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Determination of Dynamic Passenger Car Equivalent in Pokhara Metropolitan City

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Abstract
This research explores the dynamic Passenger Car Equivalent in the context of heterogeneous traffic conditions in Pokhara Metropolitan City, Nepal. The study finds that dynamic Passenger Car Equivalent values vary with altering traffic mix, flow speed, and lane count. It focuses on five different vehicle classifications. Notably, two-wheelers fall below the required standards while buses, trucks, and light commercial vehicles display greater Passenger Car Equivalent values than those specified by Nepal Road Standard 2070. This study also finds out the traffic composition of Pokhara Metropolitan City is dominated by two wheelers.

Keywords
Dynamic Passenger Car Equivalent, Traffic Composition

1. Introduction

1.1 Background

The nature of the road traffic in Nepal is heterogenous with a variety of shapes, sizes, weights, and engines using the same lane. Small incremental improvements to the quality of the road are not practical, and it is customary to design and build additional roads and other infrastructure upgrades to withstand expected traffic in the future.Due to the rapid expansion of industrial and economic activity, the amount of traffic on highways and urban streets has significantly increased, and this situation has spread throughout Nepal. The need for effective traffic flow operations on urban road like the roads of Pokhara Metropolitan City (PMC) is being driven by rising traffic demand.

Heterogenous traffic requires varying amounts of road space, travel at various speeds (for geometric design), and place various stresses on the structure of the road (for structural design). Therefore, it is essential to adopt a common traffic unit to which different vehicle kinds may be associated. The "Passenger Car Equivalent (PCE)" standard, which is that of a typical passenger car, is used for the geometric design of roadways. This PCE are multiplied by other vehicle kinds to account for them (Nepal Road Standard (NRS), 2070). PCE values for various vehicle types, including cars, trucks, Light truck, SUV, Light Van, motorcycles, rickshaws, and non-motorized carts are also specified in NRS 2070. These values were based on static characteristics of vehicles.

A key idea in traffic and transportation engineering is the dynamic PCE, which is useful for evaluating the performance and capacity of road networks. With a particular focus on passenger automobiles, it is a metric used to measure the space and time taken by various types of vehicles on the road. Due to its role in maximizing road usage and enhancing traffic flow, dynamic PCE is a crucial instrument for traffic management, urban planning, and infrastructure design. To calculate the approximate number of standard passenger cars needed to accurately reflect the effects of a variety of vehicles on a road stretch, dynamic PCE considers variables such as vehicle size, speed, acceleration, and deceleration characteristics. Traffic engineers and planners may more accurately predict traffic capacity, congestion levels, and the needs for road design by transforming all vehicle kinds into PCEs.

1.2 Objectives

The specific objective of the research is to determine the dynamic Passenger Car Equivalent in Pokhara Meteropolitan City.

2. Literature Review

The free speeds of commonly used vehicles follow a normal distribution in Bangladesh. In order to investigate the connection between free speed and the pavement and shoulder widths, a linear regression analysis was carried out. It was found that increase in pavement width, increases vehicular speed and ultimately resulted higher vehicle's PCE value [1]. The PCE values for buses, trucks and two-wheelers were found in Australia. The estimated PCE values, for all the considered vehicle categories are found to decrease with increase in their respective proportion[2].

A speed-based approach was used to estimate the PCE of various types of cars under heterogenous traffic situations in India. It made use of space rather than just a vehicle's length and speed. Ten two-lane road segments in various regions of India were the sites of data collection. At each road stretch, the PCEs of all the vehicleswhich were classified into nine different categories were estimated. The PCE values for various vehicle types as determined at various parts show the linear variation in PCE for various vehicle types with lane width at various sections. It was discovered that the PCE for a particular vehicle type grows linearly with road width. This is explained by the fact that broader roads allow for more volume and have higher speed differences between cars and other types of vehicles.[3]

A simulation technique was used for a four-lane divided road to quantify the impedance to traffic flow caused by the various vehicle categories in heterogeneous traffic in terms of PCE, over a wide roadway and traffic conditions. They also looked at the impact of road width and traffic volume on the PCE values of vehicles. The findings showed that changes in traffic volume considerably affect how much a vehicle's PCE value changes. In areas of low traffic volume, vehicles' PCE values rise as traffic volume rises, but in areas of high traffic volume, PCE values fall as traffic volume rises[4].

A multiple regression analysis was emplyed to get the PCE values on the creation of saturated flow and delay models for signalized intersection in Kathmandu. Six main kinds of vehicles were created: cars, buses, trucks, microbuses, two-wheelers, and tempos. According to the study, it is found that PCE values of vehicle type are different as presented by NRS. The fact that unified PCE concepts for various vehicles do not always hold true is reconfirmed by this research[5].

The effect of lane width on PCEs in heterogenous traffic conditions was investigated on congested highways and it was found out that the values for motorcycles and auto rickshaws obtained from all sections were lower than those specified in the Indian Road Congress (IRC) and that the values for trucks, trailers, and light commercial vehicles were higher than those specified in the IRC 64-1990 Code.This study has shown the effect of lane width on the PCE for various vehicle types on a two-lane highway. The researchers concluded that the PCE for a certain vehicle type rises as lane width increases and the relation of lane width on the PCE is linear[6]

3. Methodology

3.1 Site Selection

[7] determined Passenger Car Equivalent at different level of service of multilane interurban highways of India where they collected data on two sections on peak and non-peak hour. In this research also, study will be done on two sections of road inside PMC; Section- I: two-lane (Prithivichowk- Chorrepatan Section) and Section- II: four-lane (Harichowk- Bindabasini Section) shown in Figure 1 and 2. The sites were selected with the following criteria:

- Flow of all types of vehicles.
- Away from bus stops that will affect the traffic movement.
- Straight and level.

3.2 Data Sources

Primary data collection was used for this research. Video recording was done to collect all the necessary data from the appropriate segment. Data were extracted by running the program in Python and supervised manually to improve accuracy.

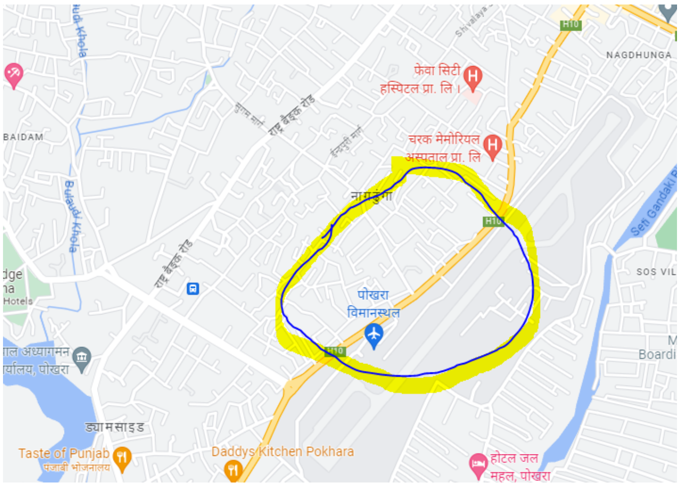

Figure 1: Location of Section-I

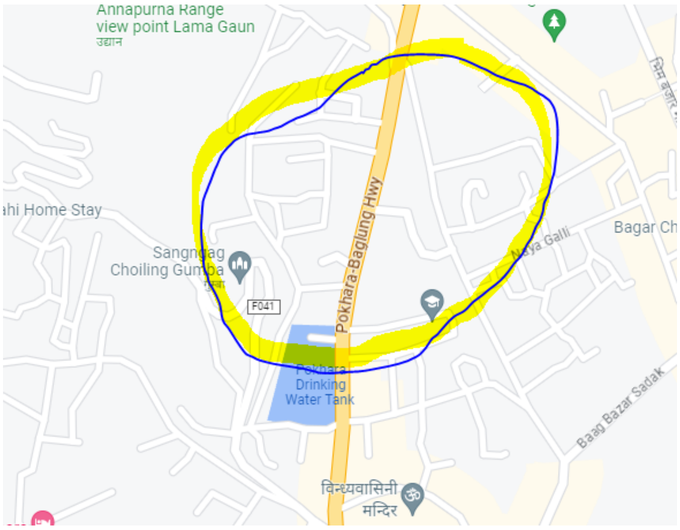

Figure 2: Location of Section-II

3.3 Data Collection and Extraction

The following steps were used for data collection and extraction:

- The video recording technique was done to collect the data. The electric poles which are 30.8 m apart in Section-I and 34.5m apart in Section-II were taken references.
- The Mobile phone was mounted on the stand and so placed to cover the references as shown in Figure 3.2.
- The recording was done for 4 hours for 3 typical weekdays from 9:00 am- 1:00 pm which covers both peak and non-peak hours on each road site.
- These data were supplemented with manually collected data on the road site.
- The recorded videos were run through the program coded in Python to determine the type of vehicle passing through the section and time taken to pass the references as shown in Figure 3 and videos were played manually to improve the accuracy of the data extraction. To make the analysis meaningful, the vehicles were

divided into five different categories as shown in Table 1. Average dimensions and projected rectangular areas of each type of vehicle category are also given in Table 1.[8]

Table 1: Vehicle Categories and their Dimension

Category	Vehicles Included	Average dimension		Projected Area on Ground
		Length(m)	Breadth(m)	
Bus	Buses	11.12	2.49	27.74
Truck	Truck, Tripper	7.5	2.35	17.62
LCV	Minibus, mini truck, micro bus	6.1	2.1	12.81
Cars	Car, jeep, van	3.74	1.44	5.39
Two-wheeler	Scooters, motorcycles	1.87	0.64	1.2

Figure 3: Data extraction from Recorded Videos

- The average time taken by each vehicle type to travel the reference points was extracted with the least count of 0.1 second.
- Fifteen-minutes classified traffic count was made to get the information on traffic volume.

3.4 Data Analysis

The following Process was used for data analysis:

- [9] determined the PCE of vehicle by using:

$$PCE_j = \frac{\gamma_j^{car}}{a_j^{car}} \tag{1}$$

$$\gamma_j^{car} = \frac{v_{car}}{v_j} \tag{2}$$

$$a_j^{car} = \frac{a_{car}}{a_j} \tag{3}$$

Here, PCE_j = the Passenger Car Equivalent for the vehicle category j; v_{car} = the average speed of passenger car; v_j – the average speed of vehicle category j; a_{car} = the projected rectangular area (length * width) of passenger car; a_j = the projected rectangular area (length * width) of vehicle category j; γ_j^{car} = speed ratio of passenger car to vehicle category j; a_j^{car} = ratio of vehicle projected area of passenger car to vehicle category j;

$$\gamma_j^{car}(n,v) = a_0 + a_c \times \frac{n_{car}}{v_{car}} + \sum\left(a_j \times \frac{n_j}{v_j}\right) \tag{4}$$

Here$\gamma_j^{car}(n,v)$ = the function of speed ratio of vehicle category j; $a_{0,c,j}$ = coefficients n_{car}, n_j = number of passenger car and vehicle category j v_{car}, v_j = the average of individual speed of passenger car and vehicle category j

4. Analysis

4.1 Traffic Volume and Composition

For the study period of 3 days and 4 hours each day, the traffic composition of Section-I consists of 1.83% bus, 0.97% truck, 1.26% LCV, 19.78% Cars and 76.16% 2W. This composition is illustrated in Figure 4.

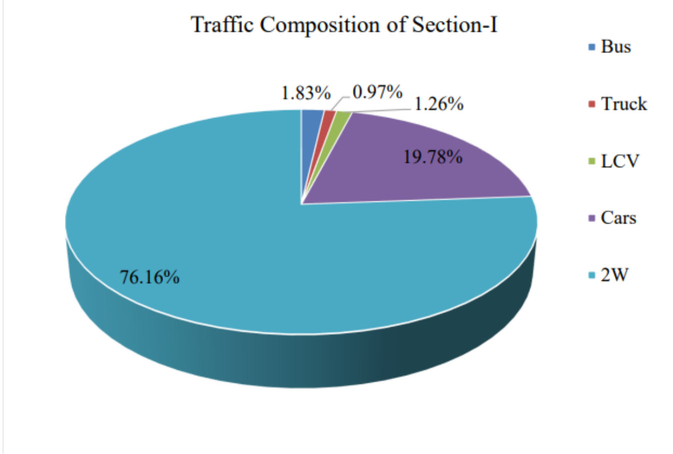

Figure 4: Traffic Volume Composition of Section-I

Similarly, for the study period of 3 days and 4 hours each day, the traffic composition of Section-II consists of 1.83% bus, 0.97% truck, 1.26% LCV, 19.78% Cars and 76.16% 2W. This Composition is illustrated in Figure 5.

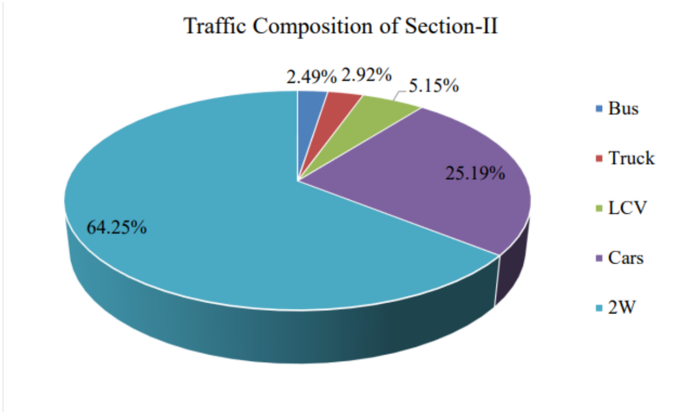

Figure 5: Traffic Volume Composition of Section-II

4.2 PCE Calculations

For calculation of PCE, speed ratio of passenger car to vehicle category j (γ_j^{car}) is calculated as explained in Equation 3.4. The linear equation of (γ_j^{car}) is obtained through multiple linear regression analysis which depends upon the number of passenger car and vehicle category j (n_{car}, n_j); the average of individual speed of passenger car and vehicle category j (v_{car}, v_j).

In a regression model, the percentage of the variation for a dependent variable that is explained by an independent variable is expressed statistically as coefficient of determination. It illustrates how much the variation of one variable explains the variance of the other, whereas correlation reveals the strength of the relationship between an independent and a dependent variable. This means half of the observed variation may be explained by the model's inputs if the model's coefficient of determination is 0.50.

The speed ratio can be estimated by the Equations 5, 6, 7 and 8 of Section-I day 1. The coefficient of determination of Equations 5, 6, 7 and 8 are 0.91, 0.54, 0.70 and 0.87 respectively.

$$\gamma_{bus}^{car} = 2.44 - 0.25 \times \frac{n_{car}}{v_{car}} - 0.24 * \sum \left(\frac{n_{bus}}{v_{bus}} \right) \tag{5}$$

$$\gamma_{truck}^{car} = 0.016 + 0.4 \times \frac{n_{car}}{v_{car}} - 1.98 \sum \left(\frac{n_{truck}}{v_{truck}} \right) \tag{6}$$

$$\gamma_{lcv}^{car} = -0.32 + 0.2 \times \frac{n_{car}}{v_{car}} - 1.98 \sum \left(\frac{n_{lcv}}{v_{lcv}} \right) \tag{7}$$

$$\gamma_{2W}^{car} = -1.53 - 0.05 \times \frac{n_{car}}{v_{car}} - 0.019 \sum \left(\frac{n_{2W}}{v_{2W}} \right) \tag{8}$$

Similarly, the speed ratio can be estimated by the Equation 9, 10, 11 and 12 of Section-I day 2. The coefficient of determination of Equation 9, 10, 11 and 12 are 0.88, 0.66, 0.72 and 0.75 respectively.

$$\gamma_{bus}^{car} = -0.09 - 0.039 \times \frac{n_{car}}{v_{car}} + 2.9 * \sum \left(\frac{n_{bus}}{v_{bus}} \right) \tag{9}$$

$$\gamma_{truck}^{car} = 0.85 + 0.026 \times \frac{n_{car}}{v_{car}} + 0.33 \sum \left(\frac{n_{truck}}{v_{truck}} \right) \tag{10}$$

$$\gamma_{lcv}^{car} = -1.67 - 0.07 \times \frac{n_{car}}{v_{car}} - 0.155 \sum \left(\frac{n_{lcv}}{v_{lcv}} \right) \tag{11}$$

$$\gamma_{2W}^{car} = -1.14 - 0.07 \times \frac{n_{car}}{v_{car}} + 0.01 \sum \left(\frac{n_{2W}}{v_{2W}} \right) \tag{12}$$

Similarly, the speed ratio can be estimated by the Equation 13, 14, 15 and 16 of Section-I day 3. The coefficient of determination of Equation 13, 14, 15 and 16 are 0.82, 0.82, 0.15 and 0.93 respectively.

$$\gamma_{bus}^{car} = 3.58 - 0.25 \times \frac{n_{car}}{v_{car}} - 1.68 * \sum \left(\frac{n_{bus}}{v_{bus}} \right) \tag{13}$$

$$\gamma_{truck}^{car} = 0.27 + 0.34 \times \frac{n_{car}}{v_{car}} - 1.05 * \sum \left(\frac{n_{truck}}{v_{truck}} \right) \tag{14}$$

$$\gamma_{lcv}^{car} = 0.76 + 0.05 \times \frac{n_{car}}{v_{car}} + 0.87 \sum \left(\frac{n_{lcv}}{v_{lcv}} \right) \tag{15}$$

$$\gamma_{2W}^{car} = 1.56 + 0.095 \times \frac{n_{car}}{v_{car}} - 0.05 \sum \left(\frac{n_{2W}}{v_{2W}} \right) \tag{16}$$

Similarly, the speed ratio can be estimated by the Equation 17, 18, 19 and 20 of Section-II day 1. The coefficient of determination of Equation 17, 18, 19 and 20 are 0.87, 0.2, 0.97 and 0.36 respectively.

$$\gamma_{bus}^{car} = 2.83 - 0.55 \times \frac{n_{car}}{v_{car}} - 0.22 * \sum \left(\frac{n_{bus}}{v_{bus}} \right) \tag{17}$$

$$\gamma_{truck}^{car} = 1.3 - 0.08 \times \frac{n_{car}}{v_{car}} + 0.36 * \sum \left(\frac{n_{truck}}{v_{truck}} \right) \tag{18}$$

$$\gamma_{lcv}^{car} = 2.26 - 0.34 \times \frac{n_{car}}{v_{car}} - 0.45 \sum \left(\frac{n_{lcv}}{v_{lcv}} \right) \tag{19}$$

$$\gamma_{2W}^{car} = 1.03 - 0.02 \times \frac{n_{car}}{v_{car}} - 0.003 \sum \left(\frac{n_{2W}}{v_{2W}} \right) \tag{20}$$

Similarly, the speed ratio can be estimated by the Equation 21, 22, 23 and 24 of Section-II day 2. The coefficient of determination of Equation 21, 22, 23 and 24 are 0.93, 0.70, 0.97 and 0.93 respectively.

$$\gamma_{bus}^{car} = 1.68 - 0.144 \times \frac{n_{car}}{v_{car}} - 0.27 * \sum \left(\frac{n_{bus}}{v_{bus}} \right) \tag{21}$$

$$\gamma_{truck}^{car} = 0.87 + 0.03 \times \frac{n_{car}}{v_{car}} + 72 * \sum \left(\frac{n_{truck}}{v_{truck}} \right) \tag{22}$$

$$\gamma_{lcv}^{car} = 0.71 + 0.06 \times \frac{n_{car}}{v_{car}} + 0.035 \sum \left(\frac{n_{lcv}}{v_{lcv}} \right) \tag{23}$$

$$\gamma_{2W}^{car} = 0.95 + 0.02 \times \frac{n_{car}}{v_{car}} - 0.01 \sum \left(\frac{n_{2W}}{v_{2W}} \right) \tag{24}$$

Similarly, the speed ratio can be estimated by the Equation 25, 26, 27 and 28 of Section-II day 3. The coefficient of determination of Equation 25, 26, 27 and 28 are 0.73, 0.63, 0.89 and 0.98 respectively.

$$\gamma_{bus}^{car} = 0.86 + 0.02 \times \frac{n_{car}}{v_{car}} + 0.99 * \sum \left(\frac{n_{bus}}{v_{bus}} \right) \tag{25}$$

$$\gamma_{truck}^{car} = 0.95 + 0.015 \times \frac{n_{car}}{v_{car}} + 1.49 * \sum \left(\frac{n_{truck}}{v_{truck}} \right) \tag{26}$$

$$\gamma_{lcv}^{car} = 1.52 - 0.09 \times \frac{n_{car}}{v_{car}} - 0.31 \sum \left(\frac{n_{lcv}}{v_{lcv}} \right) \tag{27}$$

$$\gamma_{2W}^{car} = -1.05 - 0.1 \times \frac{n_{car}}{v_{car}} + 0.36 \sum \left(\frac{n_{2W}}{v_{2W}} \right) \tag{28}$$

Finally, the PCE for each vehicle category is calculated using Equations 1, 2 and 3. The calculated PCE with traffic composition and average speed is shown in Table 2.

Table 2: PCE Values at different traffic composition

Road Type	Day	Volume (Vehicles/4h)		Traffic Composition, speed (km/h) and PCE				
				Bus	Truck	LCV	Cars	2W
Section-I (2-Lane)	1	4053	Percentage	2.22	1.16	1.23	20.31	75.08
			Avg. Speed	45.06	37.65	47.25	49.22	52.25
			PCE	6.31	3.93	2.1	1	0.23
	2	4317	Percentage	1.64	0.97	0.97	21.66	74.75
			Avg. Speed	44.01	38.37	39.89	42.42	46.84
			PCE	4.45	4.43	3.01	1	0.21
	3	4890	Percentage	1.68	0.8	1.53	17.69	78.3
			Avg. Speed	33.6	25.62	39.53	41.92	45.71
			PCE	6.51	5.31		1	0.22
Section-II (4-Lane)	1	2254	Percentage	2.75	3.01	5.01	26.31	62.91
			Avg. Speed	50.06	52.1	58.44	64.43	65.08
			PCE	7.7		2.99	1	
	2	2500	Percentage	2.32	2.68	5.04	22.68	67.28
			Avg. Speed	47.89	46.18	53.72	58.48	64.67
			PCE	6.43	3.82	2.52	1	0.21
	3	2443	Percentage	2.41	3.07	5.4	26.73	62.38
			Avg. Speed	48.35	43.92	49.68	59.09	61.56
			PCE	6.26	5.32	2.53	1	0.26

5. Conclusions

The research studies the concept of dynamic Passenger Car Equivalent in the heteregenous traffic condition at Pokhara Metropolitan City simplifying the vehicle in five categories. The study shows that:

- The traffic composition of Pokhara Metropolitan City is dominated by 2Ws. Section- I consists of 76.16% of Vehicles and Section-II consists of 64.25% of vehicles. It is also seen that 2Ws have higher average speed than other category of vehicles.
- The Passenger Car Equivalent of the Vehicles changes with the change in traffic composition, flow speed and number of lanes.
- The PCE of Bus ranges from 4.45 to 7.7, Truck ranges from 3.82 to 5.31, LCV ranges from 2.1 to 3.4 and 2W ranges from 0.21 to 0.26.
- The average PCE of Bus is 91.89%, Truck is 51.89% and LCV is 89.11% more than PCE value suggested by NRS whereas average PCE of 2W is 56% less at Section-I and average PCE of Bus is 126.56%, Truck is 46.33% and LCV is 78.6% more than PCE value suggested by NRS whereas average PCE of 2W is 54% less at Section-II are found to be greater than that suggested by NRS, 2070.

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