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STUDY ON THE EFFECT OF ROAD ROUGHNESS ON CAPACITY OF INTERMEDIATE LANE ROAD

POOJITH G N[1], DR. KIRAN KUMAR B V[2]

[1]Post Graduation Student, GSKSJTI BENGALURU-560001

[2]Associate Professor, GSKSJTI BENGALURU-560001

Abstract: The IRC 106-1990 states that the capacity of a sub arterial road under ideal condition is around 1900 PCU/hour, but the riding quality of the roads are not mentioned in the manual. This study or observation has revealed that the capacity of an intermediate lane is also impacted by the roughness of the road .Data's collected regarding the roughness of the road and the free flow speed of the vehicles which includes only heavy vehicles and cars at fourteen different stretches of two state highway's in Karnataka were used to develop the relationships between two of these variables. Additionally the speed and volume data's collected at five different sections of intermediate lane roads were studied and analyzed, the effect of roughness of road on capacity was found out.

Keywords: Unevenness index, Roughness, Capacity, Passenger Car Unit (PCU)

I. INTRODUCTION

We can see lofty increment in movement on Indian streets amid the previous decade or two. The engine vehicle populace in India has ascended from 42.5million in 2001 to 210 million in 2015. The street length amid this period has expanded from 3.3 million km to 5.5 million km. This awkwardness, combined with the financial limitations, has brought about the crumbling of streets in many conditions of the nation. The crumbling is additionally bothered by the over-burdening of the vehicles on exceedingly critical courses. The drivers drive gradually on a surface which is weakened or deteriorated than that which is all the more even. Road roughness is very common in all the countries across the globe. It is experienced by all types of road users. The roughness of the road affects the dynamics of the moving vehicle and increases wear and tear as well as vehicle operating cost. If excess roughness is present on the pavement it may lead to the stagnation of water on the pavement surface, also it may decrease the pavement performance and may provide less safety for the road users. Usually minor improvements in the roughness of road can yield major monetary returns. One of the hidden facts is the effect of the roughness of road on the speed of vehicle on the surface as well as the capacity of the road. The present investigation was considered to find the effect of roughness of road on vehicle speed and capacity of intermediate lane road (sub arterial).The speed and the roughness data's were collected on 14 different stretches of intermediate lane roads. These data's were analyzed to develop the relationship between speed of various categories of vehicles and road roughness. Similarly the data's regarding capacity and roughnesses were selected on 5 different stretches and were analyzed to find the effect of roughness of the road on capacity of intermediate lane roads.

II. LITERATURE REVIEW

"Effect of roughness on capacity of two lane roads" by Satish Chandra (2004) shows that the road roughness effects capacity of a two lane road. It shows the variation of the free flow speed with the roughness of the pavement. It also gives the effect of the roughness on the passenger car unit , similarly it provides the effect of roughness of road on the capacity of the road. The capacity estimated of two lane roads with pavement surface condition categorized as good was about 3140 PCU/hour. The conclusion was that the capacity reduces by 300 PCU/hour if road surface unevenness is increased by 1000 mm/Km. Patel Chirag et al (2013) estimated "the field capacity and level of service of urban arterial roads for heterogeneous condition of traffic for six lane divided road". The speed flow relationship was developed for Surat in Gujarat. The field capacity of the six lane roads was found and compared with recommended values given in the IRC. "Development of model for estimating capacity of roads for Heterogeneous Traffic Condition in Urban Area" by Nikhil P Raval, Dr. P.J.Gundaliya, Dr.Gargee Rajpara. In this study the speed-flow relationships for various mid blocks sections of urban roads of Ahmadabad city are developed. The capacity determined for selected mid block sections are compared with the capacity recommended by IRC: 106-1990. "Study of updating road user cost data" by Kadiyali and Vishwanathan (1992) built up a few connections on the monetary assessment of highway ventures for Indian conditions, which incorporated the connection between road roughness and vehicle speed, measured with a high-speed profile- meter. "Effect of pavement roughness on speed" by Karan (1978) set up the correlation of roughness with speed for rural highways. The "riding comfort index" (RCI) was taken as pointer of roughness. The RCI is the Canadian equivalent of "present serviceability index"(PSI) but a 0 to 10 scale was used instead of 0 to 5 scale as for PSI values. "Methodology for computing pavement riding quality from pavement roughness measurements" by Janoff (1985) adopted a arithmetical transform between the physical profile measure of a road and the slanted panel rating to predict the mean panel rating for a given pavement section.

III. DATA COLLECTION AND METHODOLOGY

This examination was made to discover the impact of roughness of roads on speed of vehicles and the capacity of the road. Initially the observations were taken for roughness of the road and the speed (free flow speed) of the vehicles. In order to find the roughness the instrument named as Road Measurement and Data Acquisition System (ROMDAS) was used. The data's were collected on two states highways of Karnataka which are intermediate lane. Two state highway's are SH-27 and SH-90 in southern part of Karnataka State. The ROMDAS provides data's in International Roughness Index (IRI) values. These IRI values are converted into Unevenness Index (UI) values by using the formula:

$$UI=IRI*720 \quad (1)$$

here
IRI= International Roughness Index
UI= Unevenness Index

The free flow speed of the vehicles is found out using the radar gun. Only two types of vehicles namely cars and heavy vehicles were considered for this part of the study.
The second part of the study aims to find out the effect of roughness of the road on capacity of the road. In this part, five stretches on the intermediate lanes are selected. The selected stretches were level, straight and free from traffic movement restrictions. This criterion ensures that the selected stretches must be free from other capacity restraints. The video recording method was adopted to collect the data's. In the laboratory the required information is gathered from the videos. All the vehicles of same categories are grouped together and are divided into ten categories as tabulated in table1. Also table1 includes the average dimension and the projected rectangular area of each categories of vehicles.

Table 1: vehicle categories and their average dimensions

Category	Vehicles included	Average dimension(length*width)(m^2)	Area(m^2)
Car	Car, Jeep, Van	3.72*1.44	5.36
Bus	Bus	10.1*2.43	24.54
Truck	Truck	7.5*2.35	17.62
Light commercial vehicle	Mini bus, Large Van, Mini truck	6.1*2.1	12.81
Multiaxle truck	Multiaxle truck	12*2.35	28.2
Tractor trailer	Tractor trailer	7.4*2.2	16.28
Two wheeler	Scooter, motor bike	1.87*0.64	1.2
Cycle	Pedal cycles	1.9*0.45	0.85
Three wheeler	Auto, tempo	3.2*1.4	4.48
Animal Driven Vehicle	Bullock cart, horse driven cart	5.5*1.75	9.62

Effect of Road Roughness on Free Speed of Vehicles:

Speeds of only two categories of vehicles were considered here namely cars and heavy vehicles. The graph showing the variation speed and the road roughness are shown in the figures. Figure1 depict the variety of speed with respect to roughness in the cars. Figure2 shows the variation of speed with respect to road roughness in heavy vehicles.

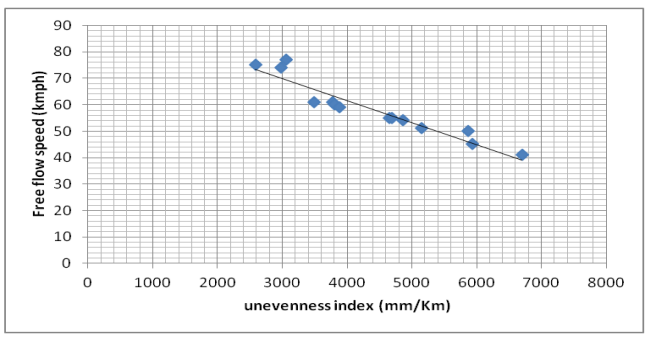

Figure1: Graph between free flow speed v/s unevenness index for car

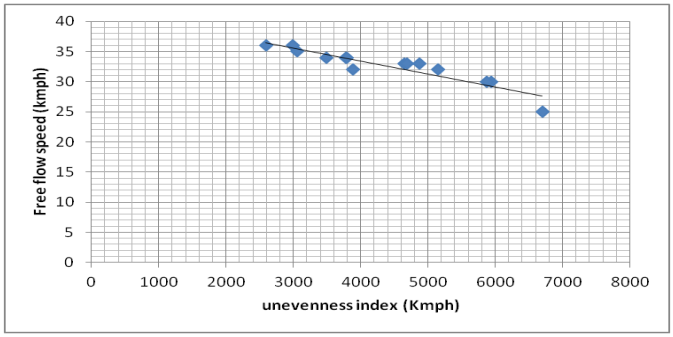

Figure2: Graph of free flow speed v/s unevenness index for heavy vehicle

V_{car}=95.1438-0.00837*UI R^2=0.9482 (2)

V_{hv}=42.057-0.00214*UI R^2=0.9194 (3)

here

V=speed in Kmph

UI= unevenness index in mm/Km

The speed of car's decreases with increase in the roughness similarly the speed of heavy vehicles also decreases with the increase in road roughness.

Table 2: Passenger Car Unit for different categories of vehicles on different sections:

Section	Unevenness index(mm/km)	Bus	Truck	LCV	Multiaxle truck	Two wheeler	Three wheeler
1	2585	6.276	4.47	4.25	11.07	0.38	1.64
2	2981	6.16	4.4	4.11	11.01	0.33	1.61
3	3057	1.25	4.09	3.96	11.684	0.36	1.7
4	3482	5.83	4.155	3.532	9.56	0.347	1.43
5	3773	5.725	4.08	3.584	9.475	0.335	1.432
6	3795	5.68	4.05	3.86	9.61	0.322	1.57
7	3885	5.53	3.92	3.34	9.45	0.31	1.47
8	4644	5.45	3.89	3.03	8.81	0.3	1.3327
9	4688	5.46	3.89	2.96	8.81	0.29	1.38
10	4864	5.41	3.86	2.94	8.78	0.26	1.3
11	5148	5.35	3.81	2.86	8.54	0.27	1.31
12	5868	5.404	3.84	2.79	8.726	0.26	1.28
13	5933	5.29	3.77	2.74	8.98	0.23	1.263
14	6700	5.16	3.67	2.52	8.65	0.21	1.25

Effect of Road Roughness on Passenger Car Unit:

Generally one type of vehicle is not as same another class of vehicle. So a common type or unit is developed known as "Passenger Car Unit" (PCU). In this study the PCU of different types of vehicles recalculated using the equation (4):

$$PCU_i = (V_c/V_i)/(A_c/A_i). \quad (4)$$

here

V_c=mean speed of car

V_i=mean speed of vehicle type i

A_c=area of car

A_i= area of vehicle type i

The Passenger car unit (PCU) of the each vehicle varies for each of the fourteen point. The unevenness indexes for the particular points are plotted in the X-axis. In the Y-axis the passenger car unit of individual vehicle (bus, truck, multi-axle, LMV, two wheeler, three wheeler) are plotted. PCU values of various categories of vehicles at various stretches are calculated and are tabulated in table2. Figure3, figure4, figure5, figure6, figure7and figure8 shows the variation of Passenger car Unit with respect to unevenness index of different categories of vehicles. As the figures indicates, the increasing in the value of unevenness index leads to the decrement of PCU values. This criterion is true for all categories of vehicles which are motorized.

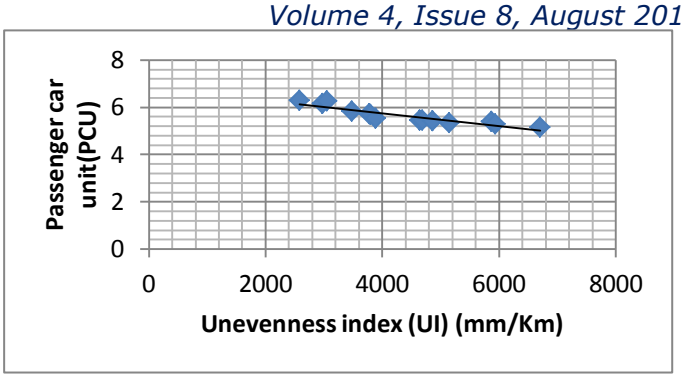

Figure3: graph of Passenger car unit v/s unevenness index for bus

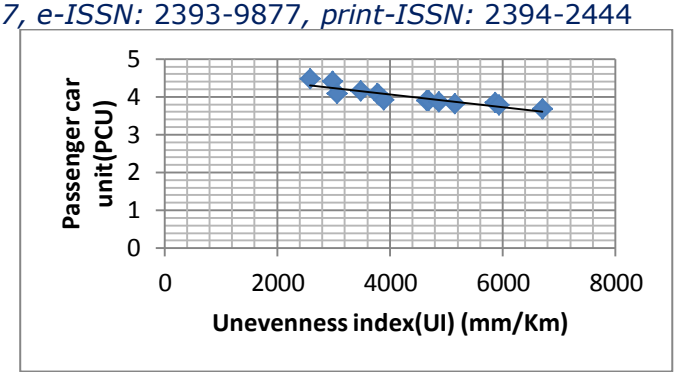

Figure4: graph of Passenger car unit v/s unevenness index for truck

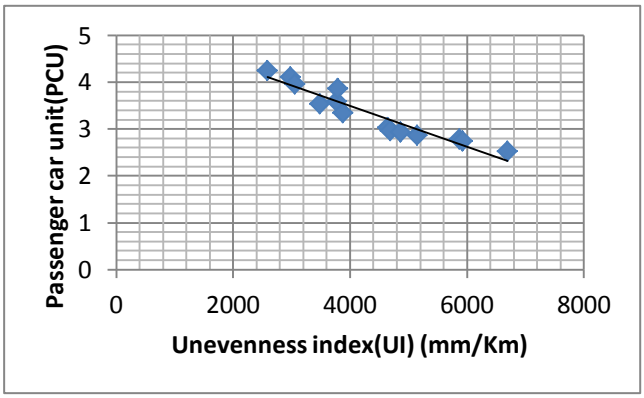

Figure5: graph of Passenger car unit v/s unevenness index for light commercial vehicle

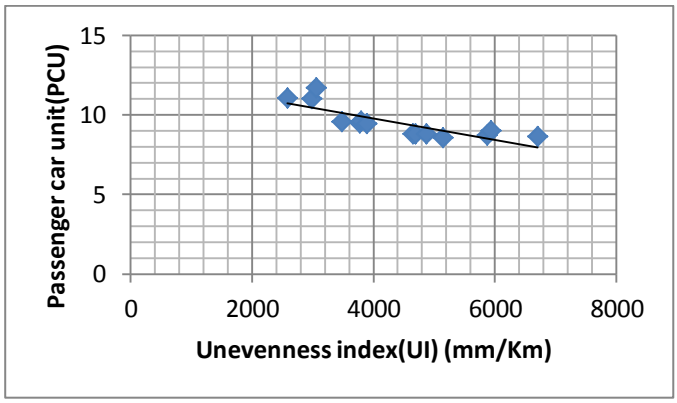

Figure6: graph of Passenger car unit v/s unevenness index for multi axle truck

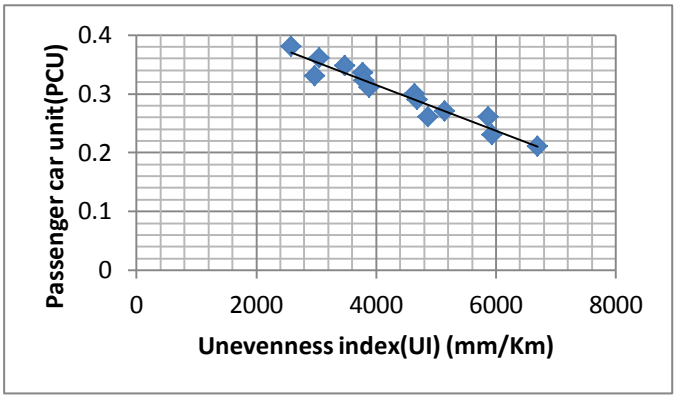

Figure7: graph of Passenger car unit v/s unevenness index for two wheeler

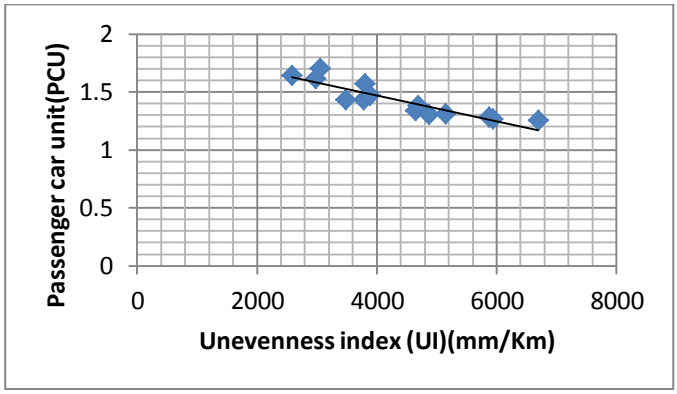

Figure8: graph of Passenger car unit v/s unevenness index for three wheeler

Effect of Road Roughness on Capacity of Road:

To get the mean stream speed, a considerable length on the highway is taken into consideration. Speed of each category of vehicle which is considered for traffic volume count is found out. Then the mean stream speed is calculated by using the formula:

$$V_m = (\sum^{k}_{i=1} n_i * v_i) / \sum^{k}_{i=1} n_i \qquad (5)$$

here

V_m= mean stream speed (Kmph)

k= total number of the vehicles category in the stream.

v_i= speed of vehicle of the category i (Kmph)
n_i= number of vehicles of the category i
Equation5 was used to find the mean stream speed. This speed was plotted against traffic volume for five spots. Figure9 and figure10 represents the plotted curves. Similarly curves were drawn for all the five spots.

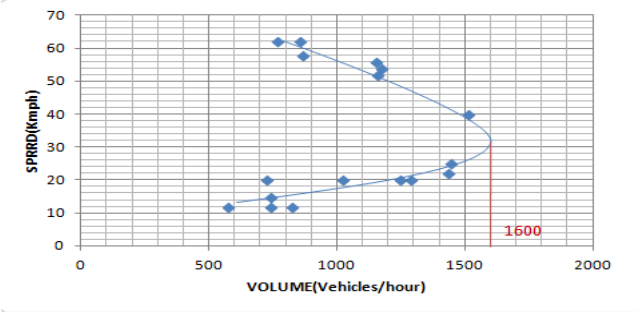

Figure 9: speed –flow diagram in section 2

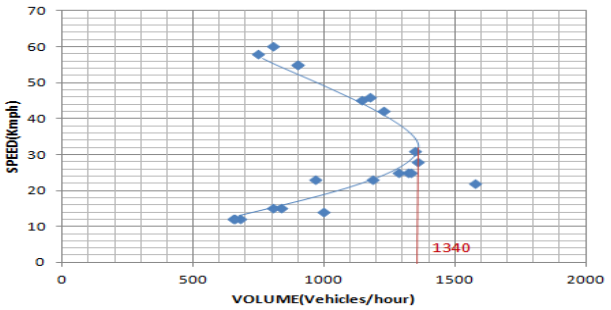

Figure 10: speed –flow diagram in section 3

The capacity estimated for five sections are given in table3

Table3:Capacity of different sections:

SECTION	UNEVENNESS INDEX(mm/Km)	CAPACITY(PCU/hour)
1	3798	1570
2	3057	1600
3	6700	1340
4	3885	1580
5	2585	1680

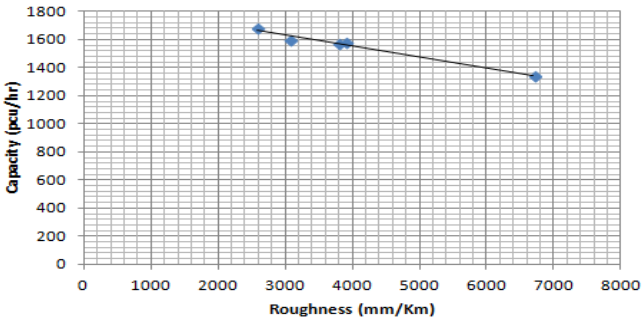

Figure11:Capacity v/s roughness

Based on the data's of table3, the graph was plotted for capacity and roughness as shown in the figure11. According to the plot of figure11 a straight line equation was obtained:

$$C=1870-0.07872*(UI) \qquad R^2= 0.98991 \qquad (6)$$

Where:
C= Capacity in PCU/hour
UI= Unevenness index in mm/Km
The equation6 demonstrates that the capacity of the road decreases by 80 PCU/hour if the unevenness index increases by 1000 mm/Km.

IV. CONCLUSION

Due to spending issues and uncontrolled vehicle over-burdening, upkeep or maintenance of street is not on the best most need criteria. This investigation demonstrates that the free flow speed of the vehicles diminishes as the roughness of the street surface increments. The impact of the roughness of the road is more obvious on the speed of the passenger cars than that of the heavy vehicles.
The speed-volume relationships plotted at different segments of the roads stipulates that the capacity decreases with the increase in the roughness of the road. The capacity of intermediate lane (sub-arterial roads) with good surface condition (unevenness index =2000mm/Km) is found to be 1713 PCU/hour, this value is close to the value given in IRC 106-1990. It decreases by 80 PCU/hour if the unevenness index increases by 1000 mm/Km. Hence it can be stated that the capacity of a intermediate lane road can be increased by 20 to 22 percent by providing the good riding surface.

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