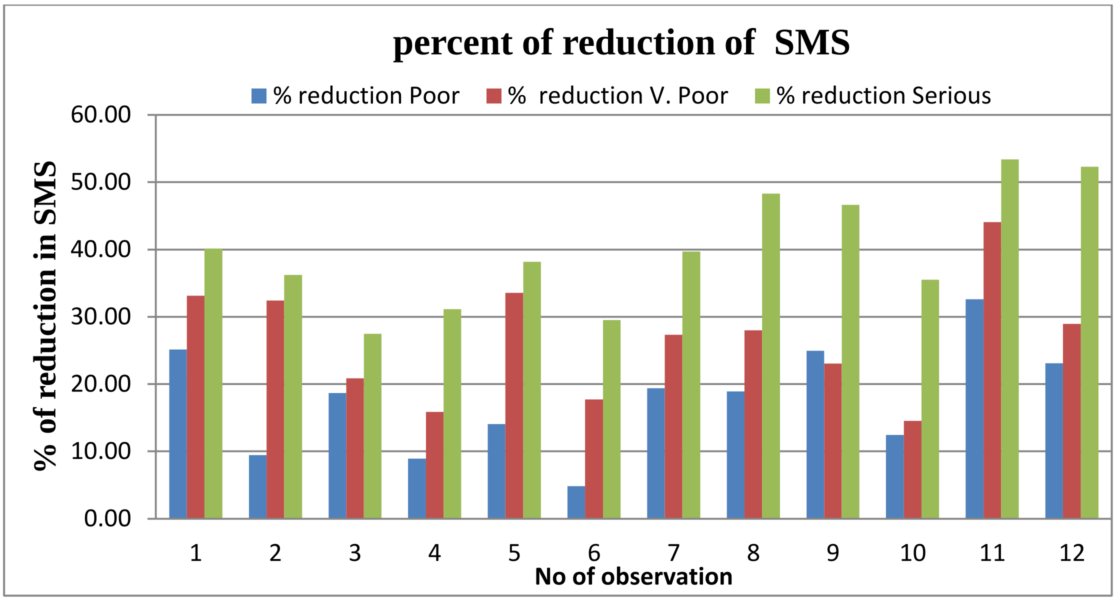


Figure 4. 4: Space Mean Speed reduction in distressed pavements.

As seen in the results of this study, macro traffic flow parameter was apparently affected by the pavement surface condition, particularly for space mean speed. Poor pavement conditions result max 32.58% reduction in SMS which is less when compared to very poor and serious pavement condition which cause maximum reduction of 44.05% and 53.4% respectively. As severity of pavement condition increase, space mean speed of study section decreases; because the vehicle takes long time to transverse distressed segment.

4.3.1. The regression analysis result of the pavement section rated as 'Good'

Further simple regression analysis was carried out among the density and space mean speed. Simple Liner regression analysis has been carried out and presented in Figure 4.5. From the figure it can be observed that the higher slope of the regression line was observed for Speed (km/hr.) versus Density (PCU/km). R2 goodness of fit measures is 99.4% of the regression models.

Table 4. 3: traffic flow parameters in Good section (section 4th)

S/no	Speed (km/hr.)	Flow (PCU/hr.)	Density(PCU/km)
1	39.642	73	1.841
2	37.740	73	1.934
3	31.875	73	2.290
4	32.989	73	2.213
5	36.103	73	2.022
6	32.760	73	2.228
7	37.440	73	1.950
8	39.312	73	1.857
9	38.880	73	1.878
10	32.989	73	2.213
11	43.016	73	1.697
12	40.903	73	1.785

Regression Analysis: Speed (km/hr.) versus Density (PCU/km)

The regression equation is:

Speed (km/hr.) = 73.37 - 18.27 Density (PCU/km) that means, $U_{s\ good}$ = 73.37 - 18.27k

S = 0.303746   R-Sq. = 99.4%   R-sq. (adj.) = 99.3%

The Space mean speed of passenger cars shows a linear relationship with density and observed that the R-Sq. goodness fit values approaches to 1.0. It means there is significant relation among these two variables.

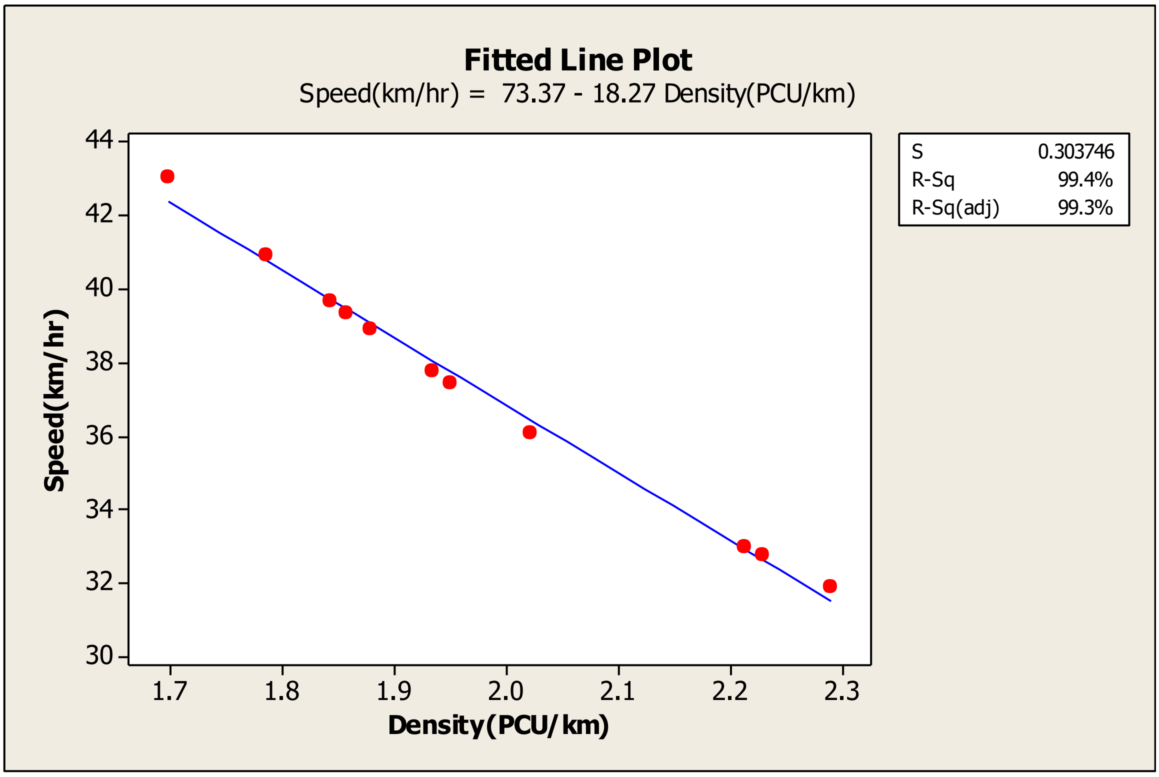


Figure 4. 5: Fitted Line of Speed (km/hr.) versus Density (PCU/km)

Optimum speed (u_o) and critical density (k_o) estimation,

$U_{s\ good}$ = 73.37 - 18.27k

According to the fundamental relationship between speed (u), flow (q) and density (k);

$$q = uk, \text{ and } k = \frac{q}{u}$$

By substituting '$U_{s\ good}$' in above fundamental equation;

$$q = 73.37k - 18.27k^2$$

$\partial q / \partial \kappa$ = 73.37-2(18.27k) = 0; therefore critical density, κ_c = 2.01≈ **2 pcu/km;**

$q = 73.37(2) - 18.27(2)^2$ = 73.66 ≈ 74pcu/hr.

Optimum speed, u_o = **74/2 ≈ 37km/hr.**

From the above regretted equation, free flow speed (u_f) of 'Good' section was 73.37km/hr. For each case optimum speed and critical density were estimated for a fixed passenger cars flow.

4.3.2. Influence of Pavement Distress on speed in 'Poor' section

At road sections with 'poor' pavement condition rating, a maximum speed is somewhat less than the optimum speed at road sections rated 'Good' pavement condition. From ‘Good’ section analysis, free flow speed is estimated of about 73.37km/hr, and the optimum speed is 37km/hr. However, once the pavement distress impact is factored in, optimum speed dropped to 29.6km/hr. This implies that the speed of the passenger car was reduced to 20% when compared to the section rating as ‘Good’. In sum the study showed that reduction in vehicle speed would result from pavement distress. The remainders findings of the poorest section are summarized in the analysis below.

4.3.2.1. The regression analysis result of the pavement section rated as ‘Poor’

Depending on the field data assessment, simple regression analysis was carried out among the observed space mean speed and density. The result of Simple Linear Regression analysis has been carried out and presented in Figure 4.13. The figure reveals that the higher slope of the regression line was observed for Speed (km/hr.) versus Density (PCU/km). The R^2 goodness of fit measures is R-Sq. = 98.9% of the regression models

Table 4. 4: Traffic flow parameters in Poor section (section 7th)

S/no	Speed (km/hr.)	Flow (PCU/hr.)	Density(PCU/km)
1	29.669	73	2.460
2	34.184	73	2.135
3	25.920	73	2.816
4	30.047	73	2.429
5	31.036	73	2.352
6	31.173	73	2.342
7	30.176	73	2.419
8	31.875	73	2.290
9	29.180	73	2.502
10	28.882	73	2.528
11	29.001	73	2.517
12	31.450	73	2.321

Regression Analysis: Speed (km/hr.) versus Density (PCU/km)

The regression equation is;

Speed (km/hr.) = 59.46 - 12.06 Density (PCU/km) therefore, $U_{spoor.}$ = 59.46 – 12.06k

S = 0.220022

R-Sq. = 98.9%

R-Sq. (adj.) = 98.8%

It was observed that a pavement characteristic has a major influence on space mean speed of passenger cars. Space mean speed of passenger cars shows a linear relationship with density and observed that the R-Sq. Goodness fit values approaches to 1.0 which emphasize that there is a significant relation among these two variables.

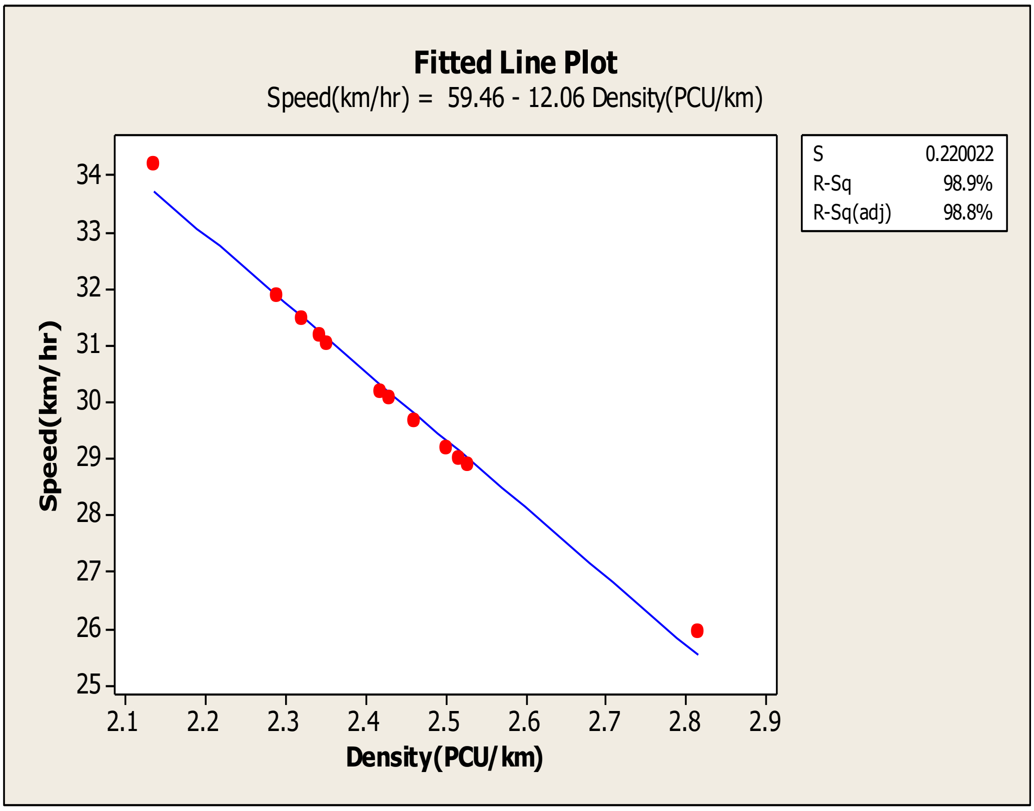


Figure 4. 6: Fitted Line of Speed (km/hr.) versus Density (PCU/km)

Optimum speed (u_o) and critical density (k_o) of poor segment,

$U_{s\ poor}$ = 59.46 – 12.06k

In fundamental relationship between speed (u), flow (q) and density (k);

$$q = uk$$

By substituting '$U_{s\ poor}$' in above fundamental equation;

$$q = 59.46k - 12.06k^2$$

$\partial q / \partial \kappa$ = 59.46-2(12.06k) = 0; therefore critical density, **κ c = 2.47≈2.5 pcu/km;**

$q = 59.46(2.5) - 12.06(2.5)^2$ = 73.28 ≈74 pcu/hr.

Optimum speed, $\mathbf{u_o}$ **= 74/3 ≈ 29.6km/hr.** and free flow speed of this section is **dropped to 59.46km/hr.**

In this section the most difficult factor that contributes to speed reduction is Alligator cracking with a relative weight of (1M) 27% and (1H) 31%.

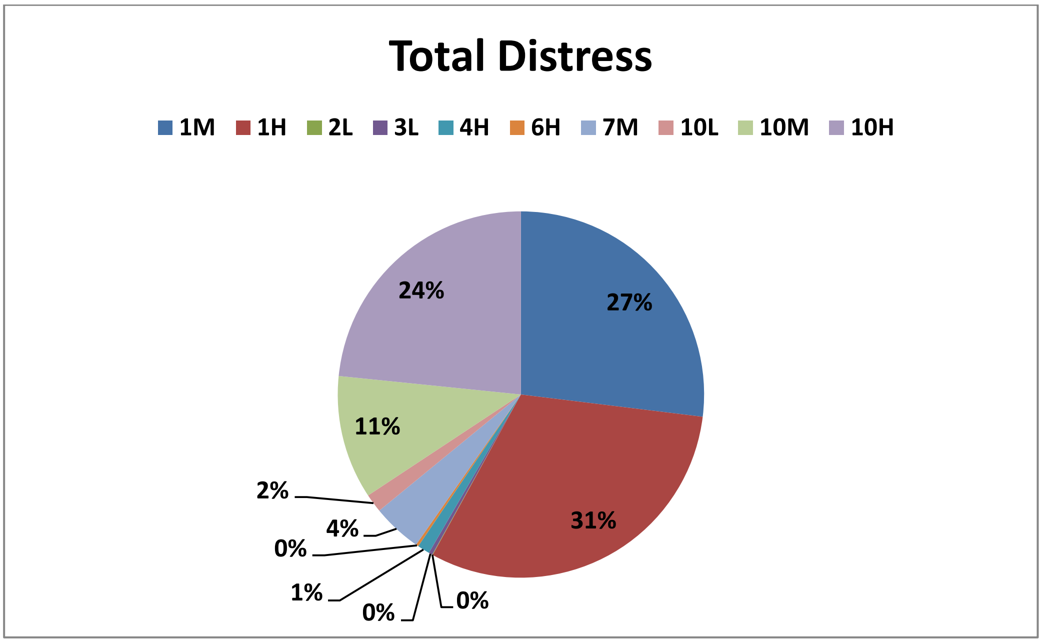


Figure 4. 7: Extent of distress contributing in speed reduction

4.3.3. Impact of Pavement Distress on speed in 'very poor' section

The performances of the 'Very Poor' pavement condition in the vicinity of the proposed, optimum speed on this section were analyzed using Minitab software for linear regression. The results are shown in the graph below. It was found that there is the worst performance in terms of macro traffic parameters due to pavement distress which play great role in reduction of optimum speed, free flow speed and increment of density occurred during weekday off-peak period.

Therefore the pavement distress impact assessments were made based on traffic flow data which represented worst case scenario of 'very poor' condition. As pavement condition faced 'very poor', the analysis show that impact of distress on, optimum speed become 34.23% when compared to the section rating as 'Good' which dropped to 24.33km/hr. This study showed that reduction in passenger car speed was the result of pavement distress extent occurred in the sample studied.

4.3.3.1. Regression analysis result of pavement section rated as 'Very Poor'

Depending on the field data assessment, simple regression analysis was carried out among the observed space mean speed and density. The result of Simple Linear regression analysis has been carried out and presented in Figure 4.13. The figure reveals that the higher slope of the regression line was observed for Speed (km/hr.) versus Density (PCU/km). R2 goodness of fit measures is R-Sq. = 98.9% of the regression models.

Table 4. 5: Traffic flow parameters in Very poor section (section 11th)

S/no	Speed (km/hr.)	Flow (PCU/hr.)	Density (PCU/km)
1	26.502	73	2.754
2	25.500	73	2.863
3	25.227	73	2.894
4	27.750	73	2.631
5	23.987	73	3.043
6	26.957	73	2.708
7	27.216	73	2.682
8	28.305	73	2.579
9	29.920	73	2.440
10	28.192	73	2.589
11	24.069	73	3.033
12	29.060	73	2.512

Regression Analysis: Speed (km/hr) versus Density (PCU/km)

The regression equation is

Speed (km/hr) = 53.28 - 9.677 Density (PCU/km) this shows,

Usv.poor = 53.28 - 9.677k

S = 0.130436

R-Sq. = 99.6%

R-Sq. (adj.) = 99.5

Space mean speed of passenger cars shows a linear relationship with density and observed that the R-Sq. goodness fit values are approach to 1 which emphasis that significant relation among these two variable.

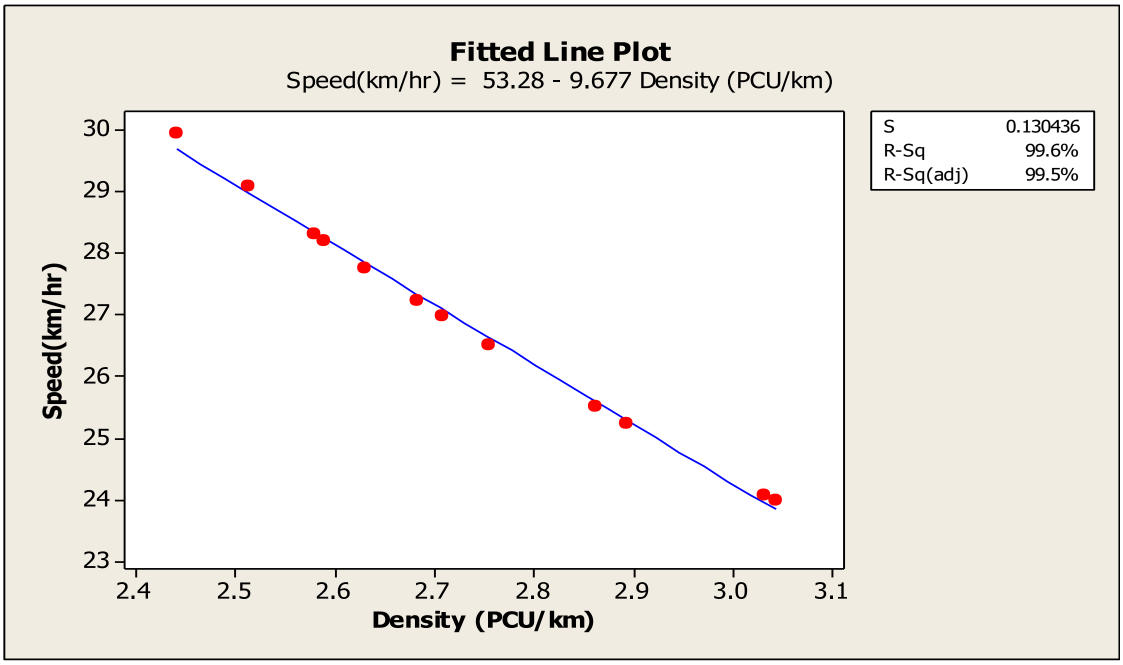


Figure 4. 8: Fitted Line of Speed (km/hr.) versus Density (PCU/km)

Estimation of optimum speed (u_o) and critical density (k_o) of very-poor segment,

$U_{s\ v.\ Poor}$ = 53.28– 9.667k

In fundamental relationship between speed (u), flow (q) and density (k);

$$q = uk$$

By substituting '$U_{s\ v.poor}$' in above fundamental equation;

$$q = 53.28k - 9.667k^2$$

$\partial q / \partial \kappa$ = 53.28-2(9.667k) = 0; therefore critical density, **κ c = 2.75≈ 3pcu/km;**

$q = 53.28(3) - 9.667(3)^2$ = 72.84pcu ≈73pcu/hr.

Optimum speed, $\mathbf{u_o}$ **= 73/3 ≈ 24.33km/hr.** and free flow speed of this section is also **dropped to 53.28km/hr.**

The most difficult factor that contributes in speed reduction is alligator cracking with a relative weight of (1M) 28% and (1H) 69%.

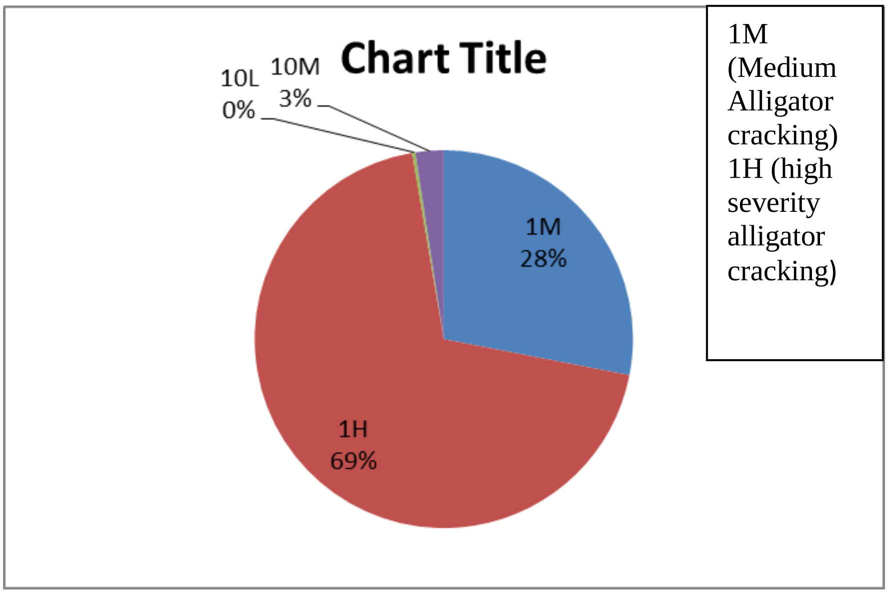


Figure 4. 9: Extent of distress contributing in speed reduction

4.3.4. Impact of Pavement Distress on speed in 'serious' section

As seen in the results of this study space mean speed, optimum speed and free flow speed was apparently affected by the pavement surface condition. Serious pavement conditions in this section leads vehicle speed oscillation is still very low-speed. The regression result shows; free flow speed is decreased to 43.44 km/hr and the optimum speed is also dropped to 17.75 km/hr., due to the serious distress condition of pavements. The output of the software is summarized below. It is quite sure that the reduction in vehicle speed would result from a pavement condition of the study site. Incorporating speed analysis into the pavement management (or vice versa) is one of the urgent needs for more effective and safer management of roadway systems.

4.3.4.1. Regression analysis result of pavement section rated as 'Serious'

Depending on field data assessment from it, simple regression analysis was carried out among the observed space mean speed and density. The result of Simple Linear regression analysis has been carried out and presented at Figure 4.10. The figure reveals that higher slope of the regression line was observed for Speed (km/hr.) versus Density (PCU/km). R^2 goodness of fit measures is R-Sq. = 98.9% for the regression models.

Table 4. 6: Traffic flow parameters in Very poor section (section 14th)

S/no	Speed (km/hr.)	Flow (PCU/hr.)	Density (PCU/km)
1	23.746	73	3.074
2	24.069	73	3.033
3	23.125	73	3.157
4	22.716	73	3.214
5	22.322	73	3.270
6	23.087	73	3.162
7	22.571	73	3.234
8	20.334	73	3.590
9	20.751	73	3.518
10	21.282	73	3.430
11	20.046	73	3.642
12	19.520	73	3.740

Regression Analysis: Speed (km/hr.) versus Density (PCU/km)

The regression equation is,

Speed (km/hr.) = 43.44 - 6.432 Density (PCU/km) this means,

$U_{s\ serious} = 43.44 - 6.432k$

S = 0.0845655

R-Sq. = 99.7%   R-Sq. (adj) = 99.7

Space mean speed of passenger cars shows a linear relationship with density and observed that the R-Sq. Goodness fit values are approaching to 1 which emphasis that significant relation among these two variables.

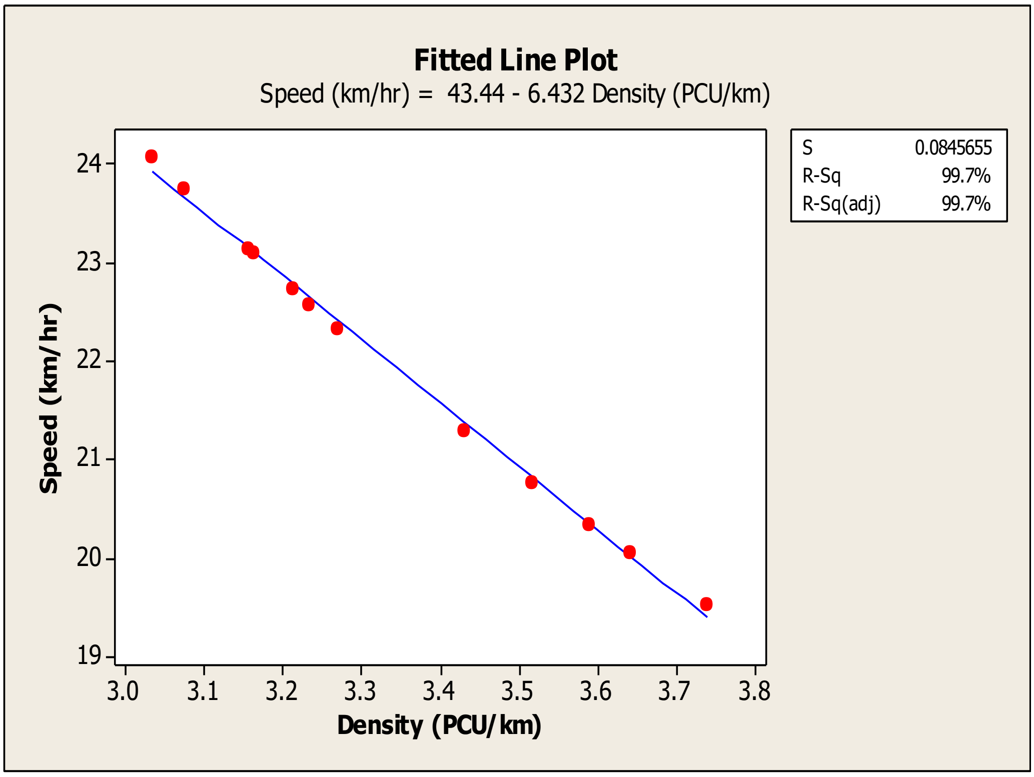


Figure 4. 10: Fitted Line of Speed (km/hr.) versus Density (PCU/km)

Optimum speed (u_o) and critical density (k_o) of serious condition sample section

$U_{s\ serious}$ = 43.44 - 6.432k

In fundamental relationship between speed (u), flow (q) and density (k);

$$q = uk$$

By substituting '$U_{s\ serious}$' in the above fundamental equation;

$q = 43.44\text{k} - 6.432k^2$

$\partial q / \partial \kappa$ = 43.44-2(6.432k) = 0; therefore critical density, **κ c = 3.4≈ 4/km;**

$q = 43.44(4) - 6.432(4)^2 =$ 70.85pcu ≈71pcu/hr. Optimum speed, **u_o = 71/4 ≈ 17.75km/hr.**

This Analysis revealed that, optimum speed of serious section is reduced by 52% when compared to the section rated as 'Good'. The reduction in passenger car speed is predominantly due to alligator cracking in the section. It covers 76% of total pavement distress extent occurred in the sample studied. Other contributed distress types are described in the pie chart below.

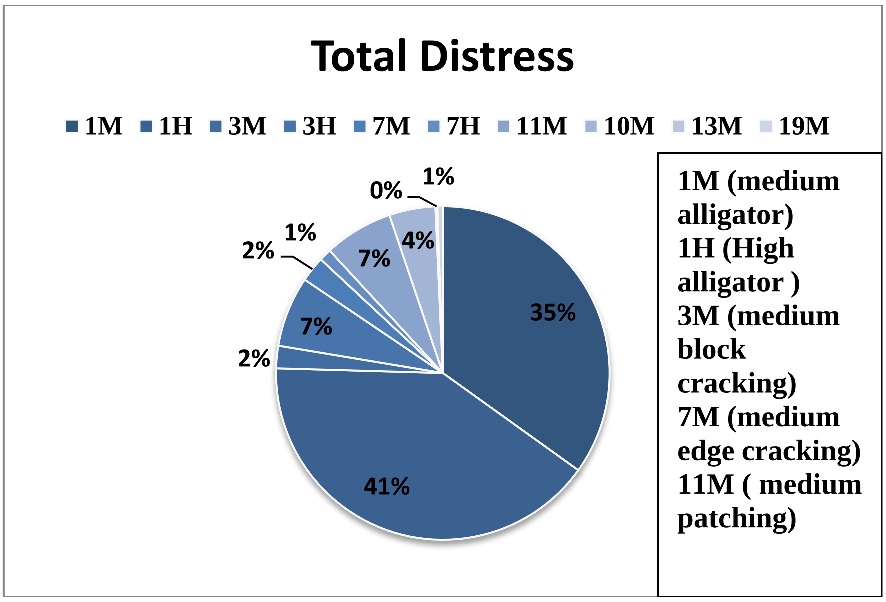


Figure 4. 11: Extent of distress contributing in speed reduction

4.3.5. Determination of impact of pavement performance on density of the existing pavements

The regression results of poor, very-poor and serious roads are presented in Tables 4.5 to 4.8, respectively. The results indicated that the 'poor' pavement condition has statistically significant effects on the density of stream. It causes increments of 22.89% in density due to speed reduction in the section. Growth of density directly leads to capacity loss in the highway. Hence capacity of any roadway follows a probability distribution depending on headways and speeds between vehicles. As the study is conducted in the rural road segment, there is no congestion problem in the study sample. But the increments of density with this amount percentage may cause congestion in the city with high traffic flow. In case of very-poor and serious road condition, pavement distress contributes in the increments of density with 36.82% and 49.75% respectively.

On the contrary, the poor, very poor and serious pavement condition decreases the likelihood of flow of the stream.

4.4. Correlation of macro traffic flow parameters and pavement distresses

In the interpretation of Pearson correlation (r), P-Value was also considered. If the result of a correlation test is (*P*-value > 0.05), it is concluded that, there is no significant correlation between the two variables. Also if the result of a correlation test is a P-value ≤ 0.05, we could conclude there was a strong/weak significant positive/negative correlation between the two types of measurement [41].

From the calculation, Pearson correlation (r) of PCI and Speed estimated r= 0.972 and P-Value = 0.028. This result shows Cor (PCI, speed), 'r' is close to 1 and P-Value < 0.05. This implies that there is significant (strong) and positive correlation between pavement condition index (PCI) and optimum speed of passenger car. This means, as PCI of the section is greater; speed of the section is also greater. Conversely, as section of the road faced several distress PCI value is reduced. This directly cause drop of speed within the stream. Hence, it is concluded that, the pavement distresses are more likely to cause a higher speed reduction for poor, very poor and serious pavement conditions. On the other hand, the reduction of speed within stream causes reduction flow and an increment of density.

It is concluded that, the pavement distresses are more likely to cause higher speed reduction for poor, very poor and serious pavement conditions. On the other hand, the reduction of speed within stream causes reduction flow and increment of density.

4.5. Suggested maintenance options for sections of Harar – Dhangago Road segments

To maintain and preserve service condition of road segment, Pavement performance assessment is fundamental prior to any activity. Evaluation of in service pavement is also very crucial for identifying the cause of distresses and taking remedial action. Therefore keeping roads in serviceable condition is the most cost-effective way to save the pavements before it reaches the failure stage.

The PCI provides feedback on pavement performance for validation or improvement of current pavement design and maintenance procedures. It provides an objective and rational basis for determining maintenance and repair needs and priorities. Continuous monitoring of the PCI is used to establish the rate of pavement deterioration, which permits early identification of major rehabilitation needs

Table 4. 7: Maintenance option depending on PCI value [33]

PCI Range	Rating	Maintenance Measures
86-100	Excellent	No maintenance required
71-85	Very Good	Little or no maintenance
56-70	Good	Routine maintenance, crack sealing and minor patching
41-55	Fairs	Preservative treatments (seal coating or thin nonstructural overlay 2" or more)
26-40	Poor	Needs patching and repair prior to major overlay Milling and removal of deterioration extends the life of overlay.
11-25	Very Poor	Needs reconstruction with extensive base repair
0-10	Failed	Total reconstructions

The techniques used for preservation treatments are slurry seal, chip seal, crack seal, and thin overlay where slurry seal is a mixture of emulsified asphalt, well-graded fine aggregate, water and mineral filler that has a creamy fluid-like appearance when applied. As a hard wearing surfacing for pavement preservation, slurry seal can be used for sealing aged pavements, filling minor cracks, restoring skid resistance and enhancing aesthetic appearance.

Chip seal is the application of bituminous binder immediately followed by the application of aggregate. The aggregate is then rolled and embed into the binder. Multiple layers may be placed and different types of binder and aggregate can be used to address specific distress or traffic situations [43].

Crack seal requires thorough crack preparation and often requires the use of specialized high quality materials placed either into or above working cracks to prevent the intrusion of water and incompressible materials. The sealants in crack seal are typically bituminous materials that soften upon heating and harden upon cooling. Its main purpose is to prevent the intrusion of moisture through existing cracks [43].

Thin overlays are generally used with a relatively high cost compared to other preservation treatments. The purposes are to improve pavement surface condition, protect pavement structure, reduce the pavement deterioration rate, correct surface deficiencies, reduce permeability, and improve the ride quality of the pavement [43].

According to PCI finding on Figure 4.2, the pavement that has been studied from Harar to Dhangago would require maintenance. Thick overlay (sometimes called

Double overlay) is needed in a comprehensive pavement. Therefore, based on findings suggested maintenances for the studied road section was summarized in the following table.

Table 4. 8: Recommended Pavement maintenance treatments for the study area.

Sno.	Section name	PCI	Pavement condition	Suggested Maintenance
1	Section 1st	55	Fair	seal coating or thin nonstructural overlay 2”(50mm) or more
2	Section 4th	80	Good	crack sealing and minor patching
3	Section 7th	60	Fair	seal coating or thin nonstructural overlay 2” (50mm) or more
4	Section 10th	84	Good	crack sealing and minor patching
5	Section 13th	46	Poor	patching and repair with major overlay
6	Section 16th	48	Poor	patching and repair with major overlay
7	Section 19th	25.5	Very poor	reconstruction with extensive base repair
8	Section 22th	16	Serious	reconstruction with extensive base repair
9	Section 25 th	10	Fail	reconstructions
10	Section 28th	24	Serious	reconstruction with extensive base repair

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study explored the effect of pavement conditions on macro traffic flow parameters. The importance of the variables was analyzed using the least square regression and Microsoft excel. Based on the findings of the study, it can be concluded that:

The pavement condition survey along the selected road shows that there were different failure type such as alligator cracking, block cracking, corrugation, depression, edge cracking, longitudinal and transverse cracking, patching, polished aggregate, potholes. The result of the research show that the PCI value range from 10 to 84, which shows, section of the road had all most all types of pavement condition Rating. From pavement condition survey analysis it was identified that; good, fair, poor, and serious covers 20% per each. Very poor and failed took 10% for each from total area of sampling. Total average value of PCI for the study area was 44.5.

Macro traffic flow parameters for poor pavement condition rating show that the space mean speed varies from 25.920km/hr. to 34.18km/hr. As seen in the results of this study, macro traffic flow parameter was apparently affected by the pavement surface condition, particularly for space mean speed. ‘Poor’ pavement conditions result maximum of 32.58% reduction in SMS which is less when compared to ‘very poor’ and ‘serious’ pavement condition which cause maximum reduction of 44.05% and 53.4% respectively. As severity of pavement condition increase, space mean speed of study section decreases; because the vehicle takes long time to transverse distressed segment.

From ‘good’ section analysis, free flow speed is estimated to be about 73.37km/hr. and the optimum speed is 37km/hr. However, once the pavement distress impact is factored in, optimum speed dropped to 29.6km/hr. in ‘poor’ section. . As pavement condition faced ‘very poor’, the analysis show that impact of distress on, optimum speed become 34.23% when compared to the section rating as ‘Good’, which was dropped to 24.33km/hr. optimum speed of 'serious' section is reduced by 52% when compared to the section rated as 'Good'.

Generally, the selected road section was faced different types of cracking, surface deformation, surface defects and Disintegration. According to PCI finding road segment Harar to Dhangago would require maintenance. For road section rated as 'Good', crack sealing and minor patching is recommended. As wells for 'Fair' road segment, seal coating or thin nonstructural overlay 2" or more is best option to restore service condition of the road. Also 'Poor' road section should have to corrected by patching and repair with major overlay. Finally 'Very poor', 'Serious' and 'Fail' road sections need reconstruction with extensive base repair.

5.2. Recommendation

As far different literature shows Harar and Oromia didn't use the traffic analysis in PMS or vice versa. Incorporating traffic analysis into the pavement management (or vice versa) is one of the urgent needs for more effective and safer management of roadway systems. Therefore, one of meaningful alternatives suggested by the authors is to develop a pavement condition-based traffic index

The results from this study suggest that the severity levels of most of speed reduction can be reduced when the pavement condition is well maintained. Thus, the recommendation is to maintain the pavement condition less than an acceptable level: pavement condition rate less than poor or pavement condition index less than 55. Although this study revealed several interesting findings, it has two limitations.

First, the macro traffic parameters analysis did not take into account the different types micro traffic flow parameter such as Gap and headway. But a specific distress type can have higher impacts on the micro parameter. In addition, the traffic analysis can be applied to different pavement types (e.g., rigid and composite pavements) because different pavement types involve different surface distresses. These two main issues could be addressed in follow-up studies collecting more objective and reliable pavement condition indices for the analysis.

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Appendix A: Pavement Condition Data

ASPHALT SURFACE ROAD AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH …………………..… SECTION ……………………..…. SAMPLE UNIT …..……..	**1**
SURVEYED BY ………………..….. DATE ……………………….. SAMPLE AREA …………	**7200m2**

1. Alligator Cracking	**6. Depression**	**11. patching & util cut patching**
2. Bleeding	**7. Edge Cracking**	**12. polished aggregate**
3. Block Cracking	**8. Jt. Reflection cracking**	**13. pothole**
4. Bumps & Sags	**9. Lane / shoulder drop off**	**14. Rail road**
5. Corrugation	**10. long & trans cracking**	**15. Rutting**

DISTRESS	A=7200m^2													DEDUCT
SEVERITY	QUANTITY											TOTAL	DENSITY %	VALUE
1M	0.8*8	40.6*3.6	30*7.2									368.6	5.12	38.9
5L	0.7*1											0.7	0.01	2.5
7L	0.5											0.5	0.01	1.3
8L	13.3											13.3	0.18	1.5
8M	4	2.5	15.3									21.8	0.30	4.5
10L	0.5	8	0.4									8.9	0.12	0
10M	1.3	9										10.3	0.14	0

m= 1+ (9/98)(100-HDV)≤ 10 6.61122 ≤ 10 Ok!
m = 6.61 > 5

No	**DEDUCT VALUE**											**TOTAL**	**q**	**CDV**
1	38.9	4.5	2.5	1.5	1.3							48.7	3	30
2	38.9	4.5	2	1.5	1.3							48.2	2	35

3	38.9	2	2	1.5	1.3						45.7	1	45

PCI = 100 - max CDV, PCI = 55 max CDV= 45
PCR = FAIR

ASPHALT SURFACE ROAD AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH ……………………. SECTION ……………………..… SAMPLE UNIT …..……… **2**

SURVEYED BY ………………..….. DATE ……………………….. SAMPLE AREA ………… **7200m2**

1. Alligator Cracking	**6. Depression**	**11. patching & util cut patching**
2. Bleeding	**7. Edge Cracking**	**12. polished aggregate**
3. Block Cracking	**8. Jt. Reflection cracking**	**13. pothole**
4. Bumps & Sags	**9. Lane / shoulder drop off**	**14. Rail road**
5. Corrugation	**10. long & trans cracking**	**15. Rutting**

DISTRESS	A=7200m^2											DEDUCT VALUE
SEVERITY	QUANTITY									TOTAL	DENSITY%	
1L	0.8*11									8.8	0.122	4.5
1M	3.65*10									36.5	0.507	15.5
5L	0.8*1.5									1.2	0.017	0
8M	21									21	0.292	3.8
10L	9.6	2.6								12.2	0.169	0
10M	0.6	14.8								15.4	0.214	1

m= 1+ (9/98)(100-HDV)≤ 10 8.7602 ≤ 10 Ok therefore m = 8.76 > 4

No	**DEDUCT VALUE**									**TOTAL**	**q**	**CDV**
1	15.5	4.5	3.8	1						24.8	3	14

2	15.5	4.5	2	1						23	2	16
3	15.5	2	2	1						20.5	1	20
												Max CDV=20

PCI = 100 - max CDV , PCI = 80

PCR = GOOD

ASPHALT SURFACE ROAD AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH …………………..… SECTION ……………………..…
SAMPLE UNIT …..……… **3**

SURVEYED BY ……………..…….. DATE ……………………….. SAMPLE AREA ………… **7200m2**

1. Alligator Cracking	**6. Depression**	**11. patching & util cut patching**
2. Bleeding	**7. Edge Cracking**	**12. polished aggregate**
3. Block Cracking	**8. Jt. Reflection cracking**	**13. pothole**
4. Bumps & Sags	**9. Lane / shoulder drop off**	**14. Rail road**
5. Corrugation	**10. long & trans cracking**	**15. Rutting**

DISTRESS	$A=7200m^2$											DEDUCT
SEVERITY	QUANTITY									TOTAL	DENSITY %	VALUE
1M	16*1	29.5*1	21.5*3							110	1.528	25.8
1H	1.5*1									1.5	0.021	0
5L	2*0.5									1	0.014	0
6L	2.5*0.8									2	0.028	0
7M	25	10.5								35.5	0.493	5.2
8M	19.5	21.8	18.7	120	70					25	0.347	5
10L	6									6	0.083	0
10M	7.9	11.4	14.8	23.7						57.75	0.802	4.5

m= 1+ (9/98)(100- 7.8142 ≤ 10 Ok m = 7.81

HDV)≤ 10 9 > 4

No						DEDUCT VALUE				TOTAL	q	CDV
1	25.8	5.2	5	4.5						40.5	1	40
2	25.8	5.2	5	2						38	2	28
3	25.8	5.2	2	2						35	3	20
4	25.8	2	2	2						31.8	4	13

max CDV= 40

PCI = 100 - max CDV , PCI = 60

PCR = FAIR

ASPHALT SURFACE ROAD AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH …………………..… SECTION ……………………..… SAMPLE UNIT …..……… 4

SURVEYED BY ………………….. DATE ……………………….. SAMPLE AREA ………… 7200m2

1. Alligator Cracking **6. Depression** **11. patching & util cut patching**

2. Bleeding **7. Edge Cracking** **12. polished aggregate**

3. Block Cracking **8. Jt. Reflection cracking** **13. pothole**

4. Bumps & Sags **9. Lane / shoulder drop off** **14. Rail road**

5. Corrugation **10. long & trans cracking** **15. Rutting**

DISTRESS	A=7200m^2												DEDUCT
SEVERITY	QUANTITY										TOTAL	DENSITY%	VALUE
1L	3.6*1	7.5*0.6									8.1	0.11	4.6
1M	0.5*1.8										22.5	0.31	11
3L	3.8*0.15										0.57	0.01	0

7M	7.5										7.5	0.10	0
10M	24	28.8	8.5	6.8	14						82.1	1.14	9.8

m= 1+ (9/98)(100-HDV)≤ 10   9.17347 ≤ 10 Ok   m = 9.17 > 3

No	**DEDUCT VALUE**										**TOTAL**	**q**	**CDV**
1	11	9.8	4.6								25.4	3	13
2	11	9.8	2								22.8	2	15
3	11	2	2								15	1	16

max CDV= 16

PCI = 100 - max CDV , PCI = 84

PCR = GOOD

ASPHALT SURFACE ROAD AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH …………………….. SECTION ……………………..…
SAMPLE UNIT …..……… **5**

SURVEYED BY …………….…….. DATE ………………………..
SAMPLE AREA ………… **7200m2**

1. Alligator Cracking	**6. Depression**	**11. patching & util cut patching**
2. Bleeding	**7. Edge Cracking**	**12. polished aggregate**
3. Block Cracking	**8. Jt. Reflection cracking**	**13. pothole**
4. Bumps & Sags	**9. Lane / shoulder drop off**	**14. Rail road**
5. Corrugation	**10. long & trans cracking**	**15. Rutting**

DISTRESS	A=7200m^2												DEDUCT
SEVERITY	QUANTITY										TOTAL	DENSITY%	VALUE
1M	2.4*1.8	2.9*1.75	7.4*3.6	60*3.6	120*3.6						684.04	9.50	47.6
1H	1.5*3										4.5	0.06	12
3L	9.3										9.3	0.13	0

10L	7	0.8	5.1								12.9	0.18	0
10M	29.2	5.6	11.84	8.6	3.7						58.5	0.81	2
13L	7										7	0.10	3.5
13M	1										1	0.01	0

m= 1+ (9/98)(100-HDV)≤ 10 5.812245 ≤ 10 Ok | m = 5.81 > 4

No							DEDUCT VALUE				TOTAL	q	CDV
1	47.6	12	3.5	2							65.1	3	43
2	47.6	12	2	2							63.6	2	47
3	47.6	2	2	2							53.6	1	54

max CDV = 54

PCI = 100 - max CDV , PCI = 46 PCR = POOR

ASPHALT SURFACE ROAD AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH ……………….…… SECTION ……………………..….
SAMPLE UNIT ….…….… **6**

SURVEYED BY ………………….. DATE ………………………..
SAMPLE AREA ………… **7200m2**

1. Alligator Cracking	**6. Depression**	**11. patching & util cut patching**
2. Bleeding	**7. Edge Cracking**	**12. polished aggregate**
3. Block Cracking	**8. Jt. Reflection cracking**	**13. pothole**
4. Bumps & Sags	**9. Lane / shoulder drop off**	**14. Rail road**
5. Corrugation	**10. long & trans cracking**	**15. Rutting**

DISTRESS	A=7200m^2												DEDUCT
SEVERITY	QUANTITY										TOTAL	DENSITY%	VALUE
1M	2.8*1.3	1*1.5	6.5*1.5	3*2	13.5*1.5	9.5*7.6	0.8*0.6	12.8*1.5			123.27	1.71	25.5
1H	7.65*3.65	6.65*1	8.3*7.6	1.2*2.5	3.5*3	3*0.6	2*3.6	2*5.4	2.5*1.6		142.15	1.97	40
2L	0.1*20										0.2	0.00	0
3L	1.5*1										1.5	0.02	0

4H	5										5	0.07	0
6H	0.3*3.5										1.05	0.01	0
7M	20										20	0.28	0
10L	6.5	1									7.5	0.10	0
10M	30	7.6	8.6	0.8	0.8	0.8	1.3				49.9	0.69	2.5
10H	99	8									107	1.49	10

m= 1+ (9/98)(100-HDV)≤ 10 6.5102 ≤ 10 Ok

m = 5.81 > 4

No	DEDUCT VALUE										TOTAL	q	CDV
1	40	25.5	10	2.5							78	4	44
2	40	25.5	10	2							77.5	3	50
3	40	25.5	2	2							69.5	2	52
4	40	2	2	2							46	1	46

max CDV = 52

PCI = 100 - max CDV , PCI = 48

PCR = POOR

ASPHALT SURFACE ROAD AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH …………………..… SECTION ……………………..…. SAMPLE UNIT …..……… **7**

SURVEYED BY ……………..…….. DATE ……………………….. SAMPLE AREA ………… **7200m2**

1. Alligator Cracking	**6. Depression**	**11. patching & util cut patching**
2. Bleeding	**7. Edge Cracking**	**12. polished aggregate**
3. Block Cracking	**8. Jt. Reflection cracking**	**13. pothole**
4. Bumps & Sags	**9. Lane / shoulder drop off**	**14. Rail road**
5. Corrugation	**10. long & trans cracking**	**15. Rutting**

DISTRESS	$A=7200m^2$	DEDUCT

SEVERITY	QUANTITY												TOTAL	DENSITY %	VALUE
1M	52*3.65	13*2.5	20.7*2	5.18*1	29.76*7.6	5*0.75							466.31	6.48	41.5
1H	64*7.2	4.1*1	9.3*2.5	27*7.2	18*1	30*1.5	3*3.5*2	9.6*1.5	4.5*1.5	12*3.65	14*3.65	34*7.2	1151.4	15.99	62
10L	4.5												4.5	0.06	0
10M	8	5.7	4	1.5	5	2.8	13						40	0.56	1.8
		m= 1+ (9/98)(100-HDV)≤ 10			4.4898	≤ 10	Ok		m = 4.49 > 4						

No	DEDUCT VALUE												TOTAL	q	CDV
1	62	41.5	1.8										105.3	2	74.5
2	62	2	1.8										65.8	1	65
															max CDV = 74.5

PCI = 100 - max CDV , PCI = 25.5

PCR = VERY POOR

ASPHALT SURFACE ROAD AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH …………………..…. SECTION ……………………..…. SAMPLE UNIT ….………. **8**

SURVEYED BY …………….…….. DATE ……………………….. SAMPLE AREA ………… **7200m2**

1. Alligator Cracking	**6. Depression**	**11. patching & util cut patching**
2. Bleeding	**7. Edge Cracking**	**12. polished aggregate**
3. Block Cracking	**8. Jt. Reflection cracking**	**13. pothole**
4. Bumps & Sags	**9. Lane / shoulder drop off**	**14. Rail road**
5. Corrugation	**10. long & trans cracking**	**15. Rutting**

DISTRESS	A=7200m²										TOTAL	DENSITY%	DEDUCT
SEVERITY	QUANTITY										TOTAL	DENSITY%	VALUE
1M	14*3.2	4.5*3.3	13*5	18*3.65	23*3.65	15*2.5	28*4.5	11*2.8	39*3.5		731.1	10.15	51.5

1H	9*2.8	28*3.65	6*2.85	9*7.2	16*3.6	18*3.6	20*5	13 *3.8	2.2*2.5	9*1.1	41*3.5	848.98	11.79	62
3M	2.5*2.5	3.5*2.5	8.5*3.6									45.6	0.63	1.5
3H	5*2.5	6*7.2	25*3.5									143.2	1.99	11.5
7M	3.64	48.1										51.74	0.72	5
7H	25											25	0.35	10
11M	15*2.4	2*1	15*3.6	5*3	7.5*4.5							140	1.94	15.8
10M	12	8.2	1.5	2.3	0.5	0.6	10	3	48.1	4	3.65	93.85	1.30	5.5
13M	4											4	0.06	7
19M	1.8*4.8	2*1.1										10.84	0.15	4.5

m= 1+ (9/98)(100-HDV)≤ 10   4.4898   ≤ 10   Ok   m = 4.49   < 7   0.49 * 4.5 = 2.21

No	DEDUCT VALUE											TOTAL	q	CDV
1	62	51.5	15.8	11.5	7	5.5	5	2.21				160.51	8	72
2	62	51.5	15.8	11.5	7	5.5	5	2				160.3	7	75
3	62	51.5	15.8	11.5	7	5.5	2	2				157.3	6	78
4	62	51.5	15.8	11.5	7	2	2	2				153.8	5	83
5	62	51.5	15.8	11.5	2	2	2	2				148.8	4	84
6	62	51.5	15.8	2	2	2	2	2				139.3	3	83
7	62	51.5	2	2	2	2	2	2				125.5	2	74
8	62	2	2	2	2	2	2	2				74	1	75

max CDV = 84

PCI = 100 - max CDV   ,   PCI =   16

PCR = SERIOUS

ASPHALT SURFACE ROAD AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH ……………….…. SECTION ……………….…... SAMPLE UNIT …..……..   **9**

SURVEYED BY ………….……….. DATE ……………………….. SAMPLE AREA …………   **7200m2**

1. Alligator Cracking	**6. Depression**	**11. patching & util cut patching**
2. Bleeding	**7. Edge Cracking**	**12. polished aggregate**
3. Block Cracking	**8. Jt. Reflection cracking**	**13. pothole**
4. Bumps & Sags	**9. Lane / shoulder drop off**	**14. Rail road**
5. Corrugation	**10. long & trans cracking**	**15. Rutting**

DISTRESS	$A=7200m^2$			DEDUCT
SEVERITY	QUANTITY	TOTAL	DENSITY%	VALUE

1L	6*2.8	9*7.2	16*3	8*3.6	10*5							208.4	2.894444	20
1M	14*6	7*3.3	13*5	21*3.65	15*3.65	8*2.5	8*3	19*3	29*3.5			731.1	10.15417	51.5
1H	9*2.8	28*3.65	6*2.85	9*7.2	16*3.6	18*3.6	20*5	13 *3.8	2.2*2.5	9*2	20*3.5	848.98	11.79139	62
3M	2.5*2.5	3.5*2.5	8.5*3.6									45.6	0.633333	1.5
3H	5*2.5	6*7.2	25*3.5									143.2	1.988889	11.5
7M	3.64	48.1										51.74	0.718611	5
7H	25											25	0.347222	9
11M	15*2.4	2*1	15*3.6	5*3	7.5*4.5	20*3.6						212	2.944444	18
10M	12	8.2	1.5	2.3	0.5	0.6	10	3	48.1	4	3.65	93.85	1.303472	5.5
12M	5*2.5	3.5*3	8*3.6									51.8	0.719444	0
13L	3											3	0.041667	10
13M	2											2	0.027778	15
19M	1.8*4.8	2*1.1										10.84	0.150556	4.5

m= 1+ (9/98)(100-HDV)≤ 10 4.489796 ≤ 10 Ok m = 4.49 < 11 0.49 * 4.5 = 2.21

No	DEDUCT VALUE												TOTAL	q	CDV
1	62	51.5	20	18	15	11.5	10	9	5.5	5	4.5	1.5	213.5	12	…
2	62	51.5	20	18	15	11.5	10	9	5.5	5	2.21	1.5	211.21	11	…
3	62	51.5	20	18	15	11.5	10	9	5.5	5	2	1.5	211	10	…
4	62	51.5	20	18	15	11.5	10	9	5.5	2	2	1.5	208	9	…
5	62	51.5	20	18	15	11.5	10	9	2	2	2	1.5	204.5	8	…
6	62	51.5	20	18	15	11.5	10	2	2	2	2	1.5	197.5	7	82.5
7	62	51.5	20	18	15	11.5	2	2	2	2	2	1.5	189.5	6	86
8	62	51.5	20	18	15	2	2	2	2	2	2	1.5	180	5	86.5
9	62	51.5	20	18	2	2	2	2	2	2	2	1.5	167	4	90
10	62	51.5	20	2	2	2	2	2	2	2	2	1.5	151	3	85
11	62	51.5	2	2	2	2	2	2	2	2	2	1.5	133	2	87
12	62	2	2	2	2	2	2	2	2	2	2	1.5	83.5	1	84

PCI = 100 - max CDV , PCI = 10 **max CDV= 90**

ASPHALT SURFACE ROAD AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	
BRANCH ……………….…. SECTION ………………….…. SAMPLE UNIT …..………	10
SURVEYED BY ………….……….. DATE ……………………….. SAMPLE AREA …………	7200m2

1. Alligator Cracking	6. Depression	11. patching & util cut patching
2. Bleeding	7. Edge Cracking	12. polished aggregate
3. Block Cracking	8. Jt. Reflection cracking	13. pothole
4. Bumps & Sags	9. Lane / shoulder drop off	14. Rail road
5. Corrugation	10. long & trans cracking	15. Rutting

DISTRESS	A=7200m^2															DEDUCT
SEVERITY	QUANTITY													TOTAL	DENSITY%	VALUE
1L	52*3.65	13*2.5	20*2	5*1	29*7.6	5*1								466.31	6.476528	41.5
1M	64*7.2	4*1	9*2.5	27*7.2	18*1	30*1.5	3*3.5*2	9.6*1.5	4.5*1.5	12*3.65	14*3.65	12*2	34*7.2	1151.4	15.99167	62
10M	4.5													4.5	0.0625	0
10H	8	5.7	4	1.5	5	2.8	13							40	0.555556	2

m= 1+ (9/98)(100-HDV)≤ 10 4.4898 ≤ 10 Ok m = 4.49 > 4

No	DEDUCT VALUE													TOTAL	q	CDV
1	62	41.5	2											105.5	2	76
2	62	2	2											66	1	65

max CDV = 76

PCI = 100 - max CDV , PCI = 24

PCR = VERY POOR

Appendix B: Traffic Flow Data

TIME-----	RECORD ONE						
s/no	category	PCE	PCE	Time taken b/n	Base	speed	speed
		Converter		entry &exit(sec)	length(m)	(m/s)	(Km/hr)
1	bajaj	0.8	0.8	5	54	10.800	38.880
2	bajaj	0.8	0.8	5	54	10.800	38.880
3	bajaj	0.8	0.8	5	54	10.800	38.880
4	bajaj	0.8	0.8	6	54	9.000	32.400
5	bajaj	0.8	0.8	4	54	13.500	48.600
6	bajaj	0.8	0.8	6	54	9.000	32.400
7	bajaj	0.8	0.8	6	54	9.000	32.400
8	bajaj	0.8	0.8	4	54	13.500	48.600
9	bajaj	0.8	0.8	5	54	10.800	38.880
10	bajaj	0.8	0.8	6	54	9.000	32.400
11	bajaj	0.8	0.8	4	54	13.500	48.600
12	bajaj	0.8	0.8	6	54	9.000	32.400
13	bajaj	0.8	0.8	5	54	10.800	38.880
14	bajaj	0.8	0.8	6	54	9.000	32.400
15	bajaj	0.8	0.8	4	54	13.500	48.600
16	bajaj	0.8	0.8	4	54	13.500	48.600
17	light	1	1	5	54	10.800	38.880
18	light	1	1	6	54	9.000	32.400
19	light	1	1	4	54	13.500	48.600
20	light	1	1	6	54	9.000	32.400
21	light	1	1	6	54	9.000	32.400
22	light	1	1	4	54	13.500	48.600
23	light	1	1	6	54	9.000	32.400
24	car	1	1	6	54	9.000	32.400
25	car	1	1	5	54	10.800	38.880
26	car	1	1	6	54	9.000	32.400
27	car	1	1	4	54	13.500	48.600
28	car	1	1	5	54	10.800	38.880
29	car	1	1	5	54	10.800	38.880
30	car	1	1	4	54	13.500	48.600
31	car	1	1	6	54	9.000	32.400
32	car	1	1	6	54	9.000	32.400
33	car	1	1	4	54	13.500	48.600
34	car	1	1	4	54	13.500	48.600
35	car	1	1	6	54	9.000	32.400
36	car	1	1	5	54	10.800	38.880
37	car	1	1	4	54	13.500	48.600
38	car	1	1	6	54	9.000	32.400
39	car	1	1	5	54	10.800	38.880
40	car	1	1	4	54	13.500	48.600
41	car	1	1	6	54	9.000	32.400
42	car	1	1	6	54	9.000	32.400
43	car	1	1	4	54	13.500	48.600
44	car	1	1	4	54	13.500	48.600
45	car	1	1	6	54	9.000	32.400

46	car	1	1	4	54	13.500	48.600
47	car	1	1	5	54	10.800	38.880
48	car	1	1	4	54	13.500	48.600
49	car	1	1	5	54	10.800	38.880
50	car	1	1	5	54	10.800	38.880
51	car	1	1	4	54	13.500	48.600
52	car	1	1	6	54	9.000	32.400
53	car	1	1	6	54	9.000	32.400
54	car	1	1	4	54	13.500	48.600
55	car	1	1	4	54	13.500	48.600
56	car	1	1	6	54	9.000	32.400
57	car	1	1	6	54	9.000	32.400
58	car	1	1	6	54	9.000	32.400
59	car	1	1	5	54	10.800	38.880
60	medium	2.5	2.5	5	54	10.800	38.880
61	medium	2.5	2.5	4	54	13.500	48.600
62	medium	2.5	2.5	5	54	10.800	38.880
63	medium	2.5	2.5	5	54	10.800	38.880
64	light	1	1	5	54	10.800	38.880
65	light	1	1	6	54	9.000	32.400
66	light	1	1	7	54	7.714	27.771
67	light	1	1	5	54	10.800	38.880
68	light	1	1	6	54	9.000	32.400
69	light	1	1	5	54	10.800	38.880
70	light	1	1	5	54	9.000	32.400

	TOTA		**72.8**	**357**			
					Sm	**39.138**	**Km/hr**
					SMS	**39.642**	**Km/hr**
					SD	**6.849**	

RECORD TWO

	category	PCE Converter	PCE	Time taken b/n entry &exit(sec)	Base length(m)	speed (m/s)	speed (Km/hr)
1	bajaj	0.8	0.8	5	54	10.800	38.880
2	Bajaaj	0.8	0.8	5	54	10.800	38.880
3	bajaaj	0.8	0.8	6	54	9.000	32.400
4	bajaaj	0.8	0.8	6	54	9.000	32.400
5	bajaaj	0.8	0.8	8	54	6.750	24.300
6	bajaaj	0.8	0.8	6	54	9.000	32.400
7	bajaaj	0.8	0.8	5	54	10.800	38.880
8	bajaaj	0.8	0.8	6	54	9.000	32.400
9	bajaaj	0.8	0.8	6	54	9.000	32.400
10	bajaaj	0.8	0.8	5	54	10.800	38.880
11	bajaaj	0.8	0.8	6	54	9.000	32.400
12	bajaaj	0.8	0.8	5	54	10.800	38.880
13	bajaaj	0.8	0.8	6	54	9.000	32.400
14	bajaaj	0.8	0.8	5	54	10.800	38.880
15	bajaaj	0.8	0.8	6	54	9.000	32.400
16	bajaaj	0.8	0.8	6	54	9.000	32.400
17	bajaaj	0.8	0.8	6	54	9.000	32.400
18	bajaaj	0.8	0.8	5	54	10.800	38.880

19	bajaaj	0.8	0.8	6	54	9.000	32.400
20	bajaaj	0.8	0.8	5	54	10.800	38.880
21	bajaaj	0.8	0.8	6	54	9.000	32.400
22	light	2	2	5	54	10.800	38.880
23	light	2	2	5	54	10.800	38.880
24	light	2	2	4	54	13.500	48.600
25	light	1	1	5	54	10.800	38.880
26	light	1	1	4	54	13.500	48.600
27	light	1	1	5	54	10.800	38.880
28	car	1	1	5	54	10.800	38.880
29	car	1	1	4	54	13.500	48.600
30	car	1	1	5	54	10.800	38.880
31	car	1	1	4	54	13.500	48.600
32	car	1	1	4	54	13.500	48.600
33	car	1	1	5	54	10.800	38.880
34	car	1	1	5	54	10.800	38.880
35	car	1	1	6	54	9.000	32.400
36	car	1	1	5	54	10.800	38.880
37	car	1	1	4	54	13.500	48.600
38	car	1	1	5	54	10.800	38.880
39	car	1	1	6	54	9.000	32.400
40	car	1	1	5	54	10.800	38.880
41	car	1	1	4	54	13.500	48.600
42	car	1	1	5	54	10.800	38.880
43	car	1	1	4	54	13.500	48.600

44	car	1	1	5	54	10.800	38.880
45	car	1	1	5	54	10.800	38.880
46	car	1	1	5	54	10.800	38.880
47	car	1	1	6	54	9.000	32.400
48	car	1	1	5	54	10.800	38.880
49	car	1	1	5	54	10.800	38.880
50	car	1	1	5	54	10.800	38.880
51	car	1	1	6	54	9.000	32.400
52	car	1	1	4	54	13.500	48.600
53	car	1	1	4	54	13.500	48.600
54	car	1	1	5	54	10.800	38.880
55	car	1	1	5	54	10.800	38.880
56	car	1	1	4	54	13.500	48.600
57	car	1	1	4	54	13.500	48.600
58	car	1	1	5	54	10.800	38.880
59	car	1	1	5	54	10.800	38.880
60	car	1	1	6	54	9.000	32.400
61	car	1	1	6	54	9.000	32.400
62	car	1	1	5	54	10.800	38.880
63	car	1	1	5	54	10.800	38.880
64	car	1	1	4	54	13.500	48.600
65	car	1	1	5	54	10.800	38.880
66	car	1	1	3	54	18.000	64.800
67	car	1	1	6	54	9.000	32.400
68	medium	2.5	2.5	5	54	10.800	38.880

69	medium	2.5	2.5	6	54	9.000	32.400
70	car	1	1	6	54	9.000	32.400
71	car	1	1	5	54	10.800	38.880
72	car	1	1	5	54	10.800	38.880
73	car	1	1	6	54	9.000	32.400
	TOTAL		**72.8**	**375**			
					Sm	**38.903**	**Km/hr**
					SMS	**37.740**	**Km/hr**
					SD	**6.540**	
TIME	**RECORD THREE**						
s/no	**category**	**PCE**	**PCE**	**Time taken b/n**	**Base**	**speed**	**speed**
		Converter		**entry &exit(sec)**	**length(m)**	**(m/s)**	**(Km/hr)**
1	bajaj	0.8	0.8	7	54	7.714	27.771
2	bajaj	0.8	0.8	8	54	6.750	24.300
3	bajaj	0.8	0.8	6	54	9.000	32.400
4	bajaj	0.8	0.8	4	54	13.500	48.600
5	bajaj	0.8	0.8	8	54	6.750	24.300
6	bajaj	0.8	0.8	5	54	10.800	38.880
7	bajaj	0.8	0.8	5	54	10.800	38.880
8	bajaj	0.8	0.8	6	54	9.000	32.400
9	bajaj	0.8	0.8	6	54	9.000	32.400
10	bajaj	0.8	0.8	6	54	9.000	32.400
11	bajaj	0.8	0.8	6	54	9.000	32.400
12	bajaj	0.8	0.8	7	54	7.714	27.771
13	bajaj	0.8	0.8	6	54	9.000	32.400

14	bajaj	0.8	0.8	6	54	9.000	32.400
15	bajaj	0.8	0.8	4	54	13.500	48.600
16	bajaj	0.8	0.8	4	54	13.500	48.600
17	bajaj	0.8	0.8	8	54	6.750	24.300
18	bajaj	0.8	0.8	5	54	10.800	38.880
19	bajaj	0.8	0.8	5	54	10.800	38.880
20	bajaj	0.8	0.8	6	54	9.000	32.400
21	bajaj	0.8	0.8	9	54	6.000	21.600
22	bajaj	0.8	0.8	6	54	9.000	32.400
23	bajaj	0.8	0.8	4	54	13.500	48.600
24	bajaj	0.8	0.8	4	54	13.500	48.600
25	bajaj	0.8	0.8	8	54	6.750	24.300
26	bajaj	0.8	0.8	6	54	9.000	32.400
27	bajaj	0.8	0.8	9	54	6.000	21.600
28	bajaj	0.8	0.8	6	54	9.000	32.400
29	bajaj	0.8	0.8	4	54	13.500	48.600
30	bajaj	0.8	0.8	6	54	9.000	32.400
31	bajaj	0.8	0.8	6	54	9.000	32.400
32	bajaj	0.8	0.8	4	54	13.500	48.600
33	bajaj	0.8	0.8	6	54	9.000	32.400
34	bajaj	0.8	0.8	5	54	10.800	38.880
35	bajaj	0.8	0.8	5	54	10.800	38.880
36	bajaj	0.8	0.8	5	54	10.800	38.880
37	car	1	1	4	54	13.500	48.600
38	car	1	1	4	54	13.500	48.600

39	light	1	1	5	54	10.800	38.880
40	light	1	1	4	54	13.500	48.600
41	light	1	1	5	54	10.800	38.880
42	light	1	1	4	54	13.500	48.600
43	car	1	1	6	54	9.000	32.400
44	car	1	1	6	54	9.000	32.400
45	car	1	1	6	54	9.000	32.400
46	car	1	1	6	54	9.000	32.400
47	car	1	1	5	54	10.800	38.880
48	car	1	1	7	54	7.714	27.771
49	car	1	1	6	54	9.000	32.400
50	car	1	1	5	54	10.800	38.880
51	car	1	1	5	54	10.800	38.880
52	car	1	1	5	54	10.800	38.880
53	car	1	1	5	54	10.800	38.880
54	car	1	1	6	54	9.000	32.400
55	car	1	1	6	54	9.000	32.400
56	car	1	1	4	54	13.500	48.600
57	car	1	1	4	54	13.500	48.600
58	car	1	1	4	54	13.500	48.600
59	car	1	1	4	54	13.500	48.600
60	car	1	1	5	54	10.800	38.880
61	car	1	1	5	54	10.800	38.880
62	car	1	1	7	54	7.714	27.771
63	car	1	1	9	54	6.000	21.600

64	car	1	1	4	54	13.500	48.600
65	car	1	1	5	54	10.800	38.880
66	car	1	1	7	54	7.714	27.771
67	car	1	1	6	54	9.000	32.400
68	car	1	1	5	54	10.800	38.880
69	car	1	1	5	54	10.800	38.880
70	car	1	1	5	54	10.800	38.880
71	Motorcyle	0.5	0.5	5	54	10.800	38.880
72	motorcyle	0.5	0.5	5	54	10.800	38.880
73	car	1	1	4	54	13.500	48.600
74	car	1	1	4	54	13.500	48.600
75	light	1	1	5	54	10.800	38.880
76	light	1	1	6	54	9.000	32.400
77	light	1	1	6	54	9.000	32.400
78	light	1	1	5	54	10.800	38.880
79	light	1	1	5	54	10.800	38.880
80	light	1	1	5	54	10.800	38.880
81	light	1	1	4	54	13.500	48.600
			72.8	**444**			
					Sm	**37.974**	**Km/hr**
					SMS	**31.875**	**Km/hr**
					SD	**7.796**	
TIME-----	**RECORD FOUR**						
s/no		**PCE**	**PCE**	**Time taken b/n**	**Base**	**speed**	**speed**

		Converter		entry &exit(sec)	length(m)	(m/s)	(Km/hr)
1	bajaj	0.8	0.8	5	54	10.800	38.880
2	bajaj	0.8	0.8	4	54	13.500	48.600
3	bajaj	0.8	0.8	5	54	10.800	38.880
4	bajaj	0.8	0.8	6	54	9.000	32.400
5	bajaj	0.8	0.8	5	54	10.800	38.880
6	bajaj	0.8	0.8	5	54	10.800	38.880
7	bajaj	0.8	0.8	6	54	9.000	32.400
8	bajaj	0.8	0.8	6	54	9.000	32.400
9	bajaj	0.8	0.8	6	54	9.000	32.400
10	bajaj	0.8	0.8	5	54	10.800	38.880
11	bajaj	0.8	0.8	4	54	13.500	48.600
12	bajaj	0.8	0.8	5	54	10.800	38.880
13	bajaj	0.8	0.8	4	54	13.500	48.600
14	bajaj	0.8	0.8	4	54	13.500	48.600
15	bajaj	0.8	0.8	5	54	10.800	38.880
16	bajaj	0.8	0.8	6	54	9.000	32.400
17	bajaj	0.8	0.8	5	54	10.800	38.880
18	bajaj	0.8	0.8	5	54	10.800	38.880
19	bajaj	0.8	0.8	6	54	9.000	32.400
20	bajaj	0.8	0.8	4	54	13.500	48.600
21	bajaj	0.8	0.8	5	54	10.800	38.880
22	bajaj	0.8	0.8	4	54	13.500	48.600
23	bajaj	0.8	0.8	5	54	10.800	38.880
24	bajaj	0.8	0.8	5	54	10.800	38.880
25	bajaj	0.8	0.8	5	54	10.800	38.880
26	bajaj	0.8	0.8	5	54	10.800	38.880
27	bajaj	0.8	0.8	5	54	10.800	38.880
28	bajaj	0.8	0.8	6	54	9.000	32.400
29	bajaj	0.8	0.8	5	54	10.800	38.880
30	bajaj	0.8	0.8	5	54	10.800	38.880
31	bajaj	0.8	0.8	6	54	9.000	32.400
32	bajaj	0.8	0.8	5	54	10.800	38.880
33	car	1	1	5	54	10.800	38.880
34	car	1	1	6	54	9.000	32.400
35	car	1	1	6	54	9.000	32.400
36	car	1	1	6	54	9.000	32.400
37	car	1	1	5	54	10.800	38.880
38	car	1	1	5	54	10.800	38.880
39	car	1	1	5	54	10.800	38.880
40	light	1	1	5	54	10.800	38.880
41	light	1	1	6	54	9.000	32.400
42	car	1	1	5	54	10.800	38.880
43	car	1	1	5	54	10.800	38.880
44	light	1	1	4	54	13.500	48.600
45	car	1	1	6	54	9.000	32.400
46	car	1	1	6	54	9.000	32.400
47	light	1	1	6	54	9.000	32.400
48	car	1	1	5	54	10.800	38.880
49	car	1	1	5	54	10.800	38.880

50	car	1	1	6	54	9.000	32.400
51	car	1	1	5	54	10.800	38.880
52	car	1	1	4	54	13.500	48.600
53	car	1	1	4	54	13.500	48.600
54	car	1	1	5	54	10.800	38.880
55	car	1	1	5	54	10.800	38.880
56	car	1	1	4	54	13.500	48.600
57	car	1	1	4	54	13.500	48.600
58	car	1	1	6	54	9.000	32.400
59	car	1	1	6	54	9.000	32.400
60	car	1	1	6	54	9.000	32.400
61	car	1	1	5	54	10.800	38.880
62	car	1	1	4	54	13.500	48.600
63	car	1	1	4	54	13.500	48.600
64	car	1	1	4	54	13.500	48.600
65	car	1	1	6	54	9.000	32.400
66	car	1	1	7	54	7.714	27.771
67	car	1	1	4	54	13.500	48.600
68	car	1	1	6	54	9.000	32.400
69	car	1	1	7	54	7.714	27.771
70	car	1	1	5	54	10.800	38.880
71	car	1	1	4	54	13.500	48.600
72	car	1	1	5	54	10.800	38.880
73	car	1	1	6	54	9.000	32.400
74	car	1	1	4	54	13.500	48.600

75	car	1	1	5	54	10.800	38.880
76	car	1	1	5	54	10.800	38.880
77	car	1	1	5	54	10.800	38.880
78	car	1	1	4	54	13.500	48.600
79	car	1	1	3	54	18.000	64.800
80	car	1	1	4	54	13.500	48.600
81	car	1	1	5	54	10.800	38.880
82	light	1	1	4	54	13.500	48.600
83	light	1	1	4	54	13.500	48.600
84	light	1	1	6	54	9.000	32.400
85	light	1	1	5	54	10.800	38.880
	TOTAL		**72.8**	**429**			
					Sm	**39.337**	**Km/hr**
					SMS	**32.989**	**Km/hr**
					SD	**6.925**	
TIME-----	**RECORD FIVE**						
s/no		**PCE**	**PCE**	**Time taken b/n**	**Base**	**speed**	**speed**
		Converter		**entry &exit(sec)**	**length(m)**	**(m/s)**	**(Km/hr)**
1	bajaj	0.8	0.8	7	54	7.714	27.771
2	bajaj	0.8	0.8	6	54	9.000	32.400
3	bajaj	0.8	0.8	6	54	9.000	32.400
4	bajaj	0.8	0.8	5	54	10.800	38.880
5	bajaj	0.8	0.8	6	54	9.000	32.400
6	bajaj	0.8	0.8	6	54	9.000	32.400
7	bajaj	0.8	0.8	7	54	7.714	27.771

8	bajaj	0.8	0.8	5	54	10.800	38.880
9	bajaj	0.8	0.8	6	54	9.000	32.400
10	bajaj	0.8	0.8	5	54	10.800	38.880
11	bajaj	0.8	0.8	5	54	10.800	38.880
12	bajaj	0.8	0.8	6	54	9.000	32.400
13	bajaj	0.8	0.8	5	54	10.800	38.880
14	bajaj	0.8	0.8	4	54	13.500	48.600
15	bajaj	0.8	0.8	5	54	10.800	38.880
16	bajaj	0.8	0.8	6	54	9.000	32.400
17	bajaj	0.8	0.8	7	54	7.714	27.771
18	bajaj	0.8	0.8	5	54	10.800	38.880
19	bajaj	0.8	0.8	5	54	10.800	38.880
20	bajaj	0.8	0.8	5	54	10.800	38.880
21	bajaj	0.8	0.8	5	54	10.800	38.880
22	light	2	2	5	54	10.800	38.880
23	light	2	2	6	54	9.000	32.400
24	light	2	2	8	54	6.750	24.300
25	light	1	1	7	54	7.714	27.771
26	light	1	1	6	54	9.000	32.400
27	light	1	1	7	54	7.714	27.771
28	light	1	1	6	54	9.000	32.400
29	car	1	1	7	54	7.714	27.771
30	car	1	1	7	54	7.714	27.771
31	car	1	1	4	54	13.500	48.600
32	car	1	1	4	54	13.500	48.600

33	car	1	1	5	54	10.800	38.880
34	car	1	1	5	54	10.800	38.880
35	car	1	1	5	54	10.800	38.880
36	car	1	1	5	54	10.800	38.880
37	car	1	1	6	54	9.000	32.400
38	car	1	1	5	54	10.800	38.880
39	car	1	1	5	54	10.800	38.880
40	car	1	1	5	54	10.800	38.880
41	car	1	1	4	54	13.500	48.600
42	car	1	1	5	54	10.800	38.880
43	car	1	1	7	54	7.714	27.771
44	car	1	1	6	54	9.000	32.400
45	car	1	1	5	54	10.800	38.880
46	car	1	1	7	54	7.714	27.771
47	car	1	1	5	54	10.800	38.880
48	car	1	1	5	54	10.800	38.880
49	car	1	1	8	54	6.750	24.300
50	car	1	1	6	54	9.000	32.400
51	car	1	1	4	54	13.500	48.600
52	car	1	1	4	54	13.500	48.600
53	car	1	1	5	54	10.800	38.880
54	car	1	1	5	54	10.800	38.880
55	car	1	1	6	54	9.000	32.400
56	car	1	1	6	54	9.000	32.400
57	car	1	1	5	54	10.800	38.880

58	car	1	1	6	54	9.000	32.400
59	car	1	1	5	54	10.800	38.880
60	motorcycle	0.5	0.5	5	54	10.800	38.880
61	motorcycle	0.5	0.5	4	54	13.500	48.600
62	car	1	1	3	54	18.000	64.800
63	car	1	1	4	54	13.500	48.600
64	car	1	1	4	54	13.500	48.600
65	car	1	1	5	54	10.800	38.880
66	medium	2.5	2.5	5	54	10.800	38.880
67	medium	2.5	2.5	5	54	10.800	38.880
68	car	1	1	6	54	9.000	32.400
69	car	1	1	6	54	9.000	32.400
70	car	1	1	5	54	10.800	38.880
71	car	1	1	6	54	9.000	32.400
72	car	1	1	5	54	10.800	38.880
			72.8	**392**			
					Sm	**36.951**	**Km/hr**
					SMS	**36.103**	**Km/hr**
					SD	**7.109**	

TIME----- **RECORD SIX**

s/no		PCE Converter	PCE	Time taken b/n entry &exit(sec)	Base length(m)	speed (m/s)	speed (Km/hr)
1	bajaj	0.8	0.8	5	54	10.800	38.880
2	bajaj	0.8	0.8	6	54	9.000	32.400
3	bajaj	0.8	0.8	5	54	10.800	38.880
4	bajaj	0.8	0.8	5	54	10.800	38.880
5	bajaj	0.8	0.8	6	54	9.000	32.400
6	bajaj	0.8	0.8	6	54	9.000	32.400
7	bajaj	0.8	0.8	6	54	9.000	32.400
8	bajaj	0.8	0.8	5	54	10.800	38.880
9	bajaj	0.8	0.8	8	54	6.750	24.300
10	bajaj	0.8	0.8	8	54	6.750	24.300
11	bajaj	0.8	0.8	4	54	13.500	48.600
12	bajaj	0.8	0.8	6	54	9.000	32.400
13	bajaj	0.8	0.8	6	54	9.000	32.400
14	bajaj	0.8	0.8	5	54	10.800	38.880
15	bajaj	0.8	0.8	4	54	13.500	48.600
16	bajaj	0.8	0.8	8	54	6.750	24.300
17	bajaj	0.8	0.8	6	54	9.000	32.400
18	bajaj	0.8	0.8	6	54	9.000	32.400
19	bajaj	0.8	0.8	5	54	10.800	38.880
20	bajaj	0.8	0.8	4	54	13.500	48.600
21	bajaj	0.8	0.8	4	54	13.500	48.600
22	car	1	1	6	54	9.000	32.400
23	car	1	1	5	54	10.800	38.880
24	car	1	1	6	54	9.000	32.400
25	car	1	1	4	54	13.500	48.600
26	light	1	1	5	54	10.800	38.880
27	light	1	1	5	54	10.800	38.880

28	light	1	1	7	54	7.714	27.771
29	light	1	1	5	54	10.800	38.880
30	light	1	1	5	54	10.800	38.880
31	light	1	1	5	54	10.800	38.880
32	light	1	1	6	54	9.000	32.400
33	light	1	1	7	54	7.714	27.771
34	light	1	1	5	54	10.800	38.880
35	light	1	1	5	54	10.800	38.880
36	car	1	1	5	54	10.800	38.880
37	car	1	1	5	54	10.800	38.880
38	car	1	1	5	54	10.800	38.880
39	car	1	1	6	54	9.000	32.400
40	car	1	1	8	54	6.750	24.300
41	car	1	1	5	54	10.800	38.880
42	car	1	1	5	54	10.800	38.880
43	car	1	1	5	54	10.800	38.880
44	car	1	1	4	54	13.500	48.600
45	car	1	1	5	54	10.800	38.880
46	car	1	1	4	54	13.500	48.600
47	car	1	1	6	54	9.000	32.400
48	car	1	1	5	54	10.800	38.880
49	car	1	1	5	54	10.800	38.880
50	car	1	1	6	54	9.000	32.400
51	car	1	1	8	54	6.750	24.300
52	car	1	1	6	54	9.000	32.400
53	car	1	1	7	54	7.714	27.771
54	car	1	1	8	54	6.750	24.300
55	car	1	1	8	54	6.750	24.300
56	car	1	1	4	54	13.500	48.600
57	car	1	1	6	54	9.000	32.400
58	car	1	1	4	54	13.500	48.600
59	car	1	1	4	54	13.500	48.600
60	car	1	1	4	54	13.500	48.600
61	car	1	1	6	54	9.000	32.400
62	car	1	1	6	54	9.000	32.400
63	car	1	1	5	54	10.800	38.880
64	car	1	1	5	54	10.800	38.880
65	car	1	1	6	54	9.000	32.400
66	car	1	1	8	54	6.750	24.300
67	car	1	1	5	54	10.800	38.880
68	car	1	1	5	54	10.800	38.880
69	car	1	1	5	54	10.800	38.880
70	motorcycle	0.5	0.5	6	54	9.000	32.400
71	motorcycle	0.5	0.5	5	54	9.000	32.400
72	car	1	1	6	54	9.000	32.400
73	car	1	1	5	54	10.800	38.880
74	car	1	1	5	54	10.800	38.880
75	car	1	1	6	54	9.000	32.400
76	car	1	1	3	54	18.000	64.800
77	car	1	1	6	54	9.000	32.400

78	light	1	1	6	54	9.000	32.400
	TOTAL		**72.8**	**432**			
					Sm	**36.584**	**Km/hr**
					SMS	**32.760**	**Km/hr**
					SD	**7.577**	
TIME-----	**RECORD SEVEN**						
s/no		**PCE**	**PCE**	**Time taken b/n**	**Base**	**speed**	**speed**
		Converter		**entry &exit(sec)**	**length(m)**	**(m/s)**	**(Km/hr)**
1	bajaj	0.8	0.8	7	54	7.714	27.771
2	bajaj	0.8	0.8	4	54	13.500	48.600
3	bajaj	0.8	0.8	6	54	9.000	32.400
4	bajaj	0.8	0.8	6	54	9.000	32.400
5	bajaj	0.8	0.8	5	54	10.800	38.880
6	bajaj	0.8	0.8	6	54	9.000	32.400
7	bajaj	0.8	0.8	5	54	10.800	38.880
8	bajaj	0.8	0.8	6	54	9.000	32.400
9	bajaj	0.8	0.8	6	54	9.000	32.400
10	bajaj	0.8	0.8	7	54	7.714	27.771
11	bajaj	0.8	0.8	9	54	6.000	21.600
12	bajaj	0.8	0.8	5	54	10.800	38.880
13	bajaj	0.8	0.8	4	54	13.500	48.600
14	bajaj	0.8	0.8	6	54	9.000	32.400
15	bajaj	0.8	0.8	5	54	10.800	38.880
16	bajaj	0.8	0.8	5	54	10.800	38.880
17	bajaj	0.8	0.8	6	54	9.000	32.400
18	bajaj	0.8	0.8	6	54	9.000	32.400
19	bajaj	0.8	0.8	7	54	7.714	27.771
20	bajaj	0.8	0.8	9	54	6.000	21.600
21	bajaj	0.8	0.8	5	54	10.800	38.880
22	bajaj	0.8	0.8	4	54	13.500	48.600
23	bajaj	0.8	0.8	6	54	9.000	32.400
24	bajaj	0.8	0.8	5	54	10.800	38.880
25	bajaj	0.8	0.8	6	54	9.000	32.400
26	bajaj	0.8	0.8	5	54	10.800	38.880
27	light	2	2	6	54	9.000	32.400
28	light	2	2	6	54	9.000	32.400
29	car	1	1	4	54	13.500	48.600
30	car	1	1	4	54	13.500	48.600
31	light	1	1	5	54	10.800	38.880
32	light	1	1	4	54	13.500	48.600
33	car	1	1	5	54	10.800	38.880
34	car	1	1	5	54	10.800	38.880
35	car	1	1	3	54	18.000	64.800
36	car	1	1	4	54	13.500	48.600
37	car	1	1	3	54	18.000	64.800
38	car	1	1	7	54	7.714	27.771
39	car	1	1	3	54	18.000	64.800
40	car	1	1	4	54	13.500	48.600
41	car	1	1	6	54	9.000	32.400
42	car	1	1	6	54	9.000	32.400

43	car	1	1	10	54	5.400	19.440
44	car	1	1	5	54	10.800	38.880
45	car	1	1	5	54	10.800	38.880
46	car	1	1	5	54	10.800	38.880
47	car	1	1	5	54	10.800	38.880
48	car	1	1	3	54	18.000	64.800
49	car	1	1	4	54	13.500	48.600
50	car	1	1	3	54	18.000	64.800
51	car	1	1	7	54	7.714	27.771
52	car	1	1	3	54	18.000	64.800
53	car	1	1	4	54	13.500	48.600
54	car	1	1	6	54	9.000	32.400
55	car	1	1	7	54	7.714	27.771
56	car	1	1	6	54	9.000	32.400
57	car	1	1	6	54	9.000	32.400
58	car	1	1	5	54	10.800	38.880
59	car	1	1	5	54	10.800	38.880
60	car	1	1	7	54	7.714	27.771
61	motorcycle	0.5	0.5	3	54	18.000	64.800
62	motorcycle	0.5	0.5	3	54	18.000	64.800
63	car	1	1	6	54	9.000	32.400
64	car	1	1	6	54	9.000	32.400
65	car	1	1	6	54	9.000	32.400
66	car	1	1	6	54	9.000	32.400
67	medium	2.5	2.5	4	54	13.500	48.600

68	medium	2.5	2.5	5	54	10.800	38.880
69	medium	2.5	2.5	5	54	10.800	38.880
70	medium	2.5	2.5	6	54	9.000	32.400
71	light	1	1	6	54	9.000	32.400
			72.8	**378**			
					Sm	**39.352**	**Km/hr**
					SMS	**37.440**	**Km/hr**
					SD	**11.466**	
	RECORD EIGHT						
s/no		**PCE**	**PCE**	**Time taken b/n**	**Base**	**speed**	**speed**
		Converter		**entry &exit(sec)**	**length(m)**	**(m/s)**	**(Km/hr)**
1	bajaj	0.8	0.8	5	54	10.800	38.880
2	bajaj	0.8	0.8	5	54	10.800	38.880
3	bajaj	0.8	0.8	5	54	10.800	38.880
4	bajaj	0.8	0.8	6	54	9.000	32.400
5	bajaj	0.8	0.8	4	54	13.500	48.600
6	bajaj	0.8	0.8	4	54	13.500	48.600
7	bajaj	0.8	0.8	6	54	9.000	32.400
8	bajaj	0.8	0.8	6	54	9.000	32.400
9	bajaj	0.8	0.8	5	54	10.800	38.880
10	bajaj	0.8	0.8	6	54	9.000	32.400
11	bajaj	0.8	0.8	7	54	7.714	27.771
12	bajaj	0.8	0.8	6	54	9.000	32.400
13	bajaj	0.8	0.8	6	54	9.000	32.400
14	bajaj	0.8	0.8	4	54	13.500	48.600

15	bajaj	0.8	0.8	4	54	13.500	48.600
16	bajaj	0.8	0.8	4	54	13.500	48.600
17	bajaj	0.8	0.8	6	54	9.000	32.400
18	bajaj	0.8	0.8	4	54	13.500	48.600
19	bajaj	0.8	0.8	4	54	13.500	48.600
20	bajaj	0.8	0.8	4	54	13.500	48.600
21	bajaj	0.8	0.8	4	54	13.500	48.600
22	bajaj	0.8	0.8	6	54	9.000	32.400
23	bajaj	0.8	0.8	6	54	9.000	32.400
24	bajaj	0.8	0.8	4	54	13.500	48.600
25	bajaj	0.8	0.8	5	54	10.800	38.880
26	bajaj	0.8	0.8	5	54	10.800	38.880
27	light	2	2	6	54	9.000	32.400
28	car	1	1	5	54	10.800	38.880
29	car	1	1	4	54	13.500	48.600
30	light	1	1	5	54	10.800	38.880
31	light	1	1	7	54	7.714	27.771
32	car	1	1	4	54	13.500	48.600
33	car	1	1	6	54	9.000	32.400
34	car	1	1	7	54	7.714	27.771
35	car	1	1	5	54	10.800	38.880
36	car	1	1	6	54	9.000	32.400
37	car	1	1	4	54	13.500	48.600
38	car	1	1	6	54	9.000	32.400
39	car	1	1	6	54	9.000	32.400

40	car	1	1	6	54	9.000	32.400
41	car	1	1	4	54	13.500	48.600
42	car	1	1	4	54	13.500	48.600
43	car	1	1	3	54	18.000	64.800
44	car	1	1	4	54	13.500	48.600
45	car	1	1	3	54	18.000	64.800
46	car	1	1	6	54	9.000	32.400
47	car	1	1	5	54	10.800	38.880
48	car	1	1	5	54	10.800	38.880
49	car	1	1	6	54	9.000	32.400
50	car	1	1	5	54	10.800	38.880
51	car	1	1	6	54	9.000	32.400
52	car	1	1	5	54	10.800	38.880
53	car	1	1	7	54	7.714	27.771
54	car	1	1	5	54	10.800	38.880
55	car	1	1	6	54	9.000	32.400
56	car	1	1	4	54	13.500	48.600
57	car	1	1	6	54	9.000	32.400
58	car	1	1	4	54	13.500	48.600
59	car	1	1	4	54	13.500	48.600
60	car	1	1	4	54	13.500	48.600
61	car	1	1	3	54	18.000	64.800
62	car	1	1	4	54	13.500	48.600
63	car	1	1	4	54	13.500	48.600
64	car	1	1	5	54	10.800	38.880

65	car	1	1	6	54	9.000	32.400
66	car	1	1	6	54	9.000	32.400
67	car	1	1	5	54	10.800	38.880
68	medium	2.5	2.5	5	54	10.800	38.880
69	medium	2.5	2.5	5	54	10.800	38.880
70	medium	2.5	2.5	6	54	9.000	32.400
71	medium	2.5	2.5	7	54	7.714	27.771
			72.8	**360**			
					Sm	**40.441**	**Km/hr**
					SMS	**39.312**	**Km/hr**
					SD	**9.307**	

TIME-----	**RECORD NINE**						
s/no		**PCE**	**PCE**	**Time taken b/n**	**Base**	**speed**	**speed**
		Converter		**entry &exit(sec)**	**length(m)**	**(m/s)**	**(Km/hr)**
1	bajaj	0.8	0.8	5	54	10.800	38.880
2	bajaj	0.8	0.8	4	54	13.500	48.600
3	bajaj	0.8	0.8	4	54	13.500	48.600
4	bajaj	0.8	0.8	6	54	9.000	32.400
5	bajaj	0.8	0.8	5	54	10.800	38.880
6	bajaj	0.8	0.8	6	54	9.000	32.400
7	bajaj	0.8	0.8	5	54	10.800	38.880
8	bajaj	0.8	0.8	5	54	10.800	38.880
9	bajaj	0.8	0.8	6	54	9.000	32.400
10	bajaj	0.8	0.8	7	54	7.714	27.771
11	bajaj	0.8	0.8	6	54	9.000	32.400
12	bajaj	0.8	0.8	3	54	18.000	64.800
13	bajaj	0.8	0.8	4	54	13.500	48.600
14	bajaj	0.8	0.8	5	54	10.800	38.880
15	bajaj	0.8	0.8	7	54	7.714	27.771
16	bajaj	0.8	0.8	4	54	13.500	48.600
17	bajaj	0.8	0.8	6	54	9.000	32.400
18	bajaj	0.8	0.8	5	54	10.800	38.880
19	bajaj	0.8	0.8	6	54	9.000	32.400
20	bajaj	0.8	0.8	7	54	7.714	27.771
21	bajaj	0.8	0.8	6	54	9.000	32.400
22	bajaj	0.8	0.8	6	54	9.000	32.400
23	bajaj	0.8	0.8	7	54	7.714	27.771
24	bajaj	0.8	0.8	6	54	9.000	32.400
27	bajaj	0.8	0.8	5	54	10.800	38.880
27	bajaj	0.8	0.8	5	54	10.800	38.880
28	medium	2.5	2.5	7	54	7.714	27.771
29	medium	2.5	2.5	8	54	6.750	24.300
30	car	1	1	4	54	13.500	48.600
31	car	1	1	4	54	13.500	48.600
32	car	1	1	5	54	10.800	38.880
33	car	1	1	5	54	10.800	38.880
34	light	1	1	5	54	10.800	38.880
35	light	1	1	6	54	9.000	32.400
36	light	1	1	5	54	10.800	38.880
37	light	1	1	6	54	9.000	32.400

38	car	1	1	6	54	9.000	32.400
39	car	1	1	4	54	13.500	48.600
40	car	1	1	5	54	10.800	38.880
41	car	1	1	5	54	10.800	38.880
42	car	1	1	4	54	13.500	48.600
43	car	1	1	5	54	10.800	38.880
44	car	1	1	3	54	18.000	64.800
45	car	1	1	4	54	13.500	48.600
46	car	1	1	5	54	10.800	38.880
47	car	1	1	4	54	13.500	48.600
51	car	1	1	9	54	6.000	21.600
52	car	1	1	5	54	10.800	38.880
53	car	1	1	6	54	9.000	32.400
57	car	1	1	5	54	10.800	38.880
58	car	1	1	5	54	10.800	38.880
59	car	1	1	4	54	13.500	48.600
60	car	1	1	5	54	10.800	38.880
61	car	1	1	4	54	13.500	48.600
62	car	1	1	5	54	10.800	38.880
63	car	1	1	4	54	13.500	48.600
64	car	1	1	5	54	10.800	38.880
65	car	1	1	3	54	18.000	64.800
66	motorcyle	0.5	0.5	3	54	18.000	64.800
67	motorcyle	0.5	0.5	5	54	10.800	38.880
68	car	1	1	6	54	9.000	32.400

69	car	1	1	6	54	9.000	32.400
70	car	1	1	5	54	10.800	38.880
72	medium	2.5	2.5	5	54	10.800	38.880
72	medium	2.5	2.5	6	54	9.000	32.400
72	medium	2.5	2.5	6	54	9.000	32.400
72	medium	2.5	2.5	5	54	10.800	38.880
73	light	1	1	5	54	10.800	38.880
74	light	1	1	6	54	9.000	32.400
75	car	1	1	5	54	10.800	38.880
			72.8	**364**			
					Sm	**39.251**	**Km/hr**
					SMS	**38.880**	**Km/hr**
					SD	**9.160**	
TIME-----	**RECORD TEN**						
s/no		**PCE**	**PCE**	**Time taken b/n**	**Base**	**speed**	**speed**
		Converter		**entry &exit(sec)**	**length(m)**	**(m/s)**	**(Km/hr)**
1	bajaj	0.8	0.8	6	54	9.000	32.400
2	bajaj	0.8	0.8	9	54	6.000	21.600
3	bajaj	0.8	0.8	4	54	13.500	48.600
4	bajaj	0.8	0.8	5	54	10.800	38.880
5	bajaj	0.8	0.8	5	54	10.800	38.880
6	bajaj	0.8	0.8	5	54	10.800	38.880
7	bajaj	0.8	0.8	4	54	13.500	48.600
8	bajaj	0.8	0.8	5	54	10.800	38.880
9	bajaj	0.8	0.8	6	54	9.000	32.400

10	bajaj	0.8	0.8	6	54	9.000	32.400
11	bajaj	0.8	0.8	6	54	9.000	32.400
16	bajaj	0.8	0.8	5	54	10.800	38.880
17	bajaj	0.8	0.8	6	54	9.000	32.400
12	bajaj	0.8	0.8	5	54	10.800	38.880
13	bajaj	0.8	0.8	4	54	13.500	48.600
14	bajaj	0.8	0.8	5	54	10.800	38.880
15	bajaj	0.8	0.8	4	54	13.500	48.600
16	bajaj	0.8	0.8	5	54	10.800	38.880
17	bajaj	0.8	0.8	6	54	9.000	32.400
18	bajaj	0.8	0.8	5	54	10.800	38.880
19	bajaj	0.8	0.8	5	54	10.800	38.880
20	bajaj	0.8	0.8	4	54	13.500	48.600
21	bajaj	0.8	0.8	5	54	10.800	38.880
22	bajaj	0.8	0.8	4	54	13.500	48.600
23	bajaj	0.8	0.8	5	54	10.800	38.880
24	bajaj	0.8	0.8	6	54	9.000	32.400
25	car	1	1	9	54	6.000	21.600
26	car	1	1	6	54	9.000	32.400
27	car	1	1	4	54	13.500	48.600
28	car	1	1	9	54	6.000	21.600
29	car	1	1	6	54	9.000	32.400
30	light	1	1	6	54	9.000	32.400
31	light	1	1	6	54	9.000	32.400
39	car	1	1	4	54	13.500	48.600

40	car	1	1	8	54	6.750	24.300
41	car	1	1	4	54	13.500	48.600
42	car	1	1	6	54	9.000	32.400
43	car	1	1	8	54	6.750	24.300
44	car	1	1	5	54	10.800	38.880
45	car	1	1	7	54	7.714	27.771
46	car	1	1	5	54	10.800	38.880
47	car	1	1	4	54	13.500	48.600
48	car	1	1	5	54	10.800	38.880
32	car	1	1	5	54	10.800	38.880
33	car	1	1	3	54	18.000	64.800
34	car	1	1	4	54	13.500	48.600
35	car	1	1	5	54	10.800	38.880
36	car	1	1	6	54	9.000	32.400
37	car	1	1	6	54	9.000	32.400
38	car	1	1	4	54	13.500	48.600
39	car	1	1	4	54	13.500	48.600
40	car	1	1	8	54	6.750	24.300
41	car	1	1	4	54	13.500	48.600
42	car	1	1	6	54	9.000	32.400
43	car	1	1	8	54	6.750	24.300
44	car	1	1	5	54	10.800	38.880
45	car	1	1	7	54	7.714	27.771
46	car	1	1	5	54	10.800	38.880
47	car	1	1	4	54	13.500	48.600

48	car	1	1	5	54	10.800	38.880
49	car	1	1	7	54	7.714	27.771
50	car	1	1	5	54	10.800	38.880
51	car	1	1	7	54	7.714	27.771
52	car	1	1	4	54	13.500	48.600
53	car	1	1	5	54	10.800	38.880
54	car	1	1	6	54	9.000	32.400
55	car	1	1	6	54	9.000	32.400
56	car	1	1	4	54	13.500	48.600
57	car	1	1	4	54	13.500	48.600
58	motorcycle	0.5	0.5	5	54	10.800	38.880
59	motorcycle	0.5	0.5	5	54	10.800	38.880
60	car	1	1	4	54	13.500	48.600
61	car	1	1	5	54	10.800	38.880
62	car	1	1	4	54	13.500	48.600
63	car	1	1	5	54	10.800	38.880
62	car	1	1	4	54	13.500	48.600
63	car	1	1	5	54	10.800	38.880
64	light	1	1	4	54	13.500	48.600
65	light	1	1	5	54	10.800	38.880
66	light	1	1	4	54	13.500	48.600
67	light	1	1	5	54	10.800	38.880
	TOTAL		**72.8**	**429**			
					Sm	**38.564**	**Km/hr**
					SMS	**32.989**	**Km/hr**

					SD	**8.535**	
TIME-----	**RECORD ELEVEN**						
s/no		**PCE**	**PCE**	**Time taken b/n**	**Base**	**speed**	**speed**
		Converter		**entry &exit(sec)**	**length(m)**	**(m/s)**	**(Km/hr)**
1	bajaj	0.8	0.8	5	54	10.800	38.880
2	bajaj	0.8	0.8	5	54	10.800	38.880
3	bajaj	0.8	0.8	5	54	10.800	38.880
4	bajaj	0.8	0.8	6	54	9.000	32.400
5	bajaj	0.8	0.8	5	54	10.800	38.880
6	bajaj	0.8	0.8	6	54	9.000	32.400
7	bajaj	0.8	0.8	4	54	13.500	48.600
8	bajaj	0.8	0.8	5	54	10.800	38.880
9	bajaj	0.8	0.8	5	54	10.800	38.880
10	bajaj	0.8	0.8	4	54	13.500	48.600
11	bajaj	0.8	0.8	6	54	9.000	32.400
12	bajaj	0.8	0.8	6	54	9.000	32.400
13	bajaj	0.8	0.8	5	54	10.800	38.880
14	bajaj	0.8	0.8	4	54	13.500	48.600
15	bajaj	0.8	0.8	6	54	9.000	32.400
16	bajaj	0.8	0.8	5	54	10.800	38.880
17	bajaj	0.8	0.8	5	54	10.800	38.880
18	bajaj	0.8	0.8	4	54	13.500	48.600
19	bajaj	0.8	0.8	5	54	10.800	38.880
20	bajaj	0.8	0.8	6	54	9.000	32.400
21	bajaj	0.8	0.8	5	54	10.800	38.880

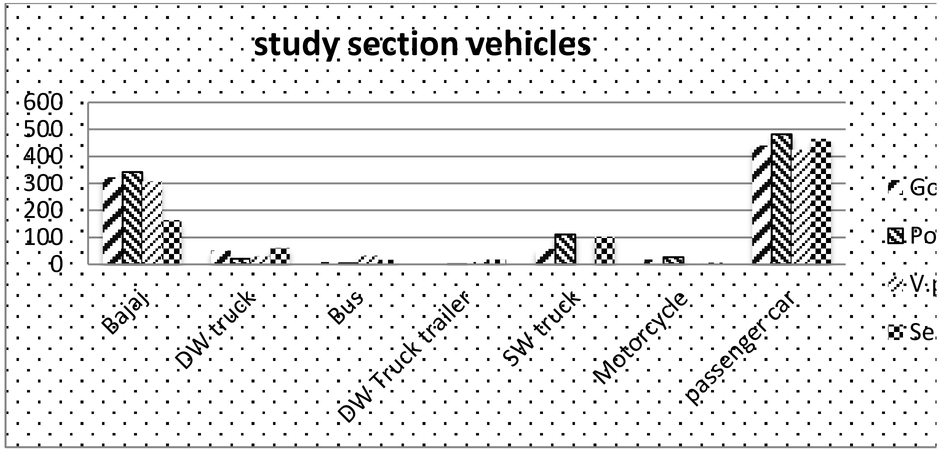
22	car	1	1	5	54	10.800	38.880
23	car	1	1	6	54	9.000	32.400
24	car	1	1	4	54	13.500	48.600
25	car	1	1	5	54	10.800	38.880
26	light	1	1	4	54	13.500	48.600
27	light	1	1	3	54	18.000	64.800
28	light	1	1	5	54	10.800	38.880
29	car	1	1	4	54	13.500	48.600
30	car	1	1	4	54	13.500	48.600
31	car	1	1	5	54	10.800	38.880
32	car	1	1	5	54	10.800	38.880
33	car	1	1	4	54	13.500	48.600
34	car	1	1	6	54	9.000	32.400
35	car	1	1	5	54	10.800	38.880
36	car	1	1	3	54	18.000	64.800
37	car	1	1	5	54	10.800	38.880
38	car	1	1	3	54	18.000	64.800
39	car	1	1	3	54	18.000	64.800
40	car	1	1	5	54	10.800	38.880
41	car	1	1	3	54	18.000	64.800
42	car	1	1	5	54	10.800	38.880
43	car	1	1	3	54	18.000	64.800
44	car	1	1	4	54	13.500	48.600
45	car	1	1	4	54	13.500	48.600
46	car	1	1	4	54	13.500	48.600
47	car	1	1	5	54	10.800	38.880
48	car	1	1	5	54	10.800	38.880
49	car	1	1	4	54	13.500	48.600
50	car	1	1	6	54	9.000	32.400
51	car	1	1	3	54	18.000	64.800
52	car	1	1	5	54	10.800	38.880
53	car	1	1	3	54	18.000	64.800
54	car	1	1	5	54	10.800	38.880
55	car	1	1	3	54	18.000	64.800
56	car	1	1	4	54	13.500	48.600
57	motorcycle	0.5	0.5	4	54	13.500	48.600
58	motorcycle	0.5	0.5	4	54	13.500	48.600
59	motorcycle	0.5	0.5	5	54	10.800	38.880
60	car	1	1	5	54	10.800	38.880
61	car	1	1	5	54	10.800	38.880
62	car	1	1	4	54	13.500	48.600
63	car	1	1	4	54	13.500	48.600
64	light	1	1	5	54	10.800	38.880
65	light	1	1	4	54	13.500	48.600
66	light	1	1	4	54	13.500	48.600
67	medium	2.5	2.5	5	54	10.800	38.880
68	medium	2.5	2.5	6	54	9.000	32.400
69	medium	2.5	2.5	5	54	10.800	38.880
70	medium	2.5	2.5	6	54	9.000	32.400
71	medium	2.5	2.5	6	54	9.000	32.400

	TOTAL		72.8	329			
					Sm	44.393	Km/hr
					SMS	43.016	Km/hr
					SD	9.753	
TIME-----	RECORD TWELVE						
s/no		PCE Converter	PCE	Time taken b/n entry &exit(sec)	Base length(m)	speed (m/s)	speed (Km/hr)
1	bajaj	0.8	0.8	5	54	10.800	38.880
2	bajaj	0.8	0.8	5	54	10.800	38.880
3	bajaj	0.8	0.8	3	54	18.000	64.800
4	bajaj	0.8	0.8	6	54	9.000	32.400
5	bajaj	0.8	0.8	6	54	9.000	32.400
6	bajaj	0.8	0.8	5	54	10.800	38.880
7	bajaj	0.8	0.8	5	54	10.800	38.880
8	bajaj	0.8	0.8	5	54	10.800	38.880
9	bajaj	0.8	0.8	5	54	10.800	38.880
10	bajaj	0.8	0.8	6	54	9.000	32.400
11	bajaj	0.8	0.8	4	54	13.500	48.600
12	bajaj	0.8	0.8	7	54	7.714	27.771
13	bajaj	0.8	0.8	6	54	9.000	32.400
14	bajaj	0.8	0.8	7	54	7.714	27.771
15	bajaj	0.8	0.8	5	54	10.800	38.880
16	bajaj	0.8	0.8	5	54	10.800	38.880
17	bajaj	0.8	0.8	6	54	9.000	32.400
18	bajaj	0.8	0.8	8	54	6.750	24.300
19	bajaj	0.8	0.8	6	54	9.000	32.400
20	bajaj	0.8	0.8	5	54	10.800	38.880
21	bajaj	0.8	0.8	6	54	9.000	32.400
22	bajaj	0.8	0.8	7	54	7.714	27.771
23	bajaj	0.8	0.8	5	54	10.800	38.880
24	bajaj	0.8	0.8	4	54	13.500	48.600
25	bajaj	0.8	0.8	5	54	10.800	38.880
26	bajaj	0.8	0.8	6	54	9.000	32.400
27	car	1	1	5	54	10.800	38.880
28	car	1	1	4	54	13.500	48.600
29	light	1	1	4	54	13.500	48.600
30	light	1	1	4	54	13.500	48.600
31	light	1	1	5	54	10.800	38.880
32	light	1	1	7	54	7.714	27.771
33	light	1	1	4	54	13.500	48.600
34	light	1	1	6	54	9.000	32.400
35	light	1	1	5	54	10.800	38.880
36	car	1	1	6	54	9.000	32.400
37	car	1	1	4	54	13.500	48.600
38	car	1	1	3	54	18.000	64.800
39	car	1	1	6	54	9.000	32.400
40	car	1	1	5	54	10.800	38.880
41	car	1	1	6	54	9.000	32.400
42	car	1	1	6	54	9.000	32.400
43	car	1	1	5	54	10.800	38.880

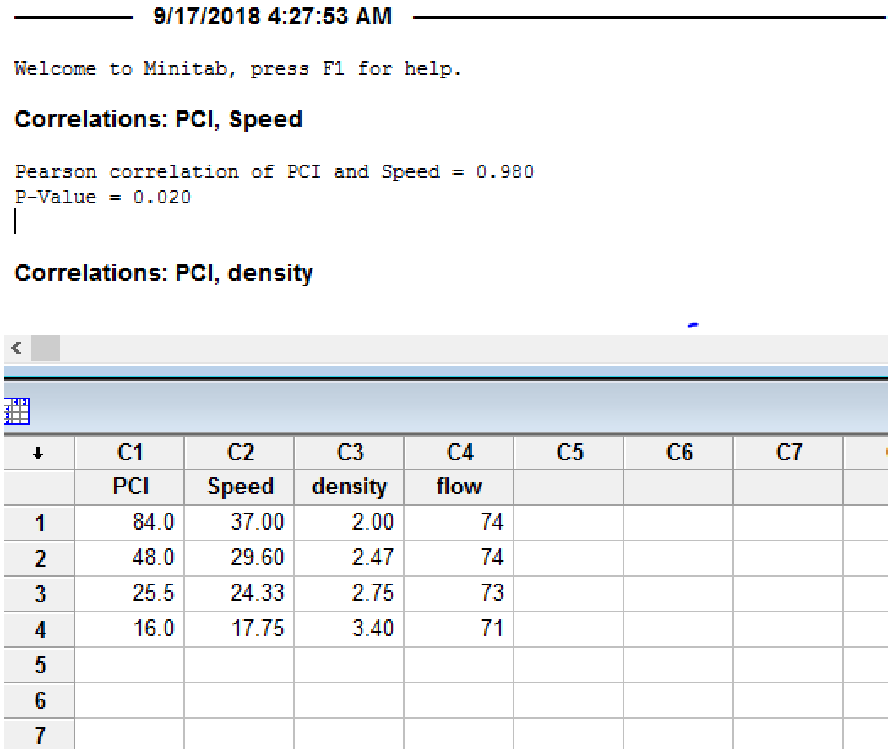
44	car	1	1	6	54	9.000	32.400
45	car	1	1	4	54	13.500	48.600
46	car	1	1	3	54	18.000	64.800
47	car	1	1	4	54	13.500	48.600
48	car	1	1	4	54	13.500	48.600
49	car	1	1	4	54	13.500	48.600
50	car	1	1	7	54	7.714	27.771
51	car	1	1	5	54	10.800	38.880
52	car	1	1	6	54	9.000	32.400
53	car	1	1	4	54	13.500	48.600
54	car	1	1	3	54	18.000	64.800
55	car	1	1	4	54	13.500	48.600
56	car	1	1	4	54	13.500	48.600
57	car	1	1	4	54	13.500	48.600
58	car	1	1	5	54	10.800	38.880
59	car	1	1	4	54	13.500	48.600
60	car	1	1	5	54	10.800	38.880
61	car	1	1	6	54	9.000	32.400
62	car	1	1	4	54	13.500	48.600
63	car	1	1	4	54	13.500	48.600
64	medium	2.5	2.5	5	54	10.800	38.880
65	medium	2.5	2.5	5	54	10.800	38.880
66	medium	2.5	2.5	4	54	13.500	48.600
67	medium	2.5	2.5	4	54	13.500	48.600
68	medium	2.5	2.5	5	54	10.800	38.880
69	medium	2.5	2.5	5	54	10.800	38.880
	TOTAL		**72.8**	**346**			
					Sm	**40.708**	**Km/hr**
					SMS	**40.903**	**Km/hr**
					SD	**9.187**	

Frequency of the Vehicle in the Study Section

Vehicle	Good	Poor	Very poor	Serious	Total	Percent
Bajaj	323	342	307	163	**1135**	**32.27**
DW truck	51	20	30	60	**161**	**4.58**
Bus	8	4	32	17	**61**	**1.73**
DW Truck trailer	0	2	8	18	**28**	**0.8**
SW truck	57	110	`102	102	**269**	**7.65**
Motorcycle	18	26	2	6	**52**	**1.48**
Passenger car	440	481	425	465	**1811**	**51.50**
TOTAL	**897**	**985**	**804**	**831**	**3517**	**100.00**



Correlation of PCI and Speed



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Welcome to Minitab, press F1 for help.

Correlations: PCI, Speed

Pearson correlation of PCI and Speed = 0.980
P-Value = 0.020

Correlations: PCI, density

↓	C1	C2	C3	C4	C5	C6	C7
	PCI	Speed	density	flow			
1	84.0	37.00	2.00	74			
2	48.0	29.60	2.47	74			
3	25.5	24.33	2.75	73			
4	16.0	17.75	3.40	71			
5							
6							
7							

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Welcome to Minitab, press F1 for help.
Retrieving project from file: 'D:\GG 1\REFERENCE\MY WORK\CORRELATION.MPJ'
```

Correlations: PCI, density

```
Pearson correlation of PCI and density = -0.934
P-Value = 0.066
```

↓	C1	C2	C3	C4	C5	C6	C7	C
	PCI	Speed	density	flow				
1	84.0	37.00	2.00	74				
2	48.0	29.60	2.47	74				
3	25.5	24.33	2.75	73				
4	16.0	17.75	3.40	71				

Correlations: PCI, flow

```
Pearson correlation of PCI and flow = 0.780
P-Value = 0.220
```

↓	C1	C2	C3	C4	C5	C6
	PCI	Speed	density	flow		
1	84.0	37.00	2.00	74		
2	48.0	29.60	2.47	74		
3	25.5	24.33	2.75	73		
4	16.0	17.75	3.40	71		
5						