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# Influence of Pavement Condition on Headway and Average Travel Speed

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**Abstract:** Pavement surface conditions have an influence on traffic safety, operating speed, manoeuvrability, and driver comfort and service volume. Although many researchers have studied the influence of different roadway characteristics on traffic stream characteristics and performance, little research has been conducted to investigate the impact of pavement conditions on traffic stream characteristics. To evaluate the capacity and service level of road section accurately, it is necessary to study the quantified influence of pavement on headway and average travel speed. In this project work, pothole width, rut depth etc. were used as indicators to evaluate the status of damaged pavements. Based on the parameter surveyed on different pavement sections, the effects of pavement condition on headway and average travel speed are analysed. The main objective of this study is to evaluate the influence of pavement condition on headway and average travel speed. From the study it was identified that the pavement condition has a greater influence on speed and headway. Section 5, 7, 10, 11 are in good condition and section 15 is rated as serious. Maximum speed obtained is 52.5 kmph and minimum speed obtained is 25 kmph. It is found that at distressed sections headway value is high and average speed value obtained is less. Models were developed to predict the headway and average speed based on shoulder width, flow and PCI value.

**Keywords:** Pavement distress, Headway, Average speed, PCI value.

## I. INTRODUCTION

In developing countries like India, traffic conditions are highly heterogeneous comprising vehicles of varying physical dimensions, axle configurations, weight, power-to-weight ratio and other dynamic characteristics such as braking power, acceleration, etc. Due to these characteristics, the vehicles do not follow lane discipline, and occupy any lateral position along the entire width of the roadway irrespective of lane markings Road transport is the primary mode of transport in India, because of advantages like door to door service easy availability and flexibility to rural habitations. It is necessary to provide a good road network for the development of any country. India has the second largest road network system in the world. National Highways are considered as main arterial routes as it connects big cities, industrial centres, major ports and different states of the country. Pavements deteriorate with age and traffic loading. Pavement evaluation is carried out to determine the existing condition of pavements. Evaluation of in-service pavements is very vital for keeping them in good serviceable condition. Damaged pavement makes traffic operation environment become worse and more traffic congestion, traffic accident, environment pollution occur frequently. Speed is one of the most important fundamental parameters to describe the performance of any roadway system. Knowledge of speed and time-headway is very important and essential in traffic engineering as development of a good transportation system is completely dependent on it. It plays important role in many areas, starting from geometric design of road, speed is required in accident studies, regulation and control of traffic operations, ascertaining travel time, determining capacity, delay and queue analysis, level of service analysis etc. Time headway is a fundamental microscopic parameter in traffic flow theories that is measured by the difference in the time interval between two successive vehicles as they pass a reference point on the roadway measured from the same common features of both the vehicles. But under mixed traffic condition definition of headway is modified as the time interval between two successive vehicles as they pass a reference line on the entire width of the roadway. Speed characteristics are important in the evaluation of traffic performance, examination of highway consistency and safety, setting appropriate traffic control devices and speed limits, and development of simulation programs, etc. The determination of headway corresponding to free flow speed is considered a key item in highway and traffic engineering applications, and especially in defining operating/design speed and setting speed limit.

The main objective of this study is to evaluate the influence of pavement condition on headway and average travel speed. The specific objectives are as listed below:

- To evaluate the pavement distresses and the rate the pavement based on ASTM D6433-07
- To find out the average speed in the selected stretches and to develop a model that predicts average speed
- To investigate the headway value corresponding to a free flow speed condition and to develop a headway model to predict the average time headway

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## II. LITERATURE REVIEW

Traffic stream characteristics are influenced by many factors. Relatively little research has been carried out investigating the relationship between roadway surface conditions and traffic stream characteristics. The existing condition of pavements can be evaluated in terms of its surface and structural adequacy. Pavements can be evaluated using destructive and non-destructive methods. One of the methods to carry out Structural evaluation of pavement is with Benkelman Beam which is used to determine the capacity of the pavement to withstand future traffic loading. From the analysis of data the overlay thickness required to maintain the pavement in serviceable condition can be deter-mined [2]. Studies are also been carries out on structural and functional evaluation of flexible pavement and relationship between the roughness and other surface distress. Pavement surface condition is measured and different types of the distresses are observed like crack, potholes, patch, raveling and rutting. From the study it was found out that Roughness and visual distresses correlates each other. Regression models can be developed between roughness and visual distress by using SPSS software [3]. In a study conducted in Rajkot city to evaluate the pavement condition, parameters like Pavement Serviceability Rating (PSR), Road Class, Road Quality, Traffic Volume and Structural Adequacy are considered. Total five arterial sections for the 6 km length of stretch in both ways were considered. Parameters were function- ally and structurally evaluated. The questionnaire has been prepared for the pair wise comparison of identified parameters and the weightage will be calculated using Expert Choice using AHP technique. A final priority index will be calculated and all sections will be ranked based on this index for maintenance prioritization. The result from Benkelman beam shows the different characteristic deflection of the given sections. The value ranges between 0.1 to 0.2 mm which is considered good. Hence there is no requirement of overlay. The results from the Bump Integrator Survey for roughness evaluation showed that all the values obtained from survey were less than 2000 mm/km as per the MORTH: Guidelines for maintenance of 8 primary, secondary and urban roads, 2004 so the riding quality can be considered as good for the selected sections of roads [4]. Study of speed characteristics is important to establish a relationship between speed and pavement condition. The data analysis revealed that poor pavement conditions caused a large variation in vehicle speeds and consequently made the speed distribution deviate from the normal distribution. There was a significant difference between the mean speeds for different classes of vehicles. Inspection of the standard deviations of speed for distressed and un-distressed sections showed significant differences occurring mainly in distressed sections [5]. An attempt has been made to find out speed and headway distribution pattern in heterogeneous traffic condition comprising of various motorized and non- motorized vehicles having widely varying speed range. Distribution of speed and time headway has been studied for different density levels namely, 0-20 PCU/km, 20-40 PCU/km, 40-60 PCU/km and 60-80 PCU/km. Statistical validity of each distribution is evaluated by Kolmogorov-Smirnov (K-S) test. Results show that the speed and time headway follow different distribution patterns under different density levels[6].

## III. METHODOLOGY AND DATA COLLECTION

The study stretch identified in the present work was between Kalmandapam and Sekharipuram section of State Highway 966 (Palakkad - Kozhikode highway). Road stretch is divided into sample units of equal size. 15 important locations of 100 m width in the highway were selected for the study. Field data collection for the present study was more challenging for the heterogeneous traffic stream with less lane disciplined flow. The analytical data necessary for this study are speed, headway, road characteristics, and distress data. The data are used to explain the relationship between the speed, the headway and lane width, roadway facilities. After clarifying data requirements, onsite data were collected.

The process of data collection to ascertain the condition of pavements includes visual inspection of defects, measurement of these defects and finally calculation of the Pavement Condition Index (PCI). Distress data are collected and analysed based on ASTM D6433-07 – "*Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys".* 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). From the distress data collected PCI (Pavement Condition Index) value is calculated. Based on PCI value pavement is rated.

The study was conducted in areas which were free from any side hindrance such as parking lot, gradient, bus-stop, intersection etc. Data is collected by using video recording technique. Digital video recorder was set up at high buildings nearby the study sites, captured all traffic movements at specified time periods. Collection of traffic data was carried out on working days during daylight hours and clear weather conditions to eliminate extraneous effects.

## IV. RESULTS

### A. *Traffic Volume Count*

The inventory details of selected study area were collected. The details includes the number of lanes, distance, road category, width of carriageway of road and median, availability of shoulder and their types, shoulder width, footpath width if footpaths are available. To count the traffic volume for the selected stretches traffic volume count surveys were carried out on each stretch for each direction of traffic from starting point towards the ending point and vice versa. Surveys were carried out for one hour duration. From the obtained classified traffic volume count flow and density were determined. Total number of vehicles in each section is shown in Fig.1

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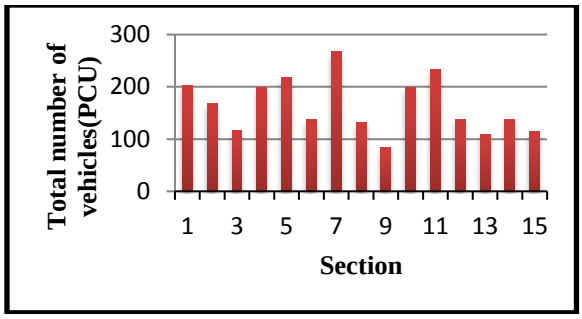


Fig.1. Total number of vehicles in each section

Traffic composition of the roads undertaken for surveys considers all types of traffic vehicles including motorized and non-motorized traffic. Motorized traffic consists of two wheelers, four wheelers, Buses, Two-axle and multi-axle trucks while a non-motorized vehicle consist of Bicycles and three wheelers. The flow in each section is mentioned in Table 1.

Table 1. Traffic volume data

| SECTION | FLOW (PCU/h) |
|---|---|
| 1 | 1210.56 |
| 2 | 1008.00 |
| 3 | 699.90 |
| 4 | 1188.00 |
| 5 | 1307.76 |
| 6 | 828.00 |
| 7 | 1605.90 |
| 8 | 792.00 |
| 9 | 504.00 |
| 10 | 1189.98 |
| 11 | 1399.92 |
| 12 | 828.00 |
| 13 | 648.00 |
| 14 | 828.00 |
| 15 | 684.00 |

B. *Pavement Condition Data*

Based on the visual inspection of the road sections considering the distress conditions, the rating was done on scale of 0-100. Functional Condition Data is collected by walk survey associated with actual measurements. The PCI provides an indication of pavement failure, maintenance and repair requirements. The PCI values obtained for the various sections are shown in Table 2.

Table 2. Pavement Condition Rating

| SECTION | PCI VALUE | PAVEMENT CONDITION RATING |
|---|---|---|
| 1 | 58 | Fair |
| 2 | 78 | Satisfactory |
| 3 | 58 | Fair |
| 4 | 70 | Fair |
| 5 | 86 | Good |
| 6 | 80 | Satisfactory |
| 7 | 96 | Good |
| 8 | 36 | Very poor |
| 9 | 43 | Poor |
| 10 | 95 | Good |
| 11 | 94 | Good |
| 12 | 28 | Very poor |
| 13 | 29 | Very poor |
| 14 | 58 | Fair |
| 15 | 17 | Serious |

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C. *Headway Data*

Headway is a measurement of the distance or time between vehicles in a transit system. . A "shorter" headway signifies closer spacing between the vehicles. In this study time headway values are analysed. The headway values are shown in Fig.2.

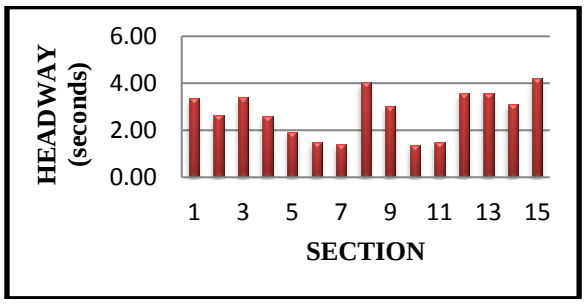


Fig.2.Headway variation in various sections

From the data collected it is observed that for the sections with good condition the headway value is less. But for the pavement sections with higher amount of distress the headway value obtained is high.

D. *Speed Data*

Speed is required in accident studies, regulation and control of traffic operations, ascertaining travel time, determining capacity, delay and queue analysis, level of service analysis etc. The average speed obtained in each section is mentioned in Table 3.From the results it is clear that in sections 8,12,13, and 15 the average speed obtained is very less.

Table 3. Average speed in each section

| SECTION | AVERAGE SPEED (kmph) |
|---|---|
| 1 | 30.0 |
| 2 | 42.5 |
| 3 | 35.0 |
| 4 | 35.0 |
| 5 | 52.5 |
| 6 | 40.0 |
| 7 | 52.5 |
| 8 | 25.0 |
| 9 | 31.0 |
| 10 | 52.5 |
| 11 | 51.0 |
| 12 | 27.0 |
| 13 | 26.0 |
| 14 | 35.0 |
| 15 | 26.0 |

## V. DEVELOPMENT OF AVERAGE SPEED AND AVERAGE TIME HEADWAY MODELS

For finding the correlation between the significant variable's correlation matrix is developed using SPSS (statistical package for social science) software. A correlation matrix is a numeric matrix or data frame method used to investigate the dependence between multiple variables at the same time. The result is a table containing the correlation coefficients between each variable and the others. Correlation helps to find out the most significant variable among them and helps in modelling. After the analysis it was found that

- Average shoulder width has least correlation with the average headway and speed.
- PCI value has the highest correlation with the average headway and is negatively correlated with the headway.
- PCI value has a greater influence on speed.

This means that as the PCI value increases the headway decreases i.e. if the pavement condition is good, the headway value will be less. As PCI values increases the speed also increases. In other words we can say that average speed maintained in the section which is rated as good is high when compared to other sections. The equations were developed using headway and speed as dependent variable and flow, Pavement Condition Index, shoulder width as independent variables

After the analysis of the field data the obtained models are

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$$Y_1=20.257 – 3.335X_1 + 0.004X_2 + 0.341X_3$$

Where $Y_1$ is the Average speed in kmph, X1- Shoulder width in m, X2 – Flow in PCU/h and $X_3$ – PCI value

$$Y_2 = 4.249 – 0.37\ Z_1 + 0.262\ Z_2$$

Where $Y_2$ is the Average time headway in seconds, $Z_1$ – PCI value and $Z_2$ – Shoulder width in m

After the analysis it can be concluded that the flow has least influence on headway and average travel speed and pavement condition has much greater influence on these. The $R^2$ value obtained is high which indicates that the models better explains the variation in headway and average travel speed.

## VI. CONCLUSION

It is identified that pavement condition has a greater influence on speed and headway. The pavement condition is inversely proportional to the headway and directly proportional to speed. Flow has least influence on speed and headway. The following general conclusions were obtained based on the findings of the study:

- Section 5, 7, 10, 11 are in good condition and section 15 is rated as serious with indicates that immediate maintenance work is required in this section
- Maximum speed obtained is 52.5 kmph at sections 6, 8, 10 and minimum speed obtained is 25 kmph at section 8
- It is found that at distressed sections headway value is high and average speed value obtained is less
- Models to predict headway and speed based on road geometry, flow and pavement condition was developed

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## BIOGRAPHIES

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**Vincy Verghese** was born in Thrissur, India in 1987. She received Bachelor’s degree in Civil Engineering and Master’s degree in Traffic and Transportation Engineering, from College of Engineering Trivandrum under Kerala University, Thiruvananthapuram, India in 2008 and 2010 respectively. She was a research scholar in Indian Institute of Technology, Madras, India from 2012 to 2017. She worked as Assistant Professor in Marian Engineering College, Thiruvananthapuram for one year in 2011 and is currently working as Assistant Professor in Jyothi Engineering College, Thrissur, India, since 2017. Her area of interest include control theory, adaptive traffic signal control, urban traffic networks, congestion mitigation, intelligent transportation systems and modifiers in bituminous pavement design.