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## **The Evaluation of the Impact of Road Width on Passenger Car Units (PCU) in Heterogeneous Traffic Conditions**

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

**Keywords:** Passenger car units, Road width, Traffic

### **Introduction**

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

Different vehicle classes have varying needs for road space, drive at varying speeds (for geometric design), and put various demands on the road's structure (for structural design). As a result, it's essential to construct a uniform traffic unit that can accommodate different vehicle kinds. The "Passenger Car Unit (PCU)" standard, which represents a typical car (passenger car), light van, or truck, is used to create the geometric layout of highways (Mohamed et al., 2023). Due to the fact that Mogadishu does not strictly adhere to the lane concept and cars frequently drive side-by-side, the purpose of the present study was to ascertain how road width affected traffic flow. In Mogadishu, the carriageway is the entire breadth of a road's paved surface, excluding its shoulders that can accommodate two lanes of traffic when there is mixed traffic (Nations, 2016).

This study acknowledges that real-life traffic situations are complicated and aims to provide results that are relevant to those situations. On this basis the current study attempted to fill the gap in the literature by

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investigating how the width of the road, specifically the roadway width, affects traffic flow in a city with a diverse and mixed population like Mogadishu (Gani et al., 2014).

## Method

### Study Area

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

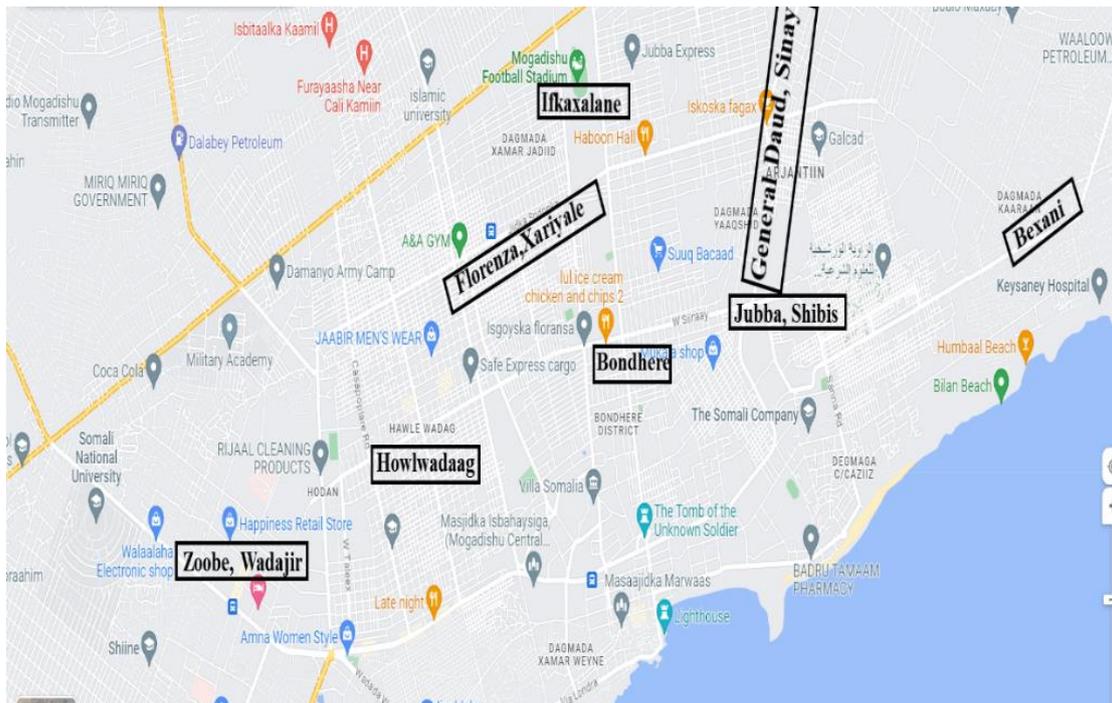


Figure 1. Study area

Bexani, Karan road is 6.8 meters wide, it has a fine paved surface and both side shoulders are 3 meters wide. It is a section of the Bexani highway. There were no obstructions or encroachments. Ifkaxalane Xamarjadid is a 6.7 m wide section of the Ifkaxalane highway with a good asphalt surface. There were no obstructions or encroachments. Bondhere, Bondhere is a portion of the bondhere road with a paved surface and a width of 6.6 meters. There were no encroachments or impediments. Zoobe Wadajir is a piece of zoobe road with a paved surface and a width of 6.5 meters. General Daud Sinay is a portion of the general Daud Road with a 6.4 m road width and a nice paved surface. Florenza Xariyale is a portion of Florenza's road with a 6.1-meter road width and a decent paved surface. Sayidka Howlwadaag is a portion of the Sayidka road with a smooth paved surface and a road width of 5.8 meters. Jubba, Shibus is a road segment that runs from Jubba, Shibus, to Darjinka, Yaqshid, and has a 5.1 m road width with a decent paved surface. Details of the studies sections were given in Figures 2a-h respectively.

### Data Collection and Extraction

The data collection method employed was video recording. On the road, a 20-meter-long longitudinal trap was constructed to monitor speed. A video camera was placed on the platform and raised high enough to capture the whole length of the trap with ample room on each side. During a typical workday, the camera was set to record for 4 to 5 hours. Additionally, specific measurements of the road width, shoulder width, and shoulder condition were taken.



Figure 2. Studied sections a) Bexani Karan b) Ifkaxalane Xamarjadid c) Bondhere Bondhere d) Zoobe Wadajir e) General Daud Sinay f) Florenza Xariyale g) Sayidka Howlwadaag h) Jubba Shibis

In the current study, the vehicles were split up into five separate groups which were bus, truck, LCV, cars and two wheelers. The dimensions of the vehicles observed in the video recordings were obtained from the supplier websites for each type of vehicles. According to AfDB (2016) typical dimensions of several categories were demonstrated in Table 1. With a precision of 0.1 s, the time shown on the video recording was used to calculate the average time it took for each kind of vehicle to complete the length of the trap. A minimum of 300 data points for each kind of vehicle were gathered at each site in order to establish the speed of a vehicle currently traversing the segment.

Table 1. The typical dimensions of several vehicle categories (AfDB, 2016)

Category	Vehicles included	Average dimension		Projected Area on Ground (m <sup>2</sup> )
		Length (m)	Width (m)	
Bus	Buses	11.12	2.49	27.74
Truck	Trucks	7.5	2.35	17.62
LCV	Minibus, mini truck, micro bus	6.10	2.10	12.81
Cars	Car, jeep, van	3.74	1.44	5.39
Two-wheeler	Scooters, motorcycles	1.87	0.64	1.2

## Result and Discussion

### Speed Distributions

The PCU factor is computed using the mean speed values of several vehicle types. In order to calculate this, the average speed of all other vehicle types were taken and subtracted from the average speed of passenger cars. In order to measure speed, a 20-meter-long longitudinal trap was constructed on the road. Following the recording

and viewing of the video on a large-screen television, data was gathered. A stopwatch was used to compute the average time each vehicle type took to complete the length of the trap, and the time was shown on the screen with an accuracy of 0.1 s. This time was used to calculate the speed at which a vehicle would pass through the segment. Table 2 below shows the average speed of various vehicles on various highway sections.

Table 2. Speed of different vehicles

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

The analysis demonstrated that the vehicle speed across all categories rise linearly as road width increases. The investigation that was done to determine how carriageway width affected vehicle speed led to the formation of the following relationships:

**For Bus**

According to the study, bus speed increases linearly as carriageway width increases, as shown by the relationship  $Speed=5.958W + 21.30$  with an R2 value of 0.986. The statically testing of regression shows the p-value below zero which proves the significance of derived relationship between speed and carriageway.

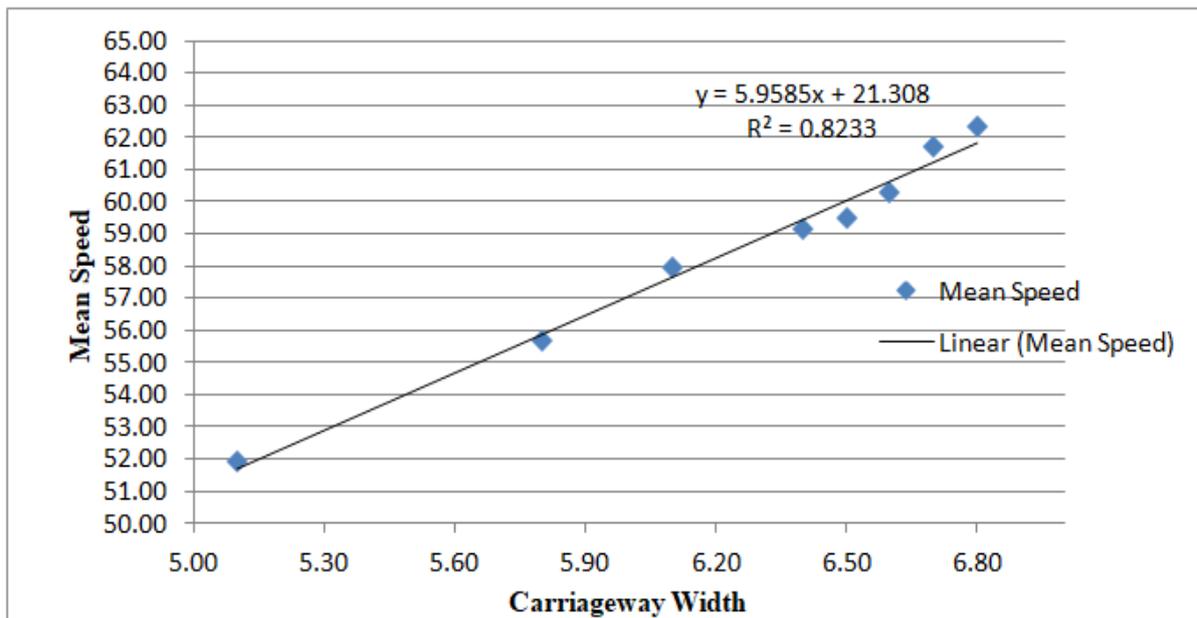


Figure 3. Bus; relationship of speed with carriageway width

**For Truck**

The study also demonstrated that the PCU values for the truck vehicle type have a linear connection and rely on the carriageway width, with  $Speed = 5.012W + 23.38$  and an R2 value of 0.95. The statically testing of regression shows the P-value below zero which demonstrates the significance of derived relationship as presented in Figure 4.

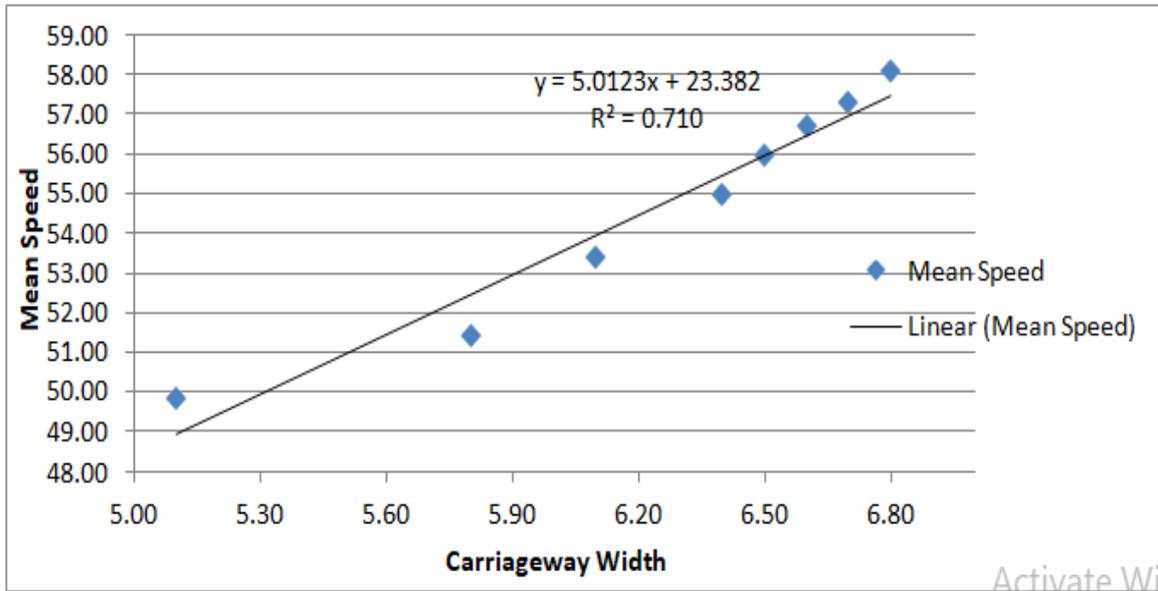


Figure 4. Truck; relationship of speed with carriageway width

### For LCV

Similarly, the study showed that the Speed of LCV were dependent on carriageway width and also have linear relationship between them. The linear equation of Speed with Carriageway width is  $\text{Speed} = 5.808W + 20.09$  with the  $R^2$  value of 0.966. The statically testing of regression shows the P-value below zero shows the significance of derived relationship

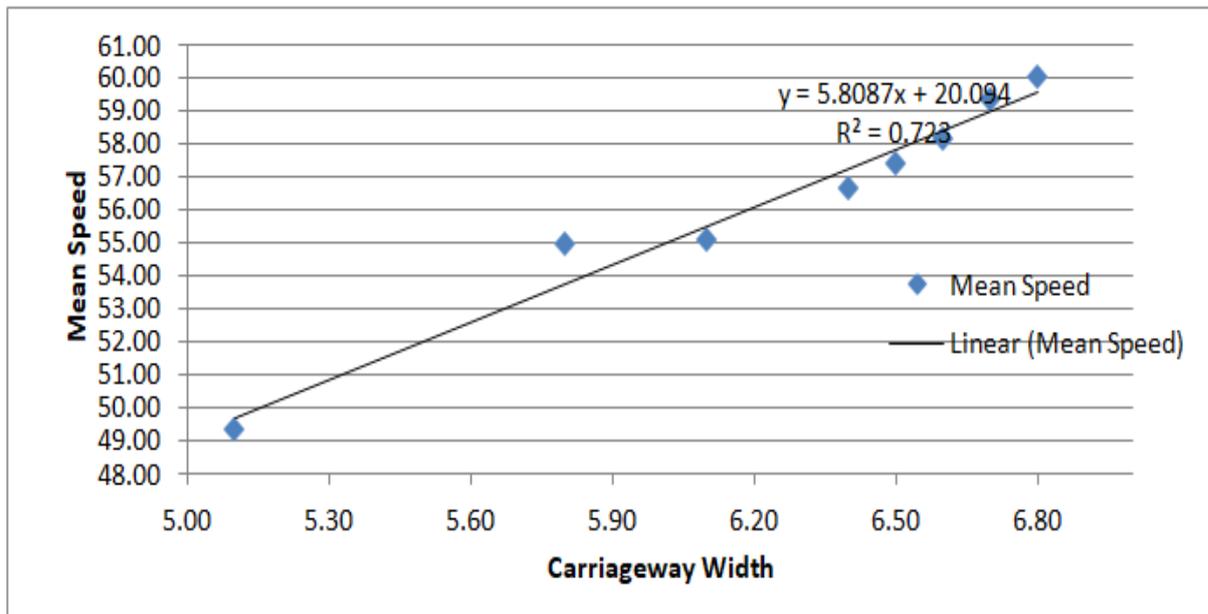


Figure 5. LCV; relationship of speed with carriageway width

### For Two-Wheeler

The study showed that the Speed of Two-Wheeler are dependent on carriageway width and also have linear relationship between them. The linear equation of PCU values with Carriageway width is  $\text{Speed} = 3.412W + 29.87$  with the  $R^2$  value of 0.881. The statically testing of regression shows the P-value below zero shows the significance of derived relationship.

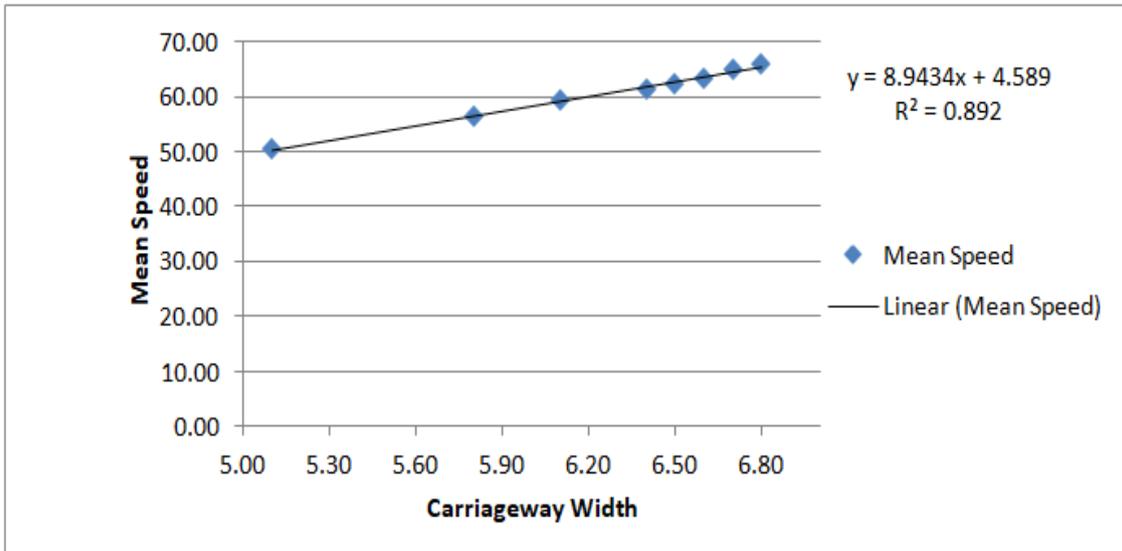


Figure 6: Two-wheeler; relationship of speed with carriageway width

### For Car

Similarly, the study showed that the Speed of Car are dependent on carriageway width and also have linear relationship between them. The linear equation of PCU values with Carriageway width is  $Speed = 8.943W + 4.589$  with the R2 value of 0.993. The statically testing of regression shows the P-value below zero shows the significance of derived relationship.

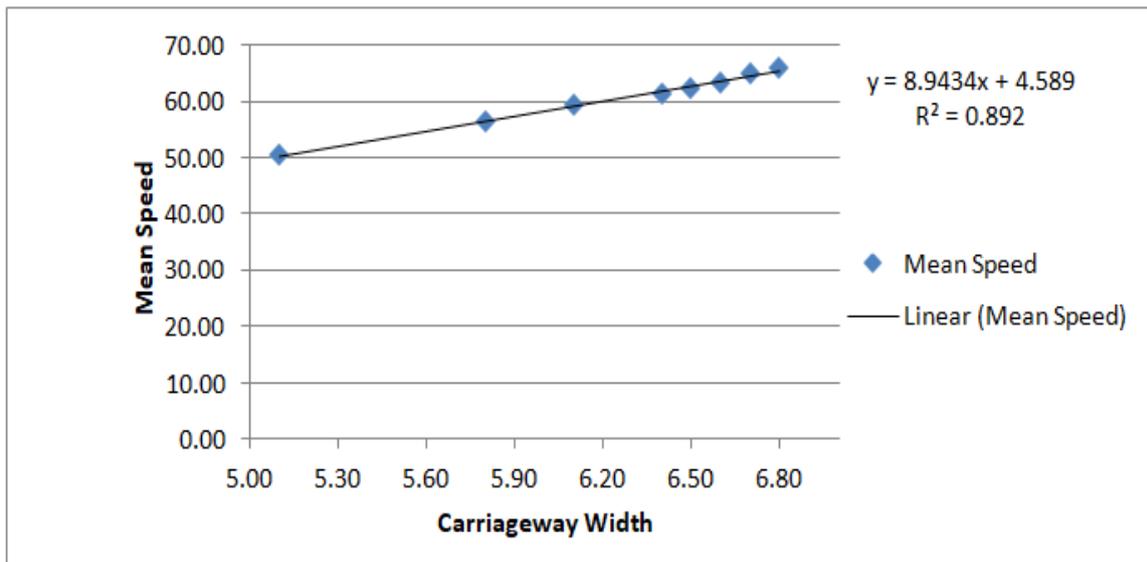


Figure 7. Car; Relationship of speed with carriageway width

### Determination of PCU Values

The present study utilized (AfDB, 2016) relationship to calculate PCU values on highways. The PCU values are inversely related to the vehicle's space occupancy ratio when compared to the standard area of the vehicle, such as a car, and directly proportional to the vehicle's clearing speed ratio. The PCU for a certain type of vehicle is taken from the 2003 report by Chandra and Kumar. One crucial factor that distinguishes the speed approach from other PCU calculation techniques is the incorporation of both dynamic and static vehicle parameters, other headway techniques only take into account the dynamic characteristics of the vehicles.

$$PCU = (V_c/V_i)/(A_c/A_i)$$

PCU, or passenger car unit value, refers to this kind of vehicle.

The car's speed to the next vehicle is  $V_c/V_i$ .

The car's space to the next vehicle is  $A_c/A_i$ .

$V_c$  is the vehicle's speed in kilometers per hour.

$V_i$ =vehicle type I's speed (kilometers per hour).

$A_i$  = static (projected rectangular) area of the vehicle type (m<sup>2</sup>).

$A_c$  = static (projected rectangular) area of an automobile.

Table 3 demonstrated the PCU values for the various vehicle categories that were determined at various road segments. This illustrates how PCU fluctuated based on the segment, vehicle type, and lane width. The PCU factor was computed by using the mean speed values of several vehicle types.

Table 3. PCU values for various vehicle categories calculated at various sections

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

### Effect of Carriageway Width on PCU Values of Different Vehicles

The following relationships have been developed as a consequence of the investigation illustrating how carriageway width affects PCU values for various vehicles:

#### For Bus

The study shows that the PCU values of vehicle type Bus are dependent on carriageway width and have linear relationship between them. The linear equation of PCU values with Carriageway width is  $PCU=0.260W+3.681$  with the R<sup>2</sup> value of 0.985.

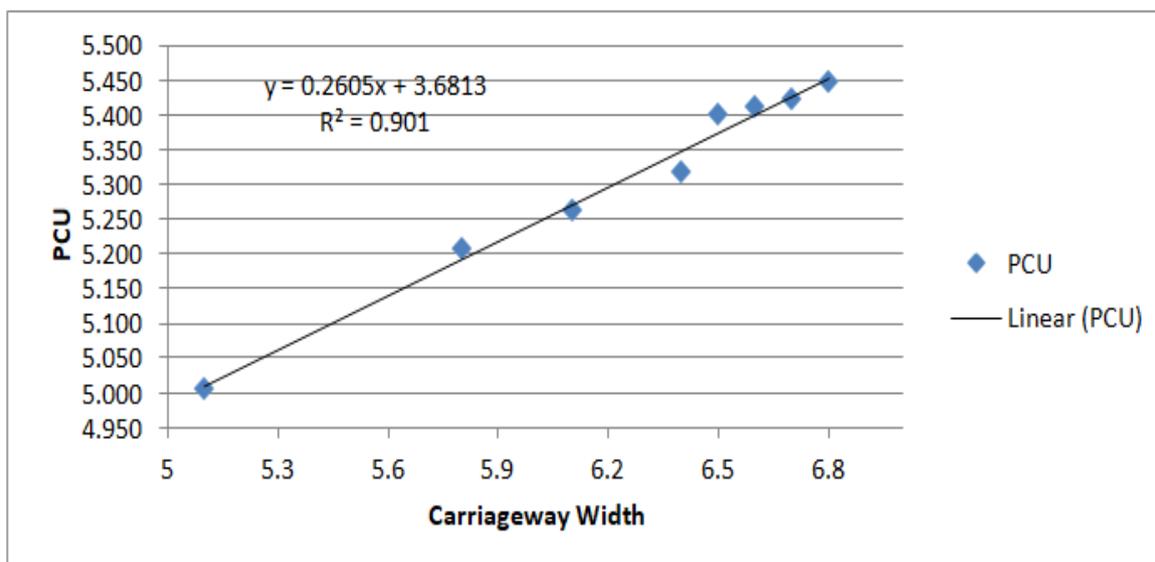


Figure 8. Bus; correlation chart of PCU with carriageway width

### For Truck

Figure 9 illustrated the linear equation of PCU values with Carriageway width for vehicle Truck is  $PCU=0.214W+2.266$  with the  $R^2$  value of 0.899 which shows the value of PCU is dependent on carriageway width.

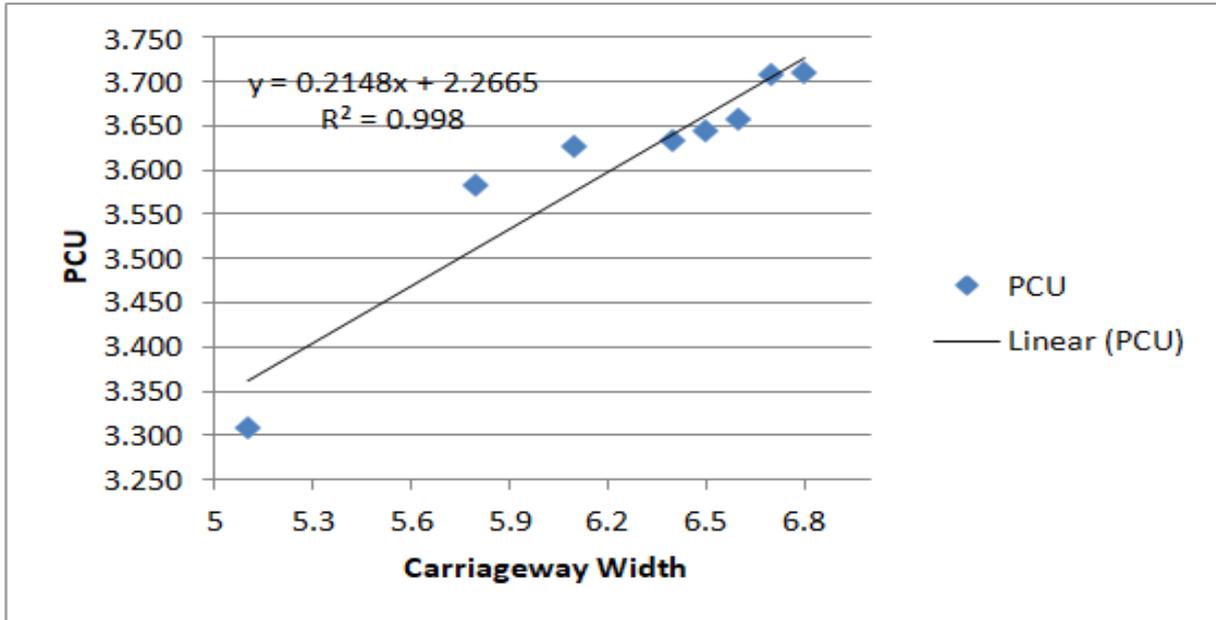


Figure 9. Truck; correlation chart of pcu with carriageway width

### For LCV

The study also showed that the PCU values of vehicle type LCV are dependent on carriageway width and have linear relationship, where  $PCU = 0.120W + 1.790$  with the  $R^2$  value of 0.883. The statically testing of regression shows the P-value below zero which demonstrates the significance of derived relationship as presented in Table 4.

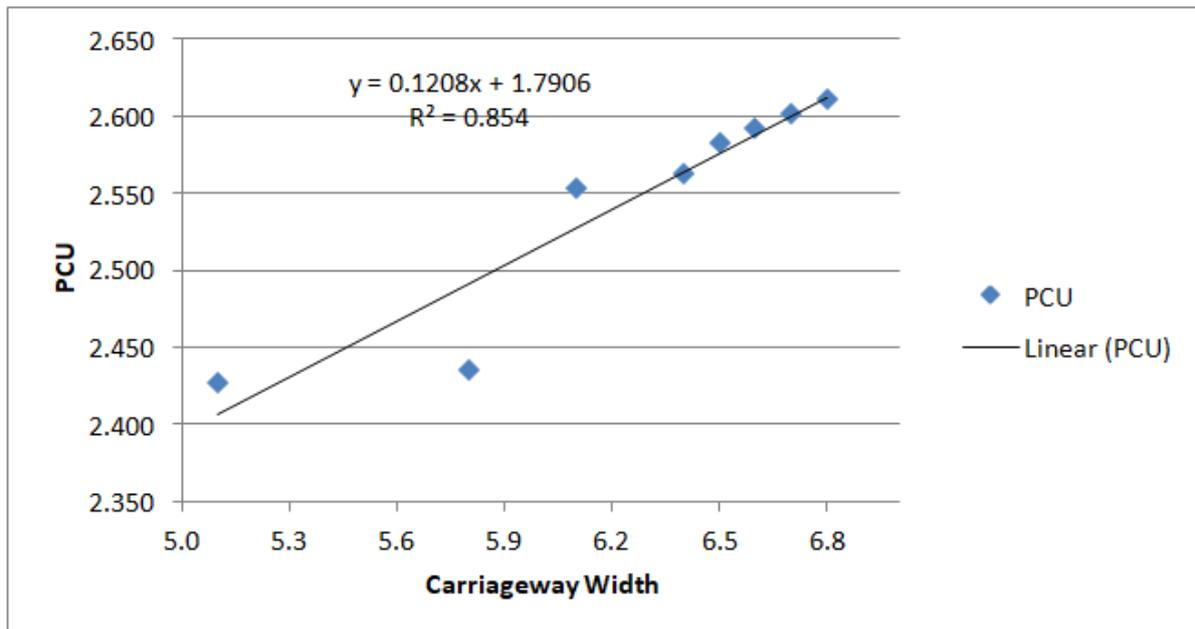


Figure 10. LCV; Correlation chart of PCU width carriageway width

### For Two-Wheeler

Similarly, the study showed that the PCU values of Two-Wheeler are dependent on carriageway width and also have linear relationship between them. The linear equation of PCU values with Carriageway width is  $PCU = 0.022W + 0.124$  with the  $R^2$  value of 0.944. The statically testing of regression shows the P-value below zero shows the significance of derived relationship.

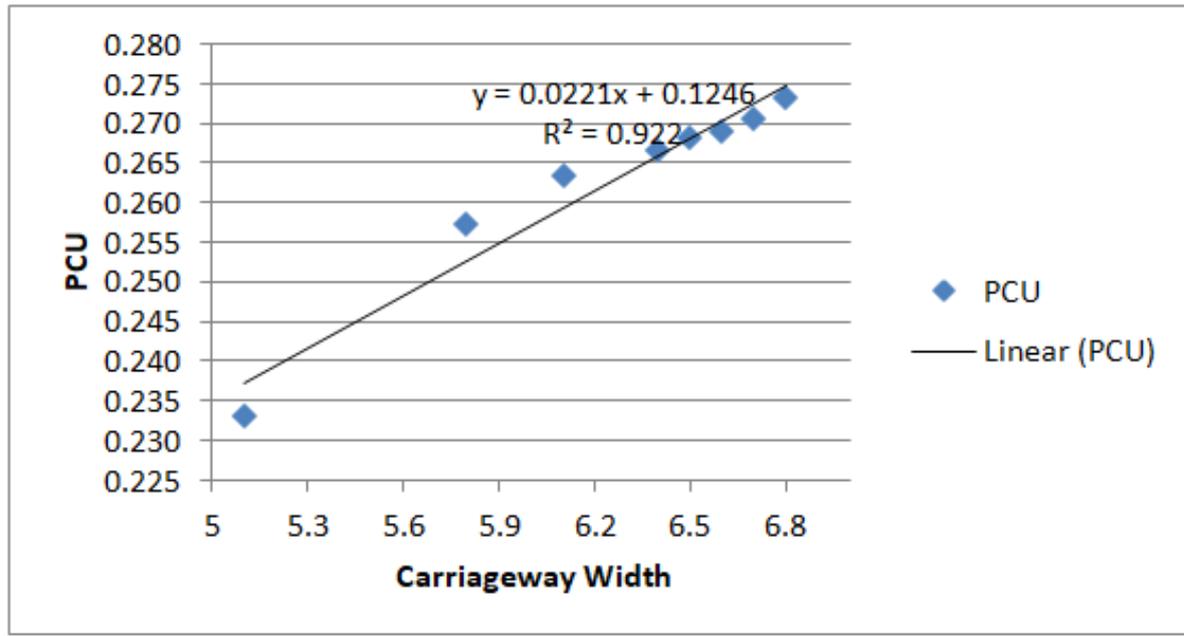


Figure 11. Two-wheeler; correlation chart of pcu with carriageway width

In Table 4. the general overview of the relationship between the PCU of various vehicle types and the carriageway width is given.

Table 4. Summary of the relationship between pcu of various vehicle types and roadway width

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

### Conclusion

The study focused on four classes of vehicles that are frequently seen in Mogadishu: buses, trucks, light commercial vehicles (LCV), and two-wheelers. The field experiments were done at eight distinct places along the Mogadishu Highway. According to the survey, two-wheelers predominately make up the traffic composition almost at all sections. With broader carriageway widths, the volume of some vehicle types such as buses, trucks, light commercial vehicles, and cars increased linearly, but the volume of two-wheelers was the maximum on smaller lanes.

Wider road widths resulted in faster moving vehicles, proving a linear relationship. The Passenger Carrying Unit (PCU) values for each type of vehicle were influenced by the traffic composition, demonstrating a linear relationship between them. With carriageway widths ranging from 6.8 to 5.1, the PCU values for buses range from 5.454 to 5.000, trucks from 3.722 to 3.309, LCVs from 2.617 to 2.429, and two-wheelers from 0.275 to 0.233.

Lane width affected the PCU values, which typically rose with wider lanes. Lane width and PCU values possessed a substantial correlation, according to regression analysis. Highway lane width clearly had a linear

effect on PCU. It's interesting to note that the study's newly determined PCU values diverge significantly from those in the NRS standard. In comparison to MRS 2070, motorcycle PCU values were lower, whereas bus, truck, and LCV PCU values were higher.

In summary, the study examined vehicle composition, speed, and PCU values across different carriageway widths in Mogadishu. It has established a linear correlation between lane width and PCU, indicating that PCU values were influenced by lane width. The PCU values determined through this research differ from those in existing standards.

## Recommendations

The recommendations provided in this article highlight the necessity for Mogadishu's urban planning and policymaking to place a high priority on infrastructure development that can support a variety of vehicle types. In order to do this, broader roads must be designed to accommodate buses, trucks, and LCVs. Additionally, safety measures must be put in place for two-wheelers, and systematic traffic monitoring must be established. Additionally, it is crucial to carry out public awareness programmed for safe driving, update outdated PCU standards to reflect the current traffic situation, and support continuous research in order to guarantee that the city's transportation infrastructure is effective and secure for all users of the roads. The overall goal of these suggestions is to improve Mogadishu's road network's adaptability, safety, and traffic management.

## Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

## Acknowledgements or Notes

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