Al-Azhar Engineering 16th International Conference

Vol. 19, No. 72, July 2024, 14 - 33

ASSESSING PASSENGER CAR UNITS ON EGYPTIAN ROADS UNDER DIFFERENT TRAFFIC CONDITIONS: A COMPREHENSIVE APPROACH

Magdy M. Abd Elsamad[1]*, Nasser M. Abdallah[2], Ahmed S. El Hakim[2]

[1]Civil Engineering Department, Faculty of Engineering Assuit University, Cairo, Egypt,

[2]Civil Engineering Department, Faculty of Engineering Al-Azhar University, Cairo, Egypt,

***Correspondence:** magdymansour2013@yahoo.com

Citation:

M.M. Abd Elsamad, N.M. Abdallah and A.S. El Hakim," Assessing Passenger Car Units on Egyptian Roads under Different Traffic Conditions: A Comprehensive Approach" Journal of Al-Azhar University Engineering Sector, vol. 19, pp. 14 - 33, 2024.

Received: 05 November 2023

Revised: 08 December 2023

Accepted: 18 December 2023

DoI:10.21608/auej.2023.246082.1458

ABSTRACT

Early in 1987, the values of PCU (Passenger Car Unit) were determined and are still used in Egyptian urban roads, so due to the change in the transport fleet in Egypt, these values are outdated and must be updated. This study investigates estimates of PCU values for twenty different vehicle types using static and dynamic features such as speed, projected vehicle area, traffic volume, and headway. Data is collected from eight urban roads in Cairo using digital video recording and Analyzed by Chandra's Method, Homogenization Coefficient Method, and Time Headway Method. The study finds that new and outdated values of PCU are significantly different because of changes in transport fleets on urban roads in Egypt during the past 36 years. The research set a relationship between PCU values and traffic volume for different vehicle classifications. It is implied that the PCU values obtained from this study should be utilized as a guideline in traffic engineering works in Egypt.

KEYWORDS: Passenger Car equivalent (PCE), Passenger Car Unit (PCU), Traffic Volume, Headway and capacity, Traffic speed.

تقييم وحدات سيارة الركاب على الطرق المصرية تحت الظروف المرورية المختلفة: منهج متكامل

مجدي منصورعبدالصمد احمد[1]*،احمد صبري الحكيم[2]، ناصر محمد عبدالله محمد[2]

[1]قسم الهندسة المدنية، كلية الهندسة، جامعة اسيوط، القاهرة، مصر.

[2]قسم الهندسة المدنية، كلية الهندسة، جامعة الأزهر، القاهرة، مصر.

*البريد الاليكتروني للباحث الرئيسي : magdymansour2013@yahoo.com

الملخص

في أوائل عام 1987، تم تحديد قيم وحدة العربة المكافئة علي الطرق الحضرية في مصر وما زالت تستخدم حتي الآن . ونظرًا للتغير في أسطول النقل في مصر، أصبحت هذه القيم قديمة ويجب تحديثها. تهدف هذه الدراسة إلى تحديد قيم وحدة العربة المكافئة علي الطرق الحضرية في مصر لعشرين نوعًا مختلفًا من المركبات باستخدام الخواص الطبيعيه والديناميكية مثل سرعة ومساحة المركبة وحجم حركة المرور والزمن البيني. تم جمع البيانات من ثمانية طرق حضرية في القاهرة باستخدام تسجيل الفيديو الرقمي وتحليله بواسطة طريقة تشاندرا، وطريقة معامل التجانس، وطريقة التقدم الزمني. توصلت الدراسة إلى أن قيم وحدة العربة المكافئة الجديدة والقديمة تختلف بشكل كبير بسبب التغيرفي اسطول النقل على الطرق الحضرية في مصر خلال الـ 36 عامًا الماضية. وكذلك تم رسم العلاقة بين قيم وحدة العربة المكافئة وحجم حركة المرور لتصنيفات المركبات المختلفة. وهذا يعني أن قيم وحدة العربة المكافئة التي تم الحصول عليها من هذه الدراسة يجب أن تستخدم للاسترشاد بها في دراسات تخطيط النقل وهندسة المرور في مصر.

الكلمات المفتاحية : وحدة العربة المكافئة، معامل سيارة الركاب، الحجم المروري، السرعة، الزمن البيني وسعة الطريق.

1. INTRODUCTION

Solving traffic congestion problems always requires comparing the traffic volume with the road capacity, and this comparison cannot be completed without determining the passenger car unit. PCU is a unit that calculates traffic volume and capacity based on a passenger car as the standard vehicle. In the past, In 1985 and 1987, only two studies were carried out for the dedication of PCU in the Egyptian Urban Road network due to a change in the fleet of transport vehicles in terms of their physical and mechanical properties, including what has been added recently. Therefore, the values of PCU are outdated and not commensurate with the current fleet of road vehicles using road networks, and the current modern values must be determined.

There are more than 20 incompatible types of vehicles on Cairo's metropolitan highways, including motorbikes, pedal cycles, non-motorist vehicles, and heavy trucks. Nowadays, more automobiles are being developed, some of which employ automatic transmission and others mix fuel and electricity (hybrid vehicles). The physical and mechanical variations between these vehicles result in heterogeneous traffic. These vehicles are all very different in terms of their dynamic qualities, like speed and acceleration, and their static qualities, such as length, width, etc. In addition, there are significant differences in the driving behaviour of the various vehicle classes. That poses a problem in designing roads, traffic signals, and intersections. Therefore, all vehicle classes must be combined into a single-passenger car unit.

PCU values for various car classes are computed using a typical passenger car. However, there are currently many different types of passenger cars in use.

This study aims to ascertain the PCU of a different class of vehicles by using the subsequent approaches during peak and off-peak hours.

Methods for calculating the PCU of various vehicle classifications were adapted as the following:[1]

- Chandra's Method
- Homogenization coefficient method
- Time headway method

The main objective of the study has been concentrated on the following:

1- Determining the values of PCU for different categories of vehicles (about 20 various types of vehicles) in a variety of traffic situations on a mid-block section in Cairo's urban roads network to Examine how the PCU values vary due to the new fleet of transport concerning different traffic stream parameters.

2- Comparing the new values of PCU with previous work to validate whether the current PCU settings are still appropriate or should be changed.

3- To develop the relationship among PCU values for various vehicle types, speed, and traffic volume.

The following scope will be adopted to achieve these objectives:

1. Selected road samples with specific criteria, as mentioned in the methodology section.

2. Three different methods are used for calculating the passenger car unit of various vehicle classifications.

PCU is a complicated parameter that is affected by numerous variables. As a result, the literature offers a variety of techniques for determining the PCU values of a given vehicle type[2]. Several studies were previously conducted to determine PCU in rural and urban road networks worldwide. However, more studies have yet to be completed in Egypt to determine PCU. **Table 1** summarizes these studies in Egypt and other countries.

The first study was performed on rural roads to determine the passenger car equivalent for different vehicle modes running over the rural Egyptian road network. Scruggs's Method was applied in Egyptian rural areas. The required data were collected in two stages using a video system. In the first stage, the video camera was usually fixed to the traffic stream, filming the traffic stream continuously for one hour. The second stage was replaying the video film over a T.V. set and using a stopwatch to measure the headways. [3]

The second study was conducted on urban roads to identify the PCU for different vehicle modes running over the urban Egyptian road network. Again, Scruggs's Method was applied in Egyptian urban areas in road links and intersections to determine PCU values. Since the equipment for measuring headways was unavailable, the required data was collected using a video camera to record the existing traffic characteristics. A digital stopwatch was used to measure the headways. [4]

The third study was carried out by to formulate a generalized model for the dedication of PCU of various types of vehicles to observe traffic flow behaviours at mid-block of links and signalized intersections within the Cairo urban road network so the Indian Method was applied to determine PCU values. Since the equipment is necessary for measuring the speeds of vehicles and headways between vehicles, two pieces of electronic equipment vs 1900 are used; one is connected to the loops and the other to the air tube. [5]

It is evident that the research on PCU values on Egyptian urban roads is outdated; thus, new research that considers changes in transportation fleets on Egyptian urban streets is required.

Table 1. Summary of literature review on PCU determination studies

	AUTHORS, REFERENCE	COUNTRY	STUDY AREA	METHODS & TOOLS
LOCAL RESEARCH (EGYPT)	(Aly 1984) [3]	Egypt	Rural	Scraggs method
	(El-hakim, 1984) [4]	Egypt	Urban (mid-block roads and intersections)	Scraggs method
	(Abou Huneidy 1987) [5]	Egypt	Urban (mid-block roads and intersections)	Indian Method
REGIONAL RESEARCH	(A.Mehar, 2014) [6]	India	interurban highways (mid-block roads)	Chandra's Method
	(Behzadi 2016) [7]	Iran	Urban (mid-block roads)	analyzing data and comparing by AIMSUN software
	(Swetha 2016) [8]	India	interurban highways (mid-block roads)	Modified density method. Time headway method Homogenization coefficient method
	(Patel 2016) [9]	India	Urban (mid-block roads)	Homogenization Coefficient Method Chandra's Method
	(Mondal,2017) [10]	India	Urban (mid-block roads)	Chandra's Method
	(Ballari,2019) [11]	India	Urban (mid-block roads)	Chandra's Method
	(S. M. R. Rahman 2020) [12]	Bangladesh	Urban (mid-block roads)	Satish Chandra Method Homogenization Co-efficient Method
	(Zero, 2022) [13]	Iraq	Urban (mid-block roads)	Headway Method Density Method Homogeneous Coefficient Method
	(Joshi, 2021) [14]	India	Urban (mid-block roads)	Chandra's Method
	(Tullu, 2021) [15]	Ethiopia	Urban (mid-block roads)	Chandra's Method
DEVELOPING COUNTRIES RESEARCH	(Satthamnuwong, 2018) [16]	China	Urban (mid-block roads)	Lagging Time Headway
	(Krausea, 2019) [17]	Germany	Urban (intersection)	a model to verify P.C.U.
	(Subotić, 2016) [18]	Serbia	Urban (mid-block roads)	Time headway method
	(Gani,2017) [19]	Indonesia	Urban (mid-block roads)	Chandra's Method
	(Sugianto,2018) [20]	Indonesia	Urban (intersection)	time occupancy method

2. Methodology

The study methodology was designed to achieve the above objectives, as shown in **Fig. 1**.

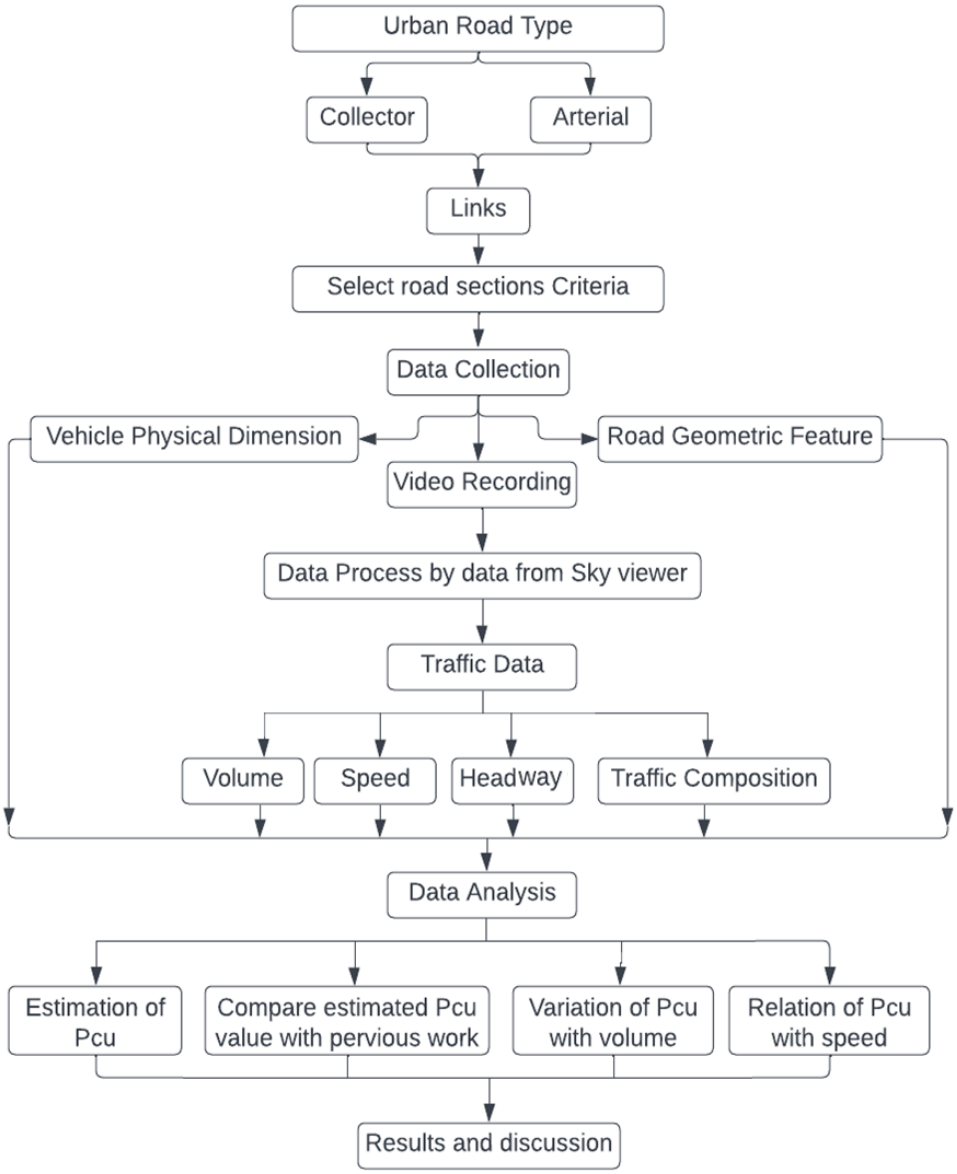

Fig. 1. Flow chart for study plan

Source : The auther

2.1. Select Road Sections Criteria.

Eight major traffic corridors were chosen to investigate, and the required data was collected. The eight corridors were selected and are listed below based on the following criteria.

- No parking is allowed along this section.
- No bus stop at this location
- Traffic composition (all types of vehicles)
- Traffic volume variation

- Traffic speed variation
- The section must be multilane divided and homogeneous (Number of lanes, lane width, and slope)

The eight selected locations are listed as shown in **Fig. 2.**

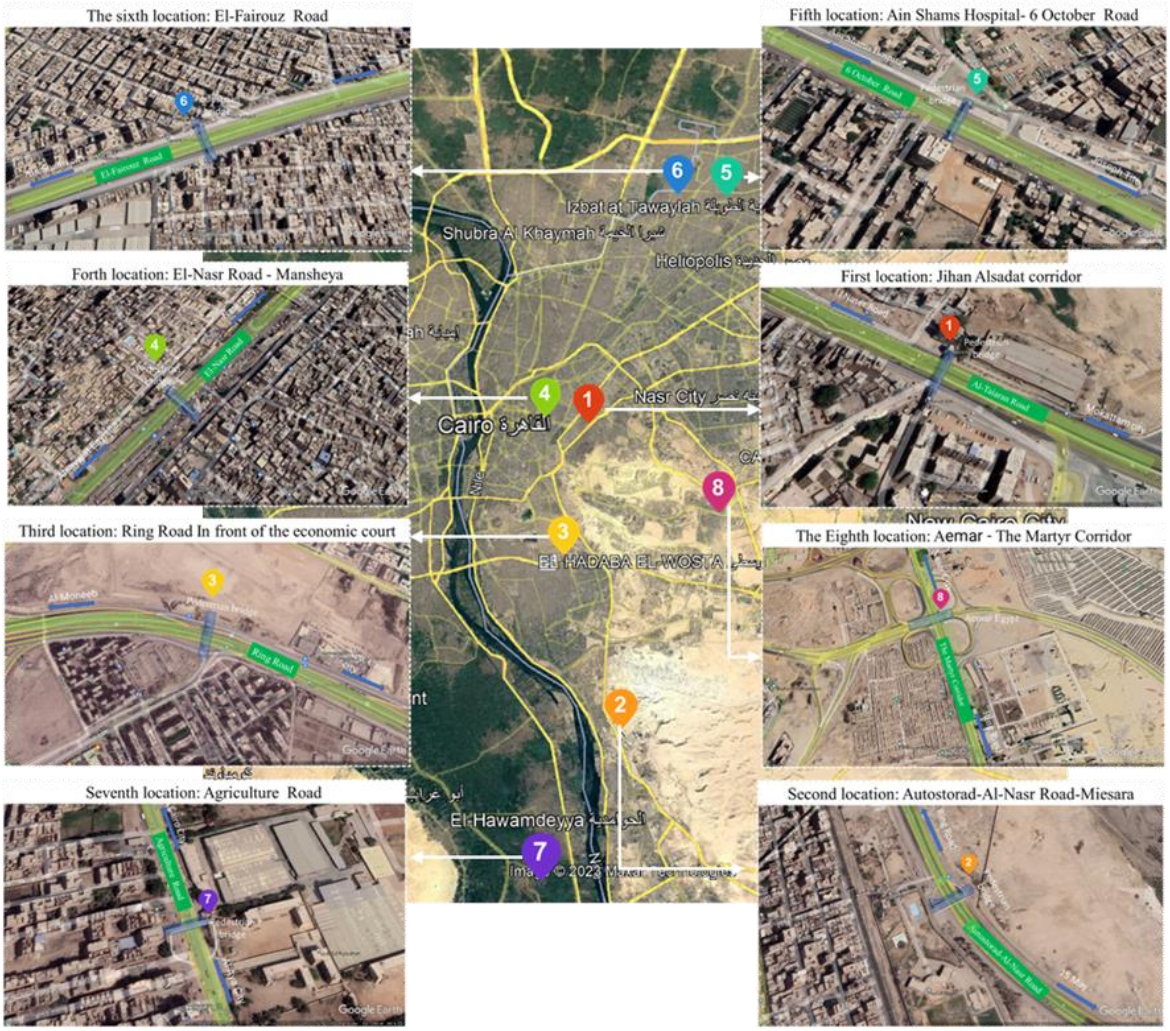

Fig. 2. Screenshot from Google Earth shows the eight selected locations.

3. Data Collection

The term traffic characteristics in this study includes the following:

1. Speed (spot speed) will be measured using the Endoscope method.
2. The traffic volume will be measured using a video recording technique.
3. The traffic composition will be calculated using the video technique method and data from the SkyView viewer.
4. Headway time.

3.1. Video Recording

A video recording procedure has been used to record vehicular traffic movements in two directions for selected corridors. Different classes of vehicles during smooth traffic flow have been

obtained. Additional traffic volume during peak hours was considered. Traffic speed varied according to road type and was accepted within static characteristics of vehicles.

A part of the highway that was straight and had no access points or intersections, a straight section of about 200 meters in length, was selected under pedestrian bridges perpendicular to these sectors so that we could install a camera in the direction of traffic movement. And at an inclination angle that shows all types of vehicles travelling in the market sector. Data on traffic flow and speed were gathered for four hours. In the morning from 7:00 am to 11:00 am and 4 hours in the evening from 12:00 pm to 4:00 pm by using a Video recording of traffic flow on each road taken on a typical day (Monday and Wednesday).

3.2. Vehicle Physical Dimension

Due to the development of the transport fleets in Egypt, the dimensions of vehicles changed, so the PCU values changed as well.

The new dimensions (the length and width) for all types of vehicles were measured in the field by measuring tape, as shown in **Table 2.**

Table 2. Average dimensions of measured vehicles

Vehicle Categories and Their Average Dimensions				
NO.	vehicle type	overall length(m)	overall width (m)	Projected rectangular area (m2)
1	sedan	4.49	1.725	7.75
2	SUV	4.354	1.687	7.35
3	hatchback	4.039	1.67	6.75
4	pick-up trucks	5.518	1.65	9.10
5	van (Suzuki)	4.31	1.672	7.21
6	Light Goods	4.3	1.45	6.24
7	Microbus(<13seets)	5.14	1.79	9.20
8	Minibus	6.3	1.95	12.29
9	Bus (>25 seats)	10.946	2.466	26.99
10	light Truck	5.661	1.868	10.57
11	Truck	8.171	2.44	19.94
12	truck with trailer	16.6	2.4	39.84
13	trailer	13.6	2.5	34.00
14	semi-trailer	11.55	2.45	28.30
15	Motorcycles	1.952	0.747	1.46
16	Three-wheeler	2.67	1.35	3.60
17	Tok-tok	2.62	1.3	3.41
18	cycle rickshaws	2.7	0.95	2.57
19	animal-drawn vehicles	5.5	1.75	9.63
20	pedal cycles	1.45	0.45	0.65

3.3. Road Geometric Feature

The eight chosen sections differ in road type, number of lanes, capacity, traffic composition, and speed, as shown in **Table 3**.

Table 3. Classification of the road section

Road Name	CLASSIFICATION	NO. OF LANE	POST SPEED (KM/HR)
The First Location	expressway	four-lane /dir.	90
The Second Location	expressway	four-lane /dir.	90
The Third Location	expressway	four-lane /dir.	90
The Forth Location	Collector	four-lane /dir.	60
The Fifth Location	Collector	four-lane /dir.	60
The Sixth Location	Collector	four-lane /dir.	60
The Seventh Location	Collector	two-lane/dir.	60
The Eighth Location	Suburban	Four-lane/dir.	90

3.4. Data Processing

The data was collected and processed using data from the SKY VEWIER Program's unique software[21]. That is used for further analysis, advanced interpretation, and visualization of traffic data, able to analyze all trajectories at a given location to measure macroscopic flow characteristics at any needed point or region, as shown in **Fig. 3**.

Figure 3 shows the steps for processing data; step 1 shows playing the video on the program to determine each vehicle type by giving it an ID. Then, step 2 shows the entry and exit gates to count the number of vehicles and get each lane's entry and exit time and headway time. Finally, step 3, as shown in **Table 4**, shows an Excel file containing a code number for each vehicle that passed through the gates, the time of entry and exit gates, and the type of each vehicle. The Endoscope Method, the vehicle's trip duration, and the known separation between field gates are used to calculate spot speeds. Ultimately, the speed of the respective vehicle class was determined by averaging the spot speeds of the vehicles.

a) Step 1

b) Step 2

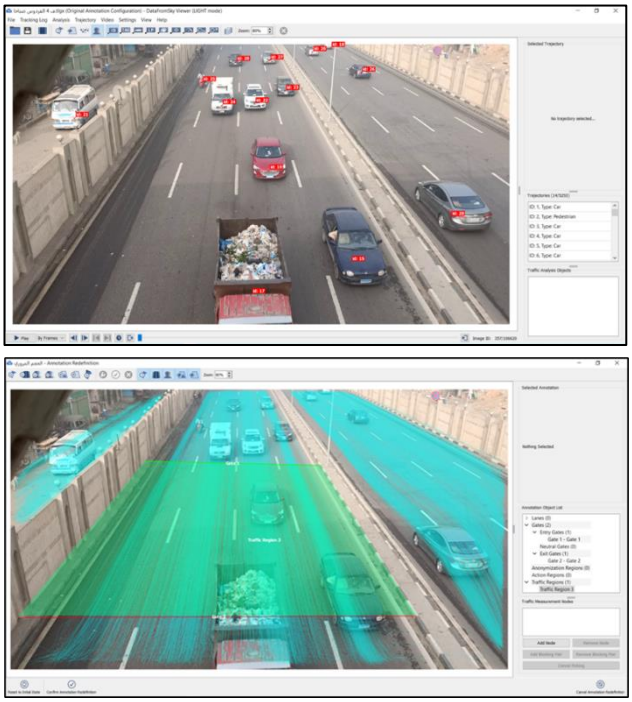

Fig. 3. Shows step 1 and step 2 in SKY VEWIER Program.

Table. 4. An Excel file containing a code number for each vehicle, the time of entry and exit gates, and speed

Track ID	Type	Colour	Entry Time [s]	Exit Time [s]	time (s)	distance (m)	speed (m\s)	speed(km\hr)
1	Hatchback	Red	2.13	4.66	2.53	35	13.81	49.72
7	Pick-ups Trucks	White	3.11	5.58	2.47	35	14.19	51.08
8	Motorcycles	Undefined	4.16	6.76	2.60	35	13.45	48.43
11	Sedan	Red	7.30	9.63	2.33	35	15.01	54.04
15	Sedan	Black	9.70	12.13	2.43	35	14.39	51.79
17	Light Truck (Jumpo)	Red	9.87	11.93	2.06	35	16.98	61.13
19	Sedan	Red	10.41	12.74	2.33	35	15.01	54.04
22	SUV	White	11.35	13.79	2.43	35	14.39	51.79
23	Sedan	Silver	11.72	14.09	2.37	35	14.80	53.27
24	Pick-ups Trucks	White	11.49	13.31	1.82	35	19.18	69.06
25	Motorcycles	Undefined	11.99	14.90	2.91	35	12.04	43.36
27	Sedan	Silver	13.11	15.58	2.47	35	14.19	51.08
28	Sedan	Black	12.87	15.10	2.23	35	15.69	56.50
32	Sedan	Black	15.20	17.50	2.30	35	15.23	54.84

3.5. Traffic Data

The speed, volume, headway, and traffic composition (all types of cars) can be determined from the Excel sheet extracted from the process program.

3.6. Adapted Methods for Estimation of Passenger Car Unit (PCU)

a) Chandra's Method

The PCU values of the automobiles were evaluated in the current investigation using Chandra's Approach. The other traffic stream factors primarily influence the vehicle speed in a heterogeneous traffic stream. This study's "standard car" is the standard passenger car, or sedan, as speed is the primary criterion. According to Chandra's Method, PCU for any vehicle may be calculated using equation (1).

$$PCU_i = \frac{V_c/V_i}{A_c/A_i} \quad \text{Equation (1)}$$

Where,

PCU_i = Passenger Car unit of vehicle i

V_c = Average passenger car speed amid a stream of traffic (km/hr)

V_i = The average speed of vehicle i in the traffic stream (km/hr.)

A_c = projected rectangular passenger car area (m^2)

A_i = Projected rectangular area of vehicle i (m^2)

The composition function of the traffic stream, its proportion, and the proportion of other vehicles are represented by the numerator in the equation above since the speed of each type of vehicle relies on its category.

b) Homogenization coefficient method

The length and speed are necessary to determine a vehicle's PCU using this Method. Spot speed studies calculate speed, and the lengths of all types of vehicles were calculated by measuring the lengths of these vehicles in the field by tape. Finally, the homogenization coefficient method's PCU value for a particular vehicle class is computed using equation (2).

$$PCU_i = \frac{L_i/U_i}{L_c/U_c} \quad \text{Equation (2)}$$

Where,

PCU_i = Passenger Car unit of vehicle i

L_i = The length of the corresponding vehicle

L_c = The car's length

U_i = corresponding vehicle speed

U_c = Car speed

(c) Time headway method

This approach is predicated on the notion that a truck has a smaller decreased capacity than a single-passenger automobile since it occupies more space. Time headway for various vehicle kinds is computed from recorded video using the processing application DATA FROM SKY Viewer. This Method considers the lower time headway, mean speed, and adequate size when calculating the PCU values for the vehicles. Thus, in this system, time headway, speed, and vehicle breadth also depend on the PCU values of the cars. The equation represents the PCU value of a vehicle class obtained using the time headway approach (3).

$$PCU_i = \left(\frac{W_i * T_i}{U_i}\right) / \left(\frac{W_c * T_c}{U_c}\right) \quad \text{Equation (3)}$$

Where,

PCU_i = Passenger Car unit of vehicle i

W_i = Corresponding vehicle width

W_c = Car width

T_i = Headway average time of vehicles class concerning other vehicles

T_c = Average time headway of car concerning other vehicles

U_i = Corresponding vehicle speed

U_c = Car speed

4. Data Analysis

The data was gathered and analyzed using Chandra's Method, Homogenization Coefficient Method, and Time Headway Method to determine PCU values on Egyptian urban roadways with mixed traffic circumstances for all vehicle kinds. Variation of PCU Values with Traffic Volume, Relation of PCU Values with Traffic Speed, and Comparison of Estimated PCU Values with Prior Work will all be covered.

4.1. Estimation of PCU values

The PCU values for various car kinds at each location are computed using alternative techniques, and the average PCU values are determined, as shown in **Table 5**.

Table 5. Average PCU values by Chandra's Method, Homogenization Coefficient Method, and Time Headway Method

vehicle type	PCU Chandra's Method	PCU Homogenization Coefficient Method	PCU Time Headway Method	Average PCU
sedan	1.00	1.00	1.00	1.00
SUV	0.96	0.99	0.98	0.98
hatchback	0.88	0.94	1.07	0.96
pick-up trucks	1.15	1.22	1.01	1.13
van (seven seats)	0.94	0.97	1.04	0.98
Light Goods	0.92	1.07	0.91	0.97
Microbus(<13seets)	1.19	1.14	1.06	1.13
Minibus	1.67	1.42	1.13	1.41
Bus (>25 seats)	3.98	2.76	1.84	2.86
light Truck	1.51	1.37	1.43	1.44
Truck	3.02	2.09	2.10	2.40
truck with trailer	5.22	4.35	1.56	3.98
trailer	4.95	3.52	2.06	3.51
semi-trailer	4.26	3.00	3.11	3.46
Motorcycles	0.19	0.43	0.49	0.37
Three-wheeler	0.56	0.71	0.94	0.74
Tok - Tok	0.46	0.60	0.77	0.61
cycle rickshaws	0.00	0.00	0	0.00
animal-drawn vehicles	4.62	4.35	3.32	4.10
pedal cycles	0.15	0.57	0.53	0.42

The variation of PCU values for a different type of vehicle derived by Chandra's Method, Homogenization Coefficient Method, and Time Headway Method are shown in **Fig. 4.**below

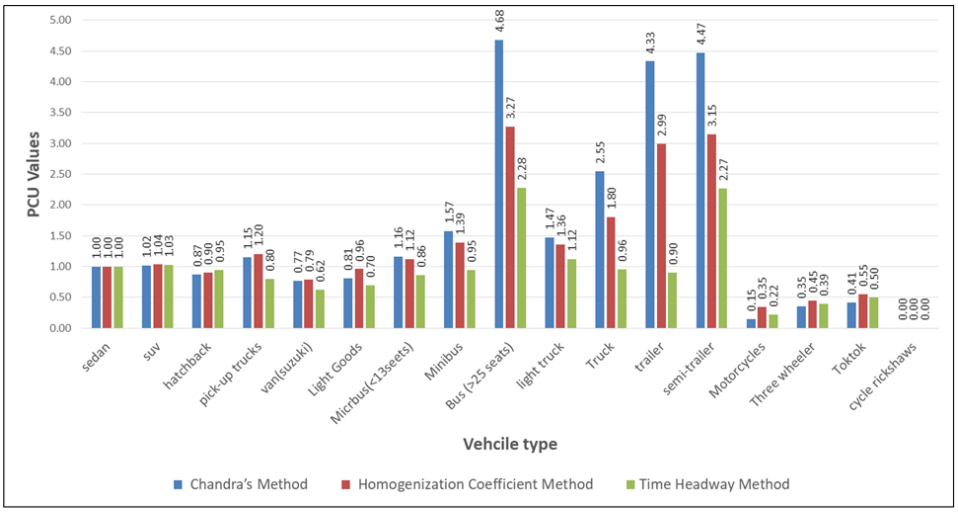

Fig. 4. PCU values for each type of vehicle by a different method

4.2. Compare estimated PCU value with previous work.

Table 6. Compare the average observed PCU values (by different methods) with additional studies and H.C.M. (2010) [22]. PCU values of all road sections show a significant difference between observed PCU values and PCU values by the previous work.

Table 6. PCU – values compared with different studies and H.C.M. (2010)

vehicle type	PCU observed	PCU Mona Abo huneidy,1987	PCU Ahmed Sabry El hakim, 1984	PCU CREDITS Phase 1 in Egypt,2002	PCU HCM 2010
sedan	1	1	1	1	1
SUV	0.98	1	1	1	1
hatchback	0.96	1	1	1	1
pick-up trucks	1.13	1.28	-	1	1
van (seven seats)	0.98	-	-	-	1
Light Goods	0.97	1.02	-	-	-
Microbus(<13seets)	1.13	1.34	-	1.5	-
Minibus	1.41	1.62	-	2	1.5
Bus (>25 seats)	2.86	2.6	2.35	2.5	1.5
light Truck	1.44	1.62	-	2	-
Truck	2.40	2.25	2.35	2.5	1.5
truck with trailer	3.98	4.27	3.35	3	1.5
trailer	3.51	-	3.35	3	1.5
semi-trailer	3.46	3.36	-	2.5	1.5
Motorcycles	0.37	.82	-	.3	1
Three-wheeler	0.74	-	-	-	-
Tok - Tok	0.61	-	-	-	-
cycle rickshaws	0.00	-	-	-	-
animal-drawn vehicles	4.10	5.41	-	-	-
pedal cycles	0.42	-	-	-	-

4.3. Variation of PCU Values with Traffic Volume

As seen in **Figs. 5 and 6**, the Jihan Al-Sadat corridor was selected to investigate the impact of volume on PCU values as a location for determining the traffic volume and traffic composition for the study period seven a.m. to four p.m. Furthermore, by classifying the cars into six groups, the designs of various vehicle categories in traffic are also discovered. Traffic volume and PCU values have a highly connected relationship, as seen in **Fig. 7**: As traffic volume increases, PCU values for heavy, light, and passenger vehicles rise while motorcycles and three-wheelers fall. That is because a road section's traffic density will rise in response to increased traffic volume. As a result, the cars will travel more slowly. Small vehicles need less space and can manoeuvre in any gap between larger vehicles in the traffic stream. So, the speed difference between the standard car and small-size vehicles decreases, while it increases for heavy vehicles.

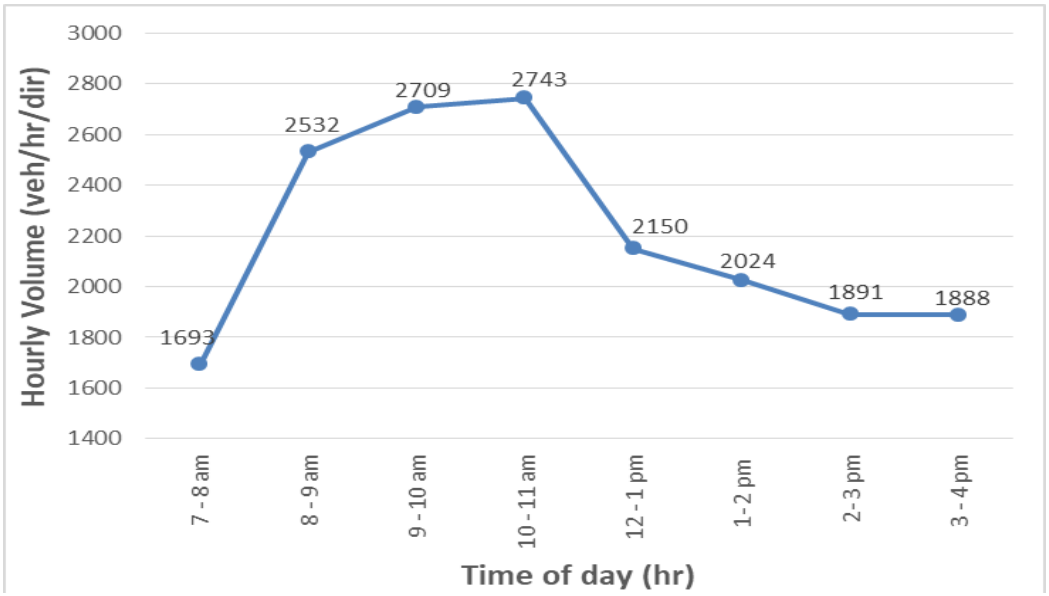

Fig. 5. Hourly variation of traffic volume on the Jihan Alsadat corridor

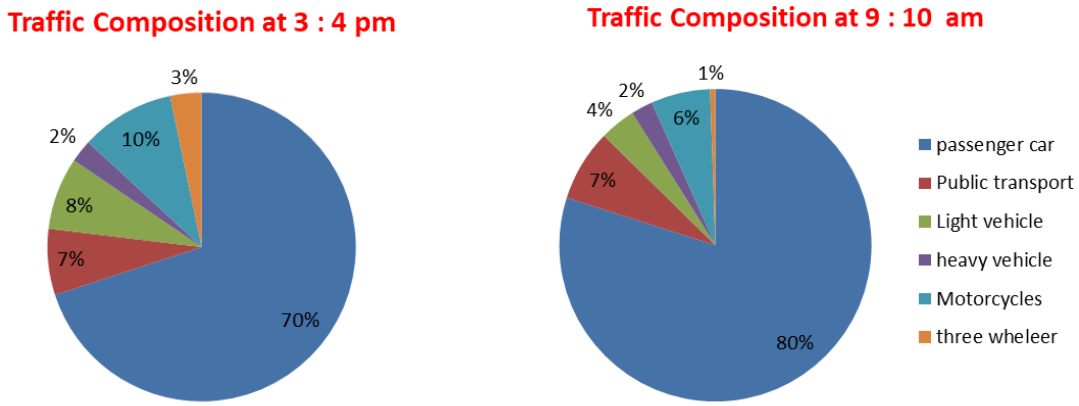

Fig. 6. Traffic composition for peak and off-peak hours at the Jihan Alsadat corridor

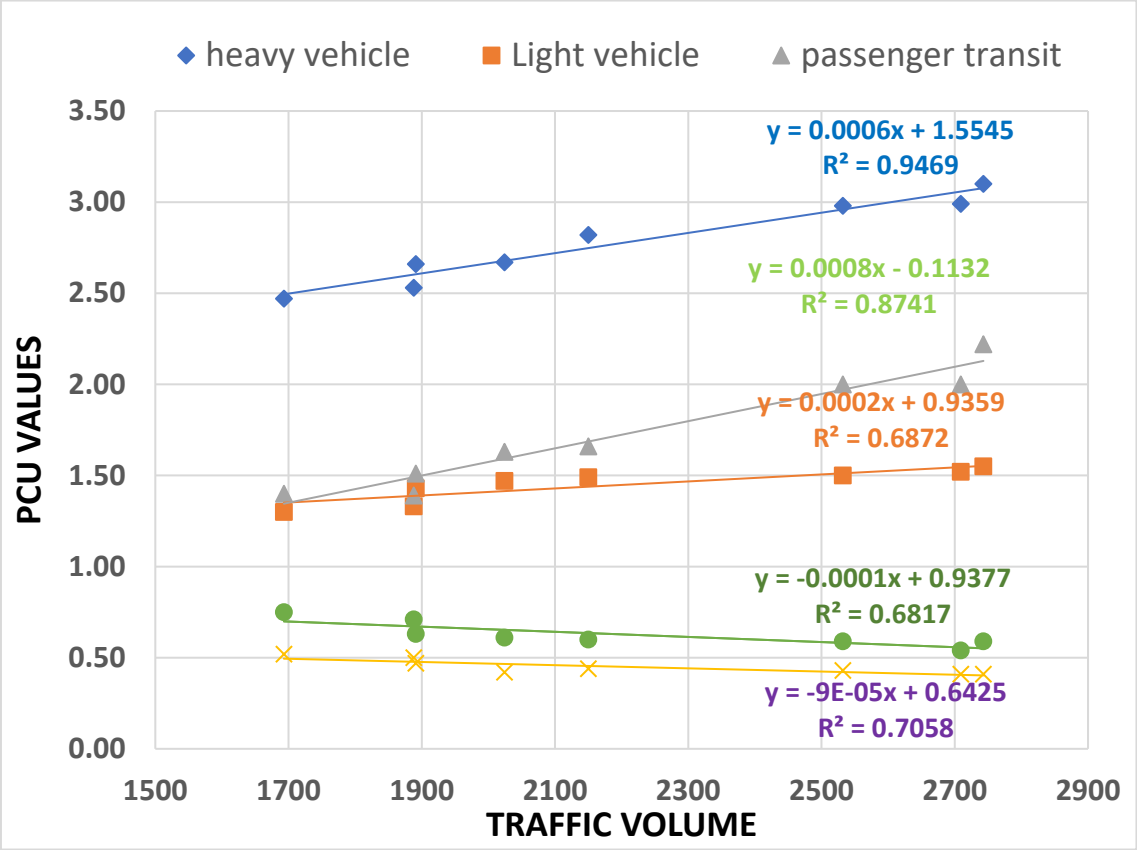

Fig. 7. Relationship of PCU values with traffic volume on the Jihan Alsadat corridor for vehicle categories

4.4. Relation of PCU Values with Traffic Speed

Fig. 8 shows the connection between the speed of vehicle type and PCU values. It can be noted that all kinds of vehicles take the same trend in all sections, whereas the speed increases with the PCU values decrease. Furthermore, it can be noted that there is a confidence difference in the observed PCU values for large vehicles at low speeds. At the same time, there is a disparity in confidence for observed PCU values for the same vehicle types at high speeds.

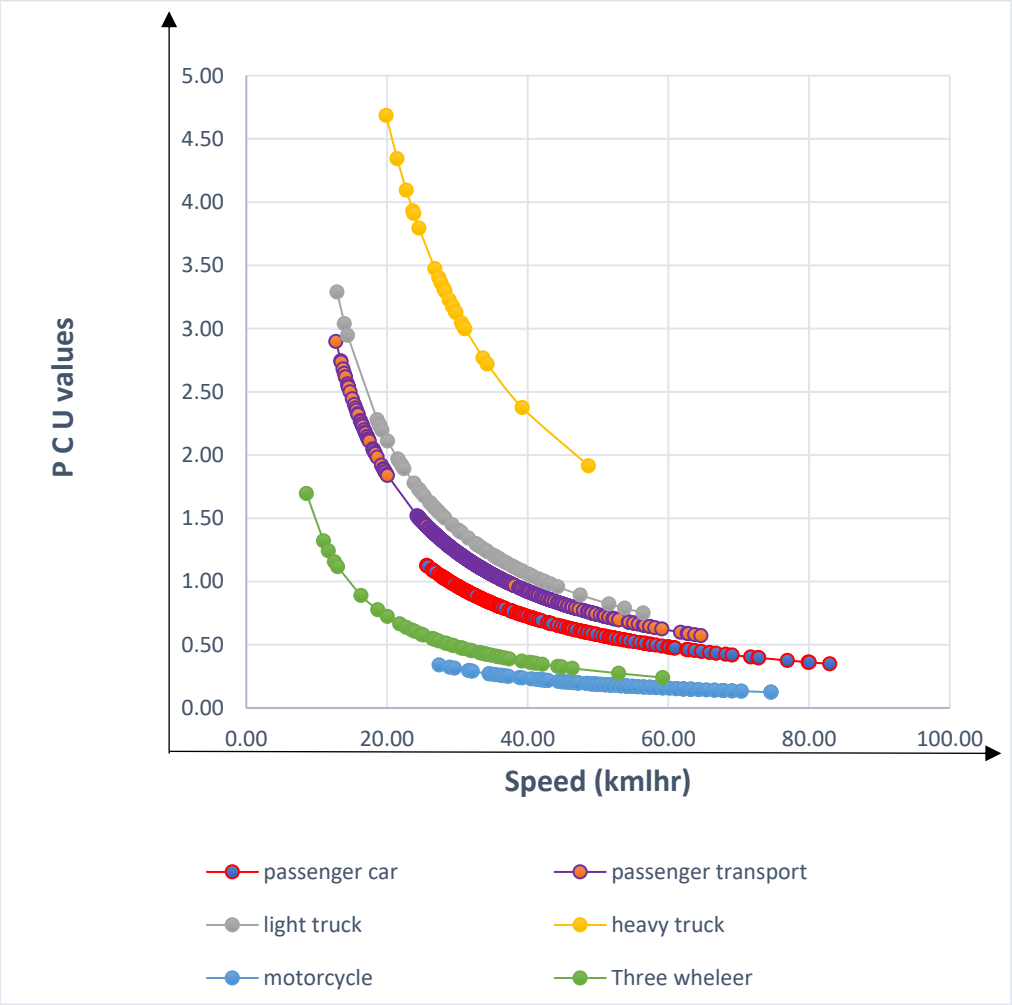

Fig. 8. PCU values versus vehicle speed at the Jihan El Sadat corridor

4.5. Relationship between variation in PCU Values among three methods

Fig. 9 shows the difference in the values of PCU, derived by the three methods used in the calculation for (four-type vehicles). The difference in trailer PCU values is as significant as possible, but the Truck's values are tiny in the three methods. In addition, because some ways depend on the vehicle's projected area, other methods depend on the length of the vehicle.

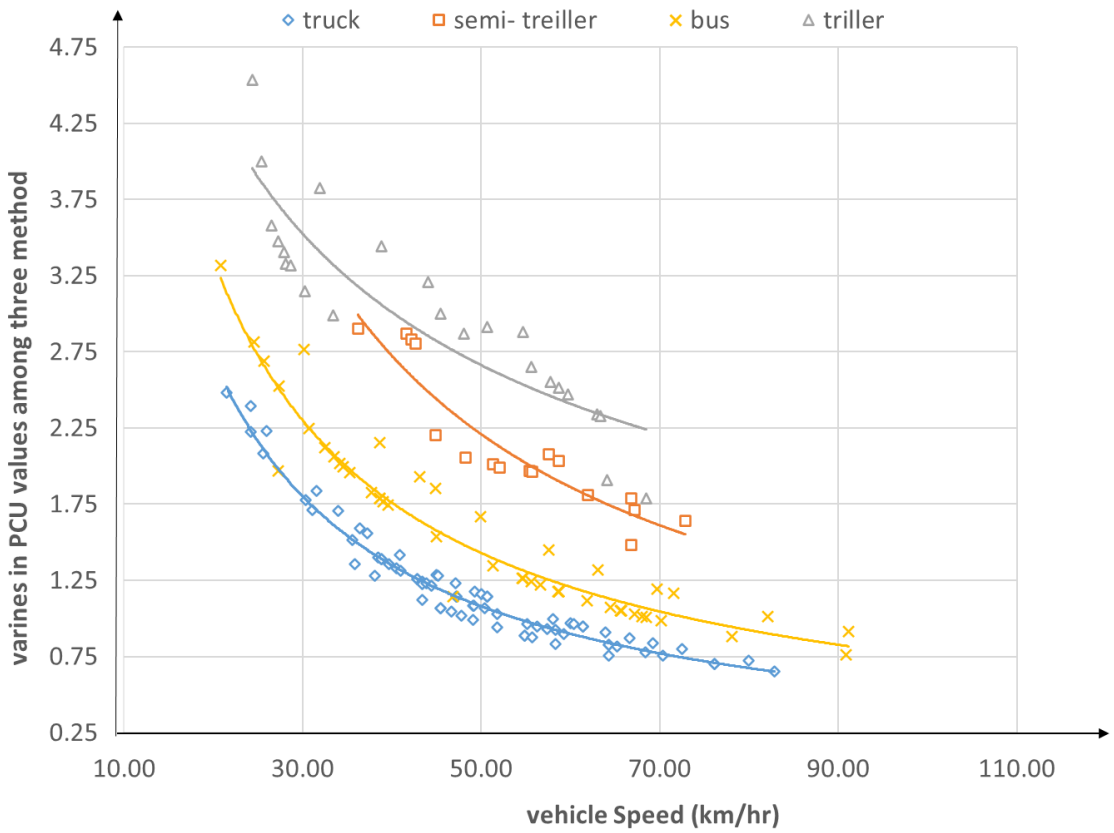

Fig. 9. Relationship between variation in PCU Values among three methods with vehicle speed for four types of vehicles

SUMMARY AND CONCLUSIONS

The results show that, for all vehicle types, the PCU values generated by Chandra's Method are more significant than those obtained by the other two approaches. Chandra's Approach and the homogenization coefficient method show a direct relationship between the PCU value and the vehicle's speed ratio. The earlier strategy's PCU value is inversely proportional to the length ratio, which sets it apart from the other way. On the other hand, the latter Approach's PCU value is inversely related to the expected area ratio. Therefore, the homogenization coefficient method has a greater PCU than Chandra's Method for smaller cars. Chandra's Method yields greater PCU values for larger vehicles than the homogenization coefficient method does.

The main objective of the study is to determine PCU values for different traffic vehicles running on the Egyptian urban network by Chandra's Method, Homogenization Coefficient Method, and Time Headway Method. Based on the results of monitored traffic data, the following conclusions are drawn:

1. Average values for PCU for different types of vehicles on Egyptian urban roads are derived using three other methods ,Sedan , Suv , Hatch back , pick-up trucks, van (seven seats), Light Goods, Microbus(<13seets) , Minibus , Bus (>25 seats), light truck, Truck, truck with trailer , trailer, semi-trailer , Motorcycles , Three-wheeler , Tok – Tok , animal-drawn vehicles and pedal cycles are 1, .98 , 0.96 , 1.13 , 0.98 , 0.97 , 1.13 , 1.41 , 2.86 , 1.44 , 2.4 , 3.98 , 3.51 , 3.46 ,0.37 , 0.74 , 0.61 , 4.1 and 0.42 respectively.

2. Determining PCU Values on urban roads with mixed traffic is the primary goal of this study. Chandra's Method, the Homogenization Coefficient Method, the Time Headway Method,

and consideration of the standard automobile are used to compute PCU values. This study's findings indicate that Three distinct methodologies are used to determine the average PCU values for all vehicle types on Egyptian urban roadways.

3. PCU values for vehicles (Microbus (<13seets), Minibus, Bus (>25 seats), light truck, Truck, Truck with trailer, trailer, and semi-trailer) by Chandra's Method are higher than their PCU values from the Homogenization Coefficient Method and Time Headway Method.
4. PCU values for other vehicles (S.U.V., hatchback, pick-up trucks, vans (seven seats), and Light Goods) by homogenization Coefficient Method are higher than their PCU values using the Time Headway Method and Chandra's Method.
5. There is a notable variation in observed PCU values for marked large vehicles PCU values at low speeds. At the same time, there is an insignificant difference for the same vehicle type PCU values at high speeds.
6. The PCU estimates for the different types of heterogeneous traffic vehicles show that the PCU value significantly varies when the transport fleet changes on Egyptian urban roadways.
7. The PCU estimations demonstrate that, for the different types of cars in mixed traffic and throughout various degrees of traffic volume, the PCU value of a vehicle changes dramatically when traffic volume changes.
8. As traffic volume grows, so does a vehicle's PCU value for larger vehicles such as heavy vehicles, light vehicles, and passenger transit. In contrast, the PCU value decreases with increased traffic volume for smaller vehicles such as motorcycles and three-wheelers.
9. The PCU values of vehicles (S.U.V., hatchback, van (seven seats), Three-wheeler, Tok-Tok, cycle rickshaws, and pedal cycles) are calculated for the first time in Egypt.

Recommendations for the following studies

From the study of PCUs in urban areas, the following points were suggested:

1) The researcher recommends using the PCU values which calculated from this study in the level of service calculation for urban roads in Egypt.
2) Update PCU values at significant intersections, especially in the roundabout on urban roads in Egypt.
3) Update PCU values on rural roads in Egypt by another method.

ACKNOWLEDGMENTS

I want to thank General Mohamed Abd El Hady and General Sherif El Hossiny in the Ministry of Interior for their assistance in collecting the data for this thesis.

CONFLICT OF INTEREST

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES

[1] Raj, P., Sivagnanasundaram, K., Asaithambi, G., & Ravi Shankar, A. U. (2019). Review Of Methods for Estimation of Passenger Car Unit Values of Vehicles. Journal Of Transportation Engineering, Part A: Systems, 145(6), 04019019.

[2] Sharma, M., & Biswas, S. (2021). Estimation of Passenger Car Unit on urban roads: A literature review. International journal of transportation science and technology, 10(3), 283-298.
[3] Aly, M. S. (1984). Determination Of P.C.E Factors for The Egyptian Rural Road Network. Egypt: Faculty of Engineering Ain Shams University.
[4] El-Hakim, A. S. (1984). Determination Of Passenger Car Equivalent in Egyptian Urban Areas. Egypt: Faculty of Engineering Al-Azhar University.
[5] Abou Huneidy, M. I. (1987). Determination Of Equivalent Car Units in The Cairo Urban Area. Egypt: Faculty of Engineering Ain Shams University.
[6] A. Mehar, A. C. (2014). Passenger Car Units at Different Levels of Service for Capacity Analysis of Multilane Interurban Highways in India. Journal Of Transportation Engineering, 81-88.
[7] Behzadi, G. &. (2016). Determination Of Passenger Car Equivalent for Bus in Urban Roads Using AIMSUN (Case Study: Emam Reza Avenue, Amol City).
[8] Swetha, D. V. (2016). Estimation Of Passenger Car Unit for Heterogeneous Traffic in Visakhapatnam. International Journal of Engineering Sciences & Research Technology, 855-862.
[9] Patel, B. N. (2016). Determination Of Dynamic PCU'S Of Different Types of Passenger Vehicles on Urban Road: A Case Study of Rajkot City. Int J Sci Res Dev.
[10] Mondal, S. C. (2017). Estimation Of Passenger Car Unit for Heterogeneous Traffic Stream of Urban Arterials: Case Study of Kolkata. Transportation Letters, 1-13.
[11] Ballari, D. S. (2019). Estimation Of Passenger Car Equivalents for Heterogeneous Traffic Stream. International Journal of Innovative Technology and Exploring Engineering (IJITEE), 1026-1031.
[12] S. M. R. Rahman, A. U. (2020). Determination Of Passenger Car Unit of Through Vehicles in Chittagong City. 2nd International Conference on Research and Innovation in Civil Engineering (Pp. 281-285). Chittagong: Icrice.
[13] Zero, B. C. (2022). Development Of Passenger Car Unit (PCU) For Streets in Erbil City. 8th International Engineering Conference on Sustainable Technology and Development (I.E.C.) (Pp. 149-154). IEEE.
[14] Joshi, R. S. (2021). Capacity And Dynamic PCU Estimation of Urban Roads for Heterogeneous Traffic: A Case Study in Indore City.
[15] Tullu, H. H. (2021). Determination Of Passenger Car Unit for Urban Roads: A Case Study in Addis Ababa. American Journal of Construction and Building Materials, 57-63.
[16] Satthamnuwong, N. C. (2018). Passenger Car Equivalents (PCE) Of Heterogeneous Vehicles on Four-Lane Highways in Thailand. Kasem Bundit Engineering Journal, 34-47. SCARC. (2015).
[17] Krausea, S. (2019). Estimation Of Passenger Car Equivalents for New Forms of Mobility Investigating the Effect of Automated Vehicles on The Saturation Flow of Urban Intersections.
[18] Subotić, M. T. (2016). PCE In Analysis Models of The Number of Following Vehicles on A Two-Lane Road. International Journal for Transport and Traffic Engineering, 25-37.
[19] Gani, F. A. (2017). Estimation Of Dynamic Value of Passenger Car Unit in The Mixed Traffic. Journal Of the Eastern Asia Society for Transportation Studies, 1665-1675.
[20] Sugianto, S., Apriandy, F., Faisal, R., & Saleh, S. M. (2018). Measuring Passenger Car Unit (PCU) At Four-Legged Roundabout Using Time Occupancy Data Collected from Drone. Aceh International Journal of Science and Technology, 7(2), 77-84.
[21] Data from sky programm. Available: https://datafromsky.com/
[22] Highway Capacity Manual (1965). Special Report 209: Third edition, Transportation Research Board, Washington.
[23] S.V. Patil and P. R. Adavi, “Development of Passenger Car Unit (PCU),” Case Study - Nal Stop, Pune, International Journal of Science and Engineering (Ijse), Vol. 3, 2015.
[24] Keller., E. L., And Saklas, J. G. (1984). Passenger Car Equivalents from Network Simulation. Journal Of Transportation Engineering, 110(4), 397-411.
[25] Demarchi., S. H., And Setti., J. R. (2003). Limitations Of Passenger-Car Equivalent Derivation for Traffic Streams with More Than One Truck Type. Transportation Research Record: Journal of The Transportation Research Board, 1852(1), 96-104.
[26] Al-Kaisy., A. F., Hall., F. L., And Reisman., E. S. (2002). Developing Passenger Car Equivalents for Heavy Vehicles on Freeways During Queue Discharge Flow. Transportation Research Part A: Policy and Practice, 36(8), 725-742.
[27] Fan., H. S. (1990). Passenger Car Equivalents for Vehicles on Singapore Expressways. Transportation Research Part A: General,24(5), 391-396.
[28] Werner, A., Morrall, J. (1976). Passenger Car Equivalencies of Trucks, Buses, and Recreational Vehicles for Two-Lane Rural Highways. In Transportation Research Record 615. TRB, National Research Council, Washington, DC, Pp. 10-17.
[29] Seguin., E., Crowley., K., And Zweig., W. (1982) Passenger Car Equivalents on Urban Freeways. Report DTFH61-80-C-00106, FHWA, U.S. Department of Transportation.

[30] Cunagin., W. D., And Messer., C. J., (1982). Passenger Car Equivalents for Rural Highways. Report FHWA/RD-82/132, FHWA, U.S. Department of Transportation.
[31] Krammes., R., And Crowley., K. (1986). Passenger Car Equivalents for Trucks on Level Freeway Segments. In Transportation Research Record 1091. TRB, National Research Council, Washington, DC. Pp. 10-17.
[32] Van Aerde., M., And Yagar., S. (1983). Capacity, Speed, And Platooning Vehicle Equivalents for Two-Lane Rural Highways. Transportation Research Record No. 971. Transportation Research Board. Washington, DC.
[33] Chandra, Satish., Kumar, V. And Sikdar, P. K. (1995) Dynamic PCU And Estimation of Capacity of Urban Roads. Indian Highways, 23(4), Indian Roads Congress, New Delhi.
[34] Werner, A., Morrall, J. (1976). Passenger Car Equivalencies of Trucks, Buses, And Recreational Vehicles for Two-Lane Rural Highways. In Transportation Research Record 615. TRB, National Research Council, Washington, DC, Pp. 10-17.
[35] Craus., J., Polus., A., And Grinberg., I. (1980). A Revised Method for The Determination of Passenger Car Equivalencies. Transportation Research Part A: General, 14(4), 241-246.
[36] Cunagin, W. D., And Messer, C. J. (1983). Passenger car equivalents For Rural Highways (Discussion) (No. Hs036 187).
[37] John., A., And Glauz., W. (1976). Speed And Service on Multilane Upgrades. Transportation Research Record No. 61, Washington, DC.
[38] Huber., M. J. (1982). Estimation Of Passenger-Car Equivalents of Trucks in Traffic Stream (Discussion and Closure). Transportation Research Record, (869).
[39] Sumner., R., Hill., D., And Shapiro., S. (1984). Segment Passenger Car Equivalent Values for Cost Allocation on Urban Arterial Roads. Transportation Research Part A: General, 18(5), 399-406.