# Passenger Car Equivalent Factor for Tricycles in Urban Local Roads Within Metro Manila

Jade Christiane M. RAYMUNDO[a], Dennis C. VERGEL[b], Sandy Mae A. GASPAY[c]

[a,b,c] *Institute of Civil Engineering, University of the Philippines Diliman, Quezon City, Metro Manila, 1101, Philippines*
[a] *E-mail: jmraymundo2@up.edu.ph*
[b] *E-mail: dcvergel@up.edu.ph*
[c] *E-mail: sagaspay1@up.edu.ph*

**Abstract**: This study estimated the Passenger Car Equivalent Factor (PCEF) of tricycles in urban local roads within Metro Manila, using Speed-Area method to determine their impact on traffic flow and road capacity in traffic analysis. With the backdrop of varying PCEF standards, including a discrepancy between local and international values, the research aimed to provide an empirically grounded PCEF estimation for tricycles. Through video surveying across midblock sections in the chosen study areas as the primary data collection method, the results indicated an overall average PCEF of 0.535. This implies that the PCEF value of 2.5 prescribed by the DPWH is an overestimation on the impact of tricycles in urban local contexts in traffic analysis. The resulting PCEF from this study, which also encourages the researchers to reassess the 2.5, should be considered to better reflect the dynamics of both urban local and national roads.

*Keywords*: Passenger Car Equivalent Factor, Speed-Area Method, Traffic Analysis, Road Capacity Estimation, Volume to Capacity Ratio, Tricycles

## 1. INTRODUCTION

### 1.1 Background

Traffic congestion in Metro Manila has been a persistent problem, worsened by the mix of different types of vehicles, including a significant number of tricycles. These three-wheeled vehicles play an important role in the local transportation network as they offer accessibility and mobility in areas less serviced by larger public transport vehicles. These areas include urban local roads that are typically characterized by lower speed limits (30-60 km/h), higher pedestrian activity, and frequent intersections, and they are significantly impacted by the presence of tricycles (Department for Transport, 2016). However, the impact of tricycles on traffic flow and congestion in these areas is not well-documented in the Philippines, particularly in terms of their Passenger Car Equivalent Factor (PCEF).

The Passenger Car Equivalent Factor (PCEF) is used as conversion mechanism for vehicles since not all vehicles have the same size, speed, and headway (Adnan, 2014). By converting different vehicles to their passenger car equivalents, PCEF ensures there is homogeneity when assessing traffic flow rate and estimating roadway capacity, allowing for more consistent traffic analysis.

The Highway Planning Manual of the Philippines currently prescribes a PCEF value of 2.5 for tricycles. This value is used to integrate tricycles into traffic flow models to reflect their relative impact compared to passenger cars. The PCEF values of these vehicles, particularly tricycles, can be shown in table 1.

Table 1. PCEF standards in the Highway Planning Manual (DPWH, 2013)

| Vehicle Type | | PCEF |
|---|---|---|
| No. | Description | |
| 1 | Motor-tricycle | 2.5 |
| 2 | Passenger car | 1.0 |
| 3-5 | Passenger and goods utility and small bus | 1.5 |
| 6 | Large bus | 2.0 |
| 7 | Rigid truck, 2 axles | 2.0 |
| 8 | Rigid truck, 3+ axles | 2.5 |
| 9 | Truck semi-trailer, 3 and 4 axles | 2.5 |
| 10 | Truck semi-trailer, 5+ axles | 2.5 |
| 11 | Truck trailers, 4 axles | 2.5 |
| 12 | Truck Trailers, 5+ axles | 2.5 |

However, in other countries, such as India, the PCEF values for vehicles analogous to the Philippine tricycles, particularly the auto-rickshaws, are lower. This indicates potential regional differences in traffic composition and behavior, which may influence PCEF standards. Table 2 shows PCEF for various types of vehicles on rural roads from the Indian Roads Congress.

Table 2. PCEF for Various Types of Vehicles on Rural Roads in India (1990)

| S. No. | Vehicle Type | Equivalency Factor |
|---|---|---|
| 1 | Motor Cycle or Scooter | 0.5 |
| 2 | Passenger Car, Pick-up Van or Auto-rickshaw | 1.0 |
| 3 | Agricultural Tractor, Light Commercial Vehicle | 1.5 |
| 4 | Truck or Bus | 3.0 |
| 5 | Truck-trailer , Agricultural Tractor-trailer | 4.5 |
| 6 | Cycle | 0.5 |
| 7 | Cycle-rickshaw | 2.0 |
| 8 | Hand Cart | 3.0 |
| 9 | Horse-drawn Vehicle | 4.0 |
| 10 | Bullock Cart | 8.0 |

Additionally, studies across Pakistan, Ghana, and India using methods like Headway, Speed-Area, and Regression have produced a range of PCEF values for three-wheeler vehicles as shown in table 3 below. In Pakistan, Adnan M. (2014) estimated PCEFs from 0.909 to 1.387, suggesting a notable impact of tricycles on traffic flow. Contrastingly, in Ghana, Adams et al. (2014) calculated a lower PCEF of 0.75. In India, the PCEFs ranged from 0.91 in urban areas to 1.32, with rural studies like Chandra & Kumar (2003) reporting a PCEF of 1.24, indicating varied impacts based on regional traffic conditions. Hence, the study of PCEF is not uniform and can result in different values based on several factors, including but not limited to road configuration, traffic conditions, and the methodologies used for calculation, where Speed-Area Method is the most common one. The discrepancy between the PCEF values for tricycles is further compounded by findings from various studies, which suggest PCEF for three-wheeler vehicles are significantly lower than the 2.5 for motor-tricycle set by the Highway Planning Manual.

Table 3. Estimated PCEF of three-wheeler vehicles in different studies

| Country | PCEF | Method | Road Type | Author(s) |
|---|---|---|---|---|
| Pakistan | 1.387 | Headway Method | Urban-Local Road | Adnan, M. (2014) |

| | | | | |
|---|---|---|---|---|
| | 0.909 | Speed-Area Method | Urban-Local Road | |
| | 1.35 | Regression Method | Urban-Local Road | |
| Ghana | 0.75 | Regression Method | Urban-Local Road | Adams, C. et al. (2014) |
| India | 1.24 | Speed-Area Method | Rural-Local Road | Chandra & Kumar (2003) |
| | 0.91 | Speed-Area Method | Urban-Local Road | Raj, P. et al. (2018) |
| | 1.32 | Speed-Area Method | Urban-Local Road | Mardani, M. et al. (2015) |

And lastly, the recommended PCEF for tricycles that was utilized in the Project for Capacity Development on Transportation Planning and Database Management in the Republic of the Philippines was 0.3. Table 4 shows the PCEF used by JICA:

Table 4. Recommended PCEF by JICA (2015)

| Mode | PCU/Vehicle | |
|---|---|---|
| | MMUTIS | MUCEP |
| Standard Bus | 2 | 2.5 |
| Minibus | 1.5 | 1.5 |
| Jeepney | 1.5 | 1.3 |
| Tricycle | | 0.3 |
| Pedicab | | 0.3 |
| Car/Jeep | 1 | 1 |
| Taxi | 1 | 1 |
| HOV Taxi | | 1.3 |
| Utility Vehicle | 1 | 1 |
| Truck/Trailer | 2 | 2 |
| Private Bus | | 2.5 |
| Motorcycle/Bicycle | 0.5 | 0.3 |
| Others | | |

Considering the apparent discrepancy between the PCEF values recommended by the Department of Public Works and Highways (DPWH) and those used in the Project for Capacity Development on Transportation Planning and Database Management in the Republic of the Philippines, this study identifies a notable inconsistency in the Passenger Car Equivalent Factor (PCEF) values for tricycles within the Philippine context. The DPWH sets a PCEF of 2.5 in the Highway Planning Manual, yet a relatively lower value of 0.3 is applied in the mentioned project. This difference in standards is not only contradictory but also central to the research problem, prompting an examination into the rationale behind these conflicting figures and their implications for traffic analysis.

### 1.2 Research Objectives

The general objective of the study is to reassess the Passenger Car Equivalent Factor (PCEF) for tricycles in urban local roads within Metro Manila based on empirical data. By doing so, the following specific objectives are executed:

1. To review existing PCEF standards in the Philippines and compare them with international PCEF values to identify potential discrepancies.
2. To conduct systematic data collection using video recordings in a continuous traffic conditions and different times to capture speed of tricycles and passenger cars
3. To utilize speed-area method in determining PCEF to assess the impact of tricycles on traffic flow and road capacity
4. To make an inference on the calculated PCEF within different urban local road context

### 1.3 Significance of the Study

The implication of PCEF would be crucial in traffic analysis as it adjusts for different types of vehicles. For instance, a PCEF of 2.5 for motor-tricycles means that one motor-tricycle will be converted to 2 and a half passenger cars in traffic modeling. Consequently, areas with a high number of tricycles will exhibit a higher VCR since there will be a higher volume of passenger cars compared to the actual capacity of the road. This adjustment suggests that roads with significant tricycle traffic may appear more congested in traffic analyses, thus identifying them as candidates for widening or other traffic management interventions to accommodate the increased traffic volume represented by the tricycles.

## 2. LITERATURE REVIEW

The concept of PCEF is important in traffic engineering, particularly in heterogeneous traffic environments where multiple vehicle types share the road. This is so as PCEF quantifies the impact of different vehicle types relative to a standard passenger car. Numerous studies across different regions and contexts have explored the estimation and application of PCEF.

### 2.1 National PCEF Standards in the Highway Planning Manual

In the Philippines, the Department of Public Works and Highways (DPWH) prescribes a PCEF of 2.5 for motor-tricycles, based not on empirical data but on their perceived impact on traffic flow due to frequent stopping and slow speeds (DPWH, 2013). They indicated the rationale behind the PCEF for tricycles that these slow-moving vehicles (25-30 km/h) cause significant queuing, especially in areas with frequent stops for loading/unloading passengers. Good, paved shoulders attract these vehicles, impacting the PCEF. Their stopping on the carriageway slows down other traffic, reducing road capacity.

### 2.2 International PCEF Standards

Contrastingly, in India, the Indian Roads Congress (1990) provided guidelines for road capacity in rural areas, prescribing a PCEF of 1.00 for three-wheelers such as the auto-rickshaw. Similarly, Satthamnuwong (2018) also indicated in their study that the prescribed standard PCEF for tricycles from the Department of Highway is also 1.00 in Thailand. Although this is recommended for rural areas, this recommendation is still substantially lower than the Philippine standard. But then, our study will investigate urban local roads hence the traffic dynamics and vehicle interactions will also be investigated and will still be assessed.

### 2.3 PCEF for Heterogeneous Traffic Environments in Urban Local Roads

Since Metro Manila commonly has heterogeneous traffic environments which means that the traffic is composed of mixed vehicles, this study also looks for related literature that investigates PCEF in locations with heterogeneous traffic environments.

For instance, Adnan (2014) conducted a study in Karachi, Pakistan, questioning the accuracy of existing PCEF used in local traffic studies. Using video recordings from 12 urban arterials, the study estimated the PCEF for heterogeneous traffic environments in urban local arterials in Karachi City. The values obtained from two headway-based methods, a speed-based method and a regression-based method differ significantly from the PCEF that are being followed in Karachi City. The results showed substantial variations from the standard PCEF used in Karachi, with three-wheelers PCEF ranging from 0.909 to 1.387. This discrepancy just emphasizes the necessity for region-specific PCEF assessments to reflect actual traffic conditions accurately.

On the other hand, Adams et al (2014) also estimated the PCEF for urban mixed traffic flow at signalized intersections in Tamale, Ghana, used multiple regression analysis to estimate PCEF, considering saturation times and vehicle types captured through three-hour video recordings at two intersections. The method involved manual data extraction from the videos and regression analysis to determine the PCEF. The resulting PCU values for tricycles were 0.75 at the Barclays Bank intersection and 0.67 at the Agric intersection. These values also highlight the variability of PCEF across different intersections. Although our study will only investigate midblock sections and not intersections, the PCEF for tricycles from their study is still notable compared to the 2.5 from HPM.

Similarly, Chandra and Kumar (2003) also a method to estimate PCEF for various vehicles under mixed traffic conditions on two-lane rural local roads in India, using the projected rectangular area of vehicles on the ground and speed as the parameters. For tricycles, the PCEF was calculated by observing their behavior on roads of varying widths (5.5 to 8.8 meters) and considering the projected rectangular area of the tricycles relative to passenger cars. The results showed that the PCEF for tricycles increased linearly with road width which actually illustrates greater movement freedom and speed differentials on wider roads. Specifically, the PCEF for tricycles ranged from 1.24 to 1.75, depending on the carriageway width. Although the study was conducted in rural local roads in India, the resulting PCEF for tricycles is still notable compared to 2.5 from HPM. With this, our study will also consider the factors affecting the speed as noted by Chandra such as the road configuration, particularly in terms of varying width and number of lanes per direction.

Additionally, Raj et al. (2018) attempted to estimate the PCEF for three wheelers using the speed-area method considering the influence of neighboring vehicles. Data were collected from four-lane divided and two-lane undivided urban mid-block sections located in Indian cities for 6 hours on weekdays using videographic technique. Dynamic PCU values were calculated using the speed of vehicles and their projected rectangular area on the ground. The PCEF for tricycles was found to be 0.91 which is still notable if compared to the 2.5 from DPWH's HPM.

And lastly, the study conducted by Mardami (2015) also estimated the Passenger Car Equivalency Factor (PCEF) for different vehicle types, including tricycles wherein data were collected at various road sections. Using the videography method, similar to Raj et al. (2018), traffic volume and vehicle speeds were recorded, and PCEFs were calculated based on the average speed and projected area ratios of standard cars to other vehicles. The study found that the PCEF for three-wheelers varied depending on the road type and traffic conditions, with values ranging from 0.91 on single-lane roads to 1.32 on intermediate-lane roads. This variation just emphasizes the influence of road width and traffic composition on PCEF values. With this, our study will also adopt the videographic techniques employed in studies like Mardami's and Raj's, but the unique feature of our methodology will still be subjected to the conditions of site of interest.

### 2.4 Influence of Road Type and Conditions

Similar to the previously discussed related studies, Bomzon et al. (2021) also investigated the PCEF of different vehicles on the hilly roads of East Sikkim using the speed area method by using traffic volume data. They utilized video graphic survey to collect data such as the vehicles' composition to determine the respective area factor and the speed for speed factor. Only the product of the two factors mentioned were used to compute for PCUs of different vehicles. The PCEF obtained in this study was 0.263 but this is for motorcycles only and not three-wheelers. We would like to highlight in this study that they also suggest that road configuration, specifically the geographical condition such as gradients and terrain, influence PCEF. Hence, this factor will be considered in our conceptual framework.

### 2.5 Technological Advancements in Traffic Monitoring

In terms of capturing vehicle speed, the Unmanned Aerial Vehicles (UAVs) have revolutionized traffic monitoring and analysis. The use of these UAVs have been reviewed by Butilă and Boboc (2022) by comparing the UAV types, camera resolution, flying height, video duration, software techniques, and vehicle types that can be monitored. They also compared the advantages of each UAV type in terms of endurance and speed. Although this is a remarkable way to capture speed of vehicles, the acquisition of such technology is beyond the capacity of our research, therefore video surveying along the sides of the highway will still be the prioritized method.

### 2.6 Review and Synthesis of Methodologies for Estimating PCEFs

As previously discussed, there are a lot of methods to assess the PCEF of vehicles, but in another study by Raj et al. (2019), they also provided a review of various methods for estimating PCEF, classifying them based on their approaches, parameters considered, and the types of facilities. The review also highlighted factors influencing PCEF, such as road width and traffic composition. According to their study, the simplest method used is the speed-area method conceptualized by Chandra and Kumar (2003) which establishes a direct relationship between vehicle speed and effective area, requiring only basic data on vehicle speeds and dimensions. Due to its straightforward implementation and minimal data requirements, the speed-area method is deemed the most practical and efficient for our research.

### 2.7 Summary

Evidence on the importance of Passenger Car Equivalency Factors has shown that they are important in traffic engineering, especially in mixed-traffic environments. Significant differences in tricycle PCEF values are revealed by different studies across places ranging from the Philippines, India, Pakistan, Ghana, and many others, which could mainly be due to the differences in traffic conditions, road types, and vehicle behaviors. Whereas DPWH in the Philippines prescribes a PCEF of 2.5 for tricycles, based on their effect on traffic flow, most other studies—from India, Thailand, and Pakistan—claim that this value is less, with most applications of the technique country-specific in nature. From speed-area analysis to more modern regression methods, the derivation of PCEF demonstrates the need for such site-specific analysis. Road width, traffic mix, and vehicle speed are parameters in all these analyses. The use of video surveying methods, similar to that in most studies, is, however possible for data collection from such locations. The related literature has pointed out the need to develop region-specific PCEF assessments, which reflect the actual traffic condition duly guiding the methodology for future research in urban local roads with heterogeneous traffic.

## 3. METHODOLOGY

### 3.1 Speed-area Method

The methodology central to the assessment of the study or method of analysis is the Speed-Area Method. Conceptualized by Chandra (1995), Speed-Area Method is grounded in the relationship between the speed of a vehicle and its projected rectangular area on the ground. This method asserts that a vehicle's PCEF is directly proportional to its speed and inversely proportional to the projected rectangular area it occupies on the ground, compared to a standard passenger car. It allows for the estimation of PCEF by analyzing the space a vehicle utilizes at different speeds, which is particularly useful in heterogeneous traffic like those found in Metro Manila. For this method, the following formula was used:

$$PCEF = \frac{V_c/V_i}{A_c/A_i} \quad (1)$$

where,

$V_c$ : the mean speed of the passenger car,
$V_i$ : the mean speed of the tricycle,
$A_c$ : the projected rectangular area of the passenger car on the ground, and
$A_i$ : the projected rectangular area of the tricycle on the ground.

### 3.2 Conceptual Framework

The conceptual framework is constructed based on the Speed-Area Method and insights from the literature review. It illustrates the relationship between PCEF, mean speed, and projected area. Figure 1 shows the framework which highlights the key variables influencing traffic analysis in this study.

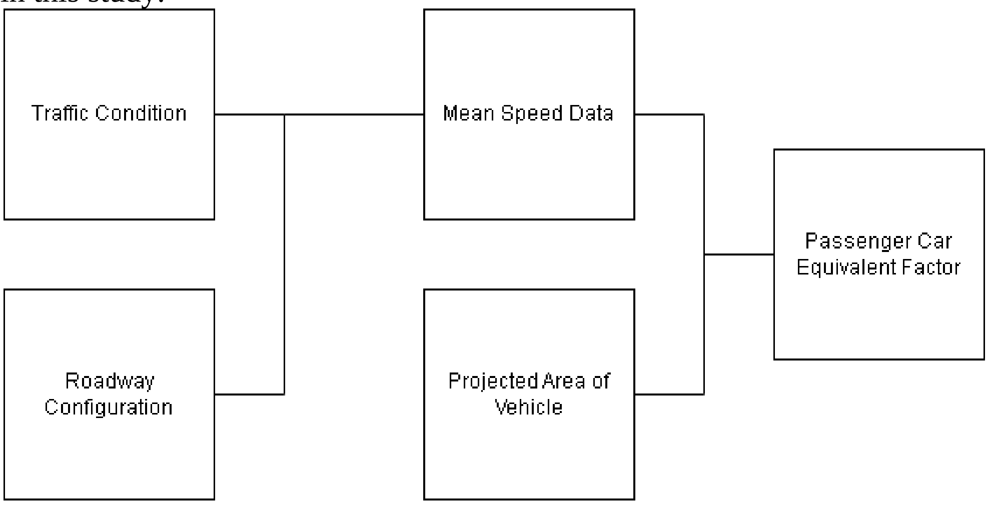


Figure 1. Speed-Area method conceptual framework

In this framework, the PCEF is determined by two factors:

1. Mean Speed: The average speed of the vehicles, influenced by traffic conditions, road configuration, and vehicle type.
2. Projected Area: The rectangular area a vehicle occupies on the ground, which differs depending on the vehicle type (e.g., passenger car vs. tricycle).

The mean speed is influenced by traffic flow and road conditions, while the projected area reflects the spatial footprint of each vehicle type. Together, these factors help quantify the relative impact of various vehicles on road capacity and traffic congestion.

### 3.3 Video Surveying as Data Collection Procedure for Vehicle Speed

To account for the speed of the vehicles, the flow of vehicles and the time it takes for them to cross a designated section of the road were recorded using a video camera, a method commonly employed in traffic studies. In this procedure, a start marker and an end marker were created along the road. The distance used between these markers varies depending on the roadway configuration and any limitations on camera vision. Specifically, Site 1, Site 2, and Site 3 have 3-meter distance markers, while Site 4 has a 4.5-meter distance. Figure 2 shows the visual representation of the setup.

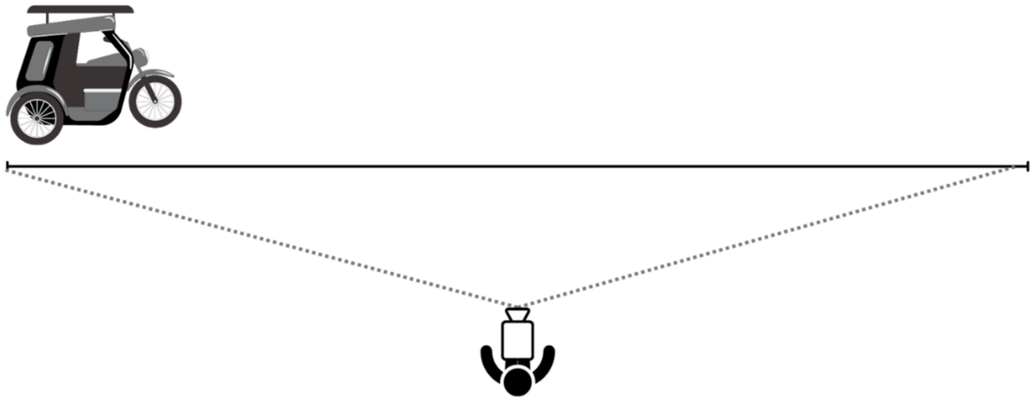

Figure 2. Start and End Marker

Video footage was recorded for at least 2-3 hours over a period of 4 typical weekdays. This duration is also necessary to ensure there are enough sample sizes to be extracted for the analysis.

To extract data from the video, the number of frames elapsed from the moment a vehicle (either a tricycle or a passenger car) crosses the start marker until it crosses the end marker was counted. Given the video recording quality of 30 frames per second (fps), the time taken for the vehicle to travel between the markers was calculated by dividing the frame difference by 30. This provides the total time in seconds.

The processed data, including the measured distance and elapsed time in seconds, was used to calculate the speed of each vehicle.

### 3.4 Area of Study and Surveying Duration Criteria

The selection of sites for this study was guided by the conceptual framework and other criteria established in related literature to ensure representative data collection.

The first criterion established was compliance with the DILG Memorandum Circular 2020-036, which prohibits tricycles, pedicabs, and motorized pedicabs from operating on national highways. Hence, all selected sites are located within urban local roads.

In terms of traffic conditions, it is necessary that the vehicles have continuous traffic flow as it influences the speed of vehicles. With this, sites were chosen to be along midblock sections to ensure that vehicles avoid intersections that could skew the continuous flow of traffic due to starting, stopping, and turning movements.

Another factor influencing traffic conditions is the pedestrian activity levels. It was considered due to their influence on vehicle operations, particularly tricycles and passenger cars, and, consequently, on traffic dynamics. High pedestrian densities can alter tricycle speeds and maneuvering, affecting their traffic flow contribution, hence the sites are away from pedestrian lanes.

In terms of road configuration, both one lane per direction and two lanes per direction types of roads were included in the assessment. This is to ensure there will be variations in road types as vehicle speeds also often depend on the road width. Site 1 and 2 are two lane per direction roads and have an approximately 14m and 12m road width, respectively, while site 3 and 4 are one lane per direction roads and have an approximately 10m and 8m road width.

To ensure sufficient sample sizes, the site's proximity to public transport hubs was factored in by selecting sites near tricycle hubs. These areas experience high tricycle traffic, and thus, adding this criterion would allow to maximize the volume of tricycles.

Furthermore, in selecting at least four sites and setting at least 2-3 hours during the afternoon, the precedent set by related literature was followed, which emphasizes capturing varying traffic conditions. Studies such as those by Mishra et al. and Raj et al. (2018) demonstrate that surveying multiple sites with varying traffic volumes and lane configurations provides better understanding of vehicle behavior. By collecting data from four different sites, there will be sufficient variation in urban traffic dynamics. This also aligns with the methodology used by Chandra (2003), who found that data collected over several hours in the afternoon on typical weekdays is sufficient to capture daily traffic pattern variability. Table 5 shows the summary of on-site duration, and how many locations were surveyed in studies relating to PCEF.

Table 5. Summary of on-site durations and locations from other PCEF studies

| Title and Author of Study | On-site Duration | Location |
|---|---|---|
| Effect of Lane Width on Capacity under Mixed Traffic Conditions in India (Chandra, S., & Kumar, U., 2003) | 4-5 hours on a typical weekday | 10 locations |
| Passenger Car Equivalent Factors in Heterogenous Traffic Environment-Are We Using the Right Numbers? (Adnan, M., 2014) | Not Indicated | 12 locations |
| Novel Area Occupancy–Based Method for Passenger Car Unit Estimation on Multilane Urban Roads Under Heterogeneous Traffic Scenario (Mishra, R., et al., 2017) | Captured morning and afternoon | 2 locations |
| Three Methods of PCU Estimation at Unsignalized Intersections (Mohan, M., & Chandra, S., 2016) | Not Indicated | 2 Locations |
| An Approach for Estimation of Passenger Car Unit Values of Vehicles Based on Influence of Neighboring Vehicles (Raj, P., et al., 2019) | Six hours on a typical weekday | 2 Locations (1 four-lane and 1 two-lane) |
| Determination of Passenger Car Unit Equivalence for Motorcycles: The Case of Metro Manila (Espenilla, N., 2010) | Not Indicated | 3 Locations (up to four lanes) |
| Determination of PCU Values for Mixed Traffic Conditions Along the Hilly Road of East Sikkim (Bomzon, U., et al., 2021) | Not Indicated | 1 road was divided into sections of 500m each along 11 km stretch |

With the on-site duration and number of sites established, the specific locations for the surveys were determined, still considering that sufficient sample sizes are collected. According to Reyes and Villamora (2006), Quezon City is one of the cities in Metro Manila where there is a profound number of tricycles, which makes QC a suitable representative of Metro Manila in terms of tricycle volume. They indicated the city hosts 148 tricycle-operator driver associations (TODAs) and has 20,568 registered tricycles—which is substantial number of tricycles enough to also garner ample number of samples for the study. To be more specific, a study by Salison et al. (2023) was considered, which indicated that District 5 of Quezon City has the highest transportation activity per tricycle unit, averaging 7,860.57 kilometers per tricycle per year. With this, Quezon City District 5 was selected as it can represent urban Metro Manila in terms of tricycle units and transportation activities.

On the other hand, the Tricycle Regulation Division of Quezon City provided data on tricycle units of District 5. According to their records, Barangay West Fairview has the highest number of registered tricycles with 820 units, while Barangay San Bartolome is the second and has 500 units. Hence, the four specific sites to be surveyed are located within these barangays to ensure high volume of tricycle traffic.

## 4. RESULTS AND DISCUSSION

In this section, the interview with DPWH as well the results of data collection through video surveying and the measurement of actual projected dimensions of tricycles on the ground, along with referencing established studies for the average projected dimensions of passenger cars, are summarized.

### 4.1 Insights from DPWH on PCEF Applications and Implications

In an interview with a key informant from the Traffic Analysis Section at the Department of Public Works and Highways (DPWH), the PCEF and its application were discussed.

The informant explained that the methodology and data used to establish the PCEF of 2.5 were based on the earlier Highway Planning Manual (HPM) from 1982. Specific details on the methodology and data used to derive the PCEF of tricycles were not available, as they were formulated several decades ago. The PCEF was determined using observations from national roads with a mix of vehicles, including a significant number of tricycles, without taking local traffic conditions into account.

The DPWH utilizes the PCEF in combination with the Volume to Capacity Ratio (VCR) to assess the need for road widening projects. Roads are considered for widening if their VCR exceeds 0.6, indicating potential congestion issues. This helps the DPWH identify roads that may require capacity improvements to enhance traffic flow.

With this, the implication of PCEF would be crucial in traffic analysis as it adjusts for different types of vehicles. For instance, a PCEF of 2.5 for motor-tricycles means that one motor-tricycle will be converted to 2 and a half passenger cars in traffic modeling. Consequently, areas with a high number of tricycles will exhibit a higher VCR since there will be a higher volume of passenger cars compared to the actual capacity of the road. This adjustment suggests that roads with significant tricycle traffic may appear more congested in traffic analyses, thus identifying them as candidates for widening or other traffic management interventions to accommodate the increased traffic volume represented by the tricycles.

### 4.2 The Mean Speed Data

Through video surveying, the mean speed data of the vehicles of interest are summarized in table 6.

Table 6. Mean speed data for vehicles of interest

| Site and No. of Lanes | Road Width (m) | Passenger Cars | | Tricycles | |
|---|---|---|---|---|---|
| | | No. of Vehicles | Mean Speed (m/s) | No. of Vehicles | Mean Speed (m/s) |
| Site 1: 4 Lanes | 14 | 641 | 6.459 | 783 | 6.478 |
| Site 2: 4 Lanes | 12 | 655 | 6.399 | 572 | 7.855 |

| | | | | | |
|---|---|---|---|---|---|
| Site 3: 2 Lanes | 10 | 359 | 6.622 | 694 | 6.471 |
| Site 4: 2 Lanes | 8 | 533 | 3.329 | 479 | 5.337 |

The data shows that lane configuration and road width significantly influence vehicle speeds. Interestingly, tricycles tend to exhibit higher speeds on narrower roads, especially on one lane per direction, suggesting they are less affected by road congestion compared to passenger cars. On wider roads, speeds of both vehicle types tend to converge, indicating that the additional space allows for more consistent traffic flow, as well wider lanes allow cars to move more freely and overtake slower vehicles. Additionally, local traffic conditions and congestion levels, as reflected by the number of vehicles recorded at each site, also impact vehicle speeds. Overall, these findings highlight that lane configurations and traffic conditions are variable in determining the mean speed data.

### 4.3 The Projected Rectangular Area of Vehicles on the Ground

From the conceptual framework, PCEF is also dependent on the projected rectangular area of vehicles on the ground. To account for this variable, the analysis refers to the average dimensions and projected rectangular areas of each type of vehicle category that is recorded in a study by Chandra (2003) shown in table 7.

Table 7. Vehicle categories and their average dimension (Chandra, 2003)

| Category | Vehicles Included | Average Dimension | | Projected Rectangular Area on Ground ($m^2$) |
|---|---|---|---|---|
| | | Length (m) | Width (m) | |
| Car | Car, Jeep | 3.72 | 1.44 | 5.39 |
| Bus | Bus | 10.1 | 2.43 | 24.74 |
| Truck | Truck | 7.5 | 2.35 | 17.62 |
| Light Commercial Vehicle | Minibus, Vans | 6.1 | 2.1 | 12.81 |
| Tractor | Tractor, Trailer | 7.4 | 2.2 | 16.28 |
| Three-Wheeler | Three-Wheeler | 3.2 | 1.4 | 4.48 |
| Two-Wheeler | Scooter, Motorbike | 1.87 | 0.64 | 1.2 |
| Cycle | Bicycles | 1.9 | 0.45 | 0.85 |
| Rickshaw | Pedal Rickshaw, Cart | 2.7 | 0.95 | 2.56 |

In the analysis, the projected rectangular area of passenger car on the ground is taken as $5.39 m^2$. The average projected dimensions on the ground of passenger car are presented in figure 3.

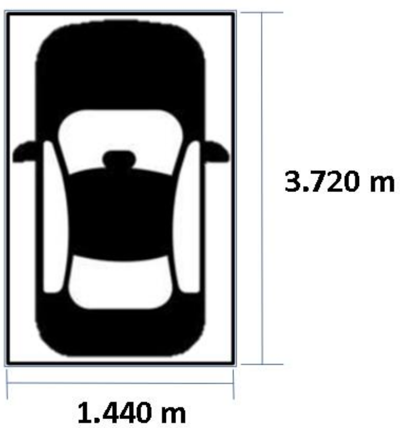


Figure 3. Projected rectangular area of passenger cars on the ground

On the other hand, the projected rectangular area of tricycles on ground in different sites were also measured. In the analysis, the average dimensions and projected areas of tricycles from different sites were taken, and they are summarized in Table 8.

Table 8. Average projected dimensions and rectangular area of tricycles on ground

| Site | | Tricycle Color Code | Length (m) | Width (m) | Projected Rectangular Area on Ground (m²) |
|---|---|---|---|---|---|
| West Fairview | 1 | Yellow | 2.400 | 1.380 | 3.312 |
| | 2 | Yellow | 2.400 | 1.380 | 3.312 |
| San Bartolome | 3 | Orange | 2.420 | 1.390 | 3.364 |
| | 4 | Orange | 2.420 | 1.390 | 3.364 |
| Average Dimensions | | | 2.410 | 1.385 | 3.33785 |

In the analysis, a sample tricycle was measured for each site to obtain its projected rectangular area on the ground. The average area of the vehicle is recorded as 3.33785m². The average projected dimensions on the ground of passenger car are presented in figure 4.

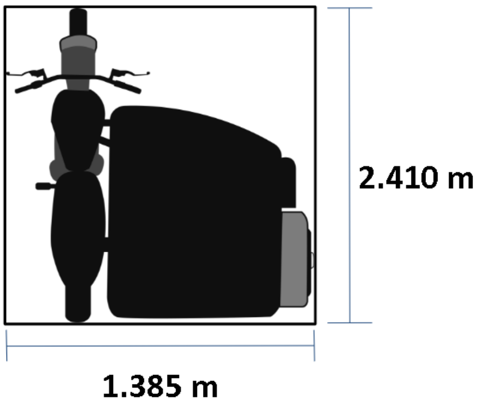

Figure 4. Projected Rectangular Area of Tricycles on the Ground

It can also be noted that there is an apparent discrepancy between the average dimensions of three-wheeler vehicles presented in Table 7 and Table 8. This is because the three-wheeler vehicles referenced in other countries differ in design and configuration from the tricycles commonly used in the Philippines. With this, the actual dimensions for the three-wheelers (or tricycles) from the chosen sites are measured.

## 5. PCEF CALCULATIONS

With the mean speed data and the projected rectangular area of vehicles on the ground established, which are variables in the PCEF according to the conceptual framework, PCEF are calculated using the Speed-Area Method. Table 9 summarizes the calculated PCEF for each site.

Table 9. Average projected Dimensions and Rectangular Area of Tricycles on Ground

| Site | Road Width (m) | No. of Vehicles (Trike & Car) | Tricycles | | Car | | PCEF |
|---|---|---|---|---|---|---|---|
| | | | Speed (m/s) | Area (m²) | Speed (m/s) | Area (m²) | |
| Site 1: Two Lane per Direction | 14 | 783 & 641 | 6.478 | 3.338 | 6.459 | 5.390 | 0.617 |
| Site 2: Two Lane | 12 | 572 & 655 | 7.855 | 3.338 | 6.399 | 5.390 | 0.504 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| per Direction | | | | | | | |
| Site 3: One Lane per Direction | 10 | 694 & 359 | 6.471 | 3.338 | 6.622 | 5.390 | 0.634 |
| Site 4: One Lane per Direction | 8 | 479 & 533 | 5.337 | 3.338 | 3.329 | 5.390 | 0.386 |
| Average PCEF | | | | | | | 0.535 |

The data shows that road width and lane configuration significantly influence vehicle speeds and the resulting PCEF values. Tricycles tend to have higher speeds than passenger cars on narrower roads, leading to lower PCEF values. Conversely, on wider roads, the speeds of both vehicle types tend to become similar, resulting in higher PCEF values. The average PCEF of 0.535 indicates that, on average, a tricycle impacts traffic flow slightly more than half as much as a passenger car.

Additionally, the data shows how road dimensions and lane configurations affect traffic flow for tricycles compared to passenger cars. Notably, there is a difference in PCEF values between sites with varying road widths and lane numbers. For example, tricycles on the two-lane per direction with wider road width (Site 1 vs. Site 2) have higher PCEF values, indicating that passenger cars tend to perform more similarly to tricycles when more space is available. The difference between the two sites with the same number of lanes per direction is visually represented in figure 5.

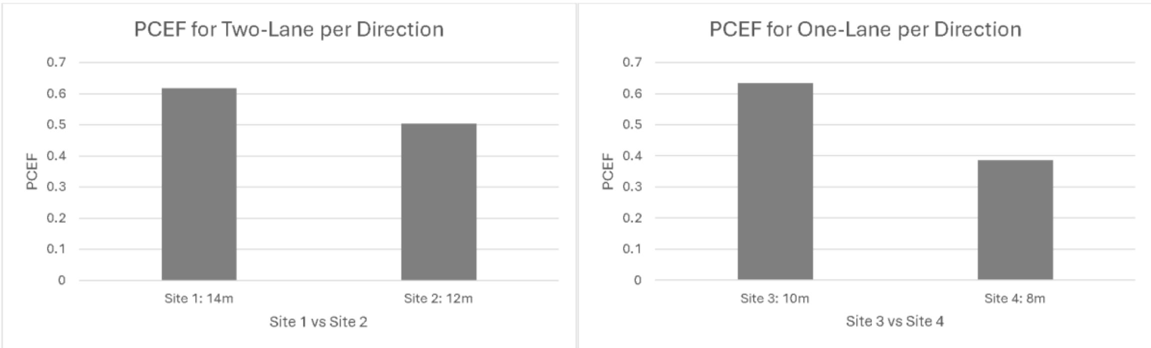


Figure 5. PCEF Comparison

This pattern is also observed in sites with one lane per direction (Site 3 and Site 4), where tricycles have higher PCEF values on relatively wider roads. The data indicates that even within such road configurations, increased road width allows for higher relative speeds for tricycles, resulting in higher PCEF values. This difference can be visualized in the figure below:

It can also be noted that the PCEF values for Site 1 (0.617) and Site 3 (0.634) are more similar despite differences in road width and lane configuration. Site 1's wider road and two-lane configuration reduce congestion, and likewise Site 3's single-lane setup with decent road width tends to allow passenger car to increase maneuverability, and consequently the speed. This results in comparable speeds for tricycles and passenger cars, suggesting that maneuvering space has a similar impact on both sites, leading to similar PCEF values.

On the other hand, the PCEF values for Site 2 (0.504) and Site 4 (0.386) differ more significantly, reflecting the combined effects of road width and lane configuration on traffic flow. Site 4, with an 8m road width and one lane per direction, allows for higher relative speeds for tricycles compared to passenger car due to their ability to maneuver in congested areas while Site 2’s 12m and two-lane per direction allows passenger cars to maneuver differently which results to higher speed, and consequently the PCEF. This results in a lower PCEF for Site 4, indicating that narrower roads with fewer lanes can significantly reduce the traffic impact of tricycles compared to wider, multi-lane roads.

Consequently, these imply that in more congested areas, tricycles are less disruptive to continuous traffic flow than passenger cars. In traffic modeling, this lower PCEF value also suggests that tricycles have lesser implications on the Volume-to-Capacity Ratio of a road, which means that the volume of tricycles affects the capacity of narrower roads less significantly. Hence, roads with significant tricycle traffic might not require as extensive interventions as initially thought.

To account for the potential differences in PCEF across all other possible site pairings, an analysis was also conducted to determine if such differences are significant in the PCEF. In conducting this test, the following hypotheses were made:

- Null Hypothesis (H0): The difference between PCEF values among the sites are not significant
- Alternative Hypothesis (H1): The difference between PCEF values among the sites are significant

Independent samples t-tests were conducted for all possible pairings of the PCEF values across the four sites. Each test compared two pairs of sites at a time, and the pairings are shown in table 10.

Table 10. Site Pairings

| Pair | Site | PCEF | |
|---|---|---|---|
| 1 | Site 1 vs Site 2 | 0.617 | 0.504 |
| 2 | Site 1 vs Site 3 | 0.617 | 0.634 |
| 3 | Site 1 vs Site 4 | 0.617 | 0.386 |
| 4 | Site 2 vs Site 3 | 0.504 | 0.634 |
| 5 | Site 2 vs Site 4 | 0.504 | 0.386 |
| 6 | Site 3 vs Site 4 | 0.634 | 0.386 |

The results showed that the p-values for all combinations were consistently greater than 0.05, indicating no statistically significant differences between the means of any groups. Consequently, it can be confidently concluded that averaging the PCEF values across the four sites is valid. Table 11 summarizes the independent samples t-test.

Table 11. Independent Samples T-test

| Possible Combinations | | | | x̄ | σ2 | Sp | t-statistic | p-value | Conclusion |
|---|---|---|---|---|---|---|---|---|---|
| C1 | Site 1 vs Site 2 | 0.62 | 0.50 | 0.56 | 0.01 | 0.06 | -1.13 | 0.341 | p > 0.05, difference not significant |
| | Site 1 vs Site 3 | 0.62 | 0.63 | 0.63 | 0.00 | | | | |
| C2 | Site 1 vs Site 4 | 0.62 | 0.39 | 0.50 | 0.03 | 0.13 | -0.51 | 0.645 | p > 0.05, difference not significant |
| | Site 2 vs Site 3 | 0.50 | 0.63 | 0.57 | 0.01 | | | | |
| C3 | Site 2 vs Site 4 | 0.50 | 0.39 | 0.45 | 0.01 | 0.14 | -0.47 | 0.670 | p > 0.05, difference not significant |
| | Site 3 vs Site 4 | 0.63 | 0.39 | 0.51 | 0.03 | | | | |
| C4 | Site 1 vs Site 2 | 0.62 | 0.50 | 0.56 | 0.01 | 0.13 | 0.46 | 0.677 | p > 0.05, difference not significant |
| | Site 1 vs Site 4 | 0.62 | 0.39 | 0.50 | 0.03 | | | | |
| C5 | Site 1 vs Site 2 | 0.62 | 0.50 | 0.56 | 0.01 | 0.09 | -0.09 | 0.934 | p > 0.05, difference not significant |
| | Site 2 vs Site 3 | 0.50 | 0.63 | 0.57 | 0.01 | | | | |
| C6 | Site 1 vs Site 2 | 0.62 | 0.50 | 0.56 | 0.01 | 0.08 | 1.41 | 0.253 | p > 0.05, difference not significant |
| | Site 2 vs Site 4 | 0.50 | 0.39 | 0.45 | 0.01 | | | | |
| C7 | Site 1 vs Site 2 | 0.62 | 0.50 | 0.56 | 0.01 | 0.14 | 0.37 | 0.736 | p > 0.05, difference not significant |
| | Site 3 vs Site 4 | 0.63 | 0.39 | 0.51 | 0.03 | | | | |
| C8 | Site 1 vs Site 3 | 0.62 | 0.63 | 0.63 | 0.00 | 0.12 | 1.07 | 0.363 | p > 0.05, difference not significant |
| | Site 1 vs Site 4 | 0.62 | 0.39 | 0.50 | 0.03 | | | | |
| C9 | Site 1 vs Site 3 | 0.62 | 0.63 | 0.63 | 0.00 | 0.07 | 0.87 | 0.448 | p > 0.05, difference not significant |
| | Site 2 vs Site 3 | 0.50 | 0.63 | 0.57 | 0.01 | | | | |
| C10 | Site 1 vs Site 3 | 0.62 | 0.63 | 0.63 | 0.00 | 0.06 | 3.02 | 0.057 | p > 0.05, difference not significant |
| | Site 2 vs Site 4 | 0.50 | 0.39 | 0.45 | 0.01 | | | | |
| C11 | Site 1 vs Site 3 | 0.62 | 0.63 | 0.63 | 0.00 | 0.12 | 0.93 | 0.421 | p > 0.05, difference not significant |
| | Site 3 vs Site 4 | 0.63 | 0.39 | 0.51 | 0.03 | | | | |
| C12 | Site 1 vs Site 4 | 0.62 | 0.39 | 0.50 | 0.03 | 0.13 | 0.44 | 0.690 | p > 0.05, difference not significant |
| | Site 2 vs Site 4 | 0.50 | 0.39 | 0.45 | 0.01 | | | | |
| C13 | Site 1 vs Site 4 | 0.62 | 0.39 | 0.50 | 0.03 | 0.17 | -0.05 | 0.963 | p > 0.05, difference not significant |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Site 3 vs Site 4 | 0.63 | 0.39 | 0.51 | 0.03 | | | | |
| C14 | Site 2 vs Site 3 | 0.50 | 0.63 | 0.57 | 0.01 | 0.09 | 1.41 | 0.253 | $p > 0.05$, difference not significant |
| | Site 2 vs Site 4 | 0.50 | 0.39 | 0.45 | 0.01 | | | | |
| C15 | Site 2 vs Site 3 | 0.50 | 0.63 | 0.57 | 0.01 | 0.14 | 0.42 | 0.703 | $p > 0.05$, difference not significant |
| | Site 3 vs Site 4 | 0.63 | 0.39 | 0.51 | 0.03 | | | | |

## 6. CONCLUSIONS AND RECOMMENDATIONS

This study provides an analysis of the impact of tricycles on traffic flow in urban local roads using the PCEF. The results show that road width and lane configuration influence vehicle speeds and PCEF values. Tricycles generally have higher speeds relative to passenger cars on narrower roads, resulting in lower PCEF values, while on wider roads, the speeds of both vehicle types tend to become more similar, leading to higher PCEF values. The average PCEF calculated in this study is 0.535, indicating that a tricycle impacts traffic flow slightly more than half as much as a passenger car in urban local roads. This contrasts sharply with the DPWH prescribed PCEF of 2.5 for tricycles from the Highway Planning Manual.

The prescribed 2.5 PCEF for tricycles is based on conditions found on national roads. It does not account for the traffic dynamics and conditions present on urban local roads. National roads are designed for higher speeds, with broader lanes and less frequent intersections, whereas urban local roads have lower speed limits and are characterized by narrower lanes. If conducted on national roads, the PCEF values for tricycles would likely be higher, potentially aligning with the DPWH's prescribed value of 2.5, due to the broader road width and higher speeds which is also because of more diverse traffic typical of national roads.

The findings indicate that tricycles, which operate at lower speeds and maneuver differently in congested urban environments, have a lesser impact on traffic flow in urban local roads compared to the implication of the 2.5 PCEF. Therefore, the current PCEF of 2.5 implies an overestimation on the impact of tricycles in urban local contexts in traffic analysis, especially in estimating roadway capacity.

The findings indicate that tricycles, which operate at lower speeds and maneuver differently in congested urban environments, have a lesser impact on traffic flow in urban local roads compared to the implication of the 2.5 PCEF. Therefore, the current PCEF of 2.5 implies an overestimation on the impact of tricycles in urban local contexts in traffic analysis, especially in estimating roadway capacity. The resulting PCEF from this study, which also encourages the researchers to reassess the 2.5, should be considered to better reflect the dynamics of both urban local and national roads. And lastly, since there is variation in PCEF values across different sites, this also suggests that local traffic conditions, such as road configuration and traffic density, have an influence on the PCEF. With this, site-specific factors must be considered when applying PCEF values, and localized traffic studies should inform policy decisions so there will be accurate traffic modeling. In addition to this, the presence of higher volumes and speeds on national roads could amplify the impact of tricycles, justifying a higher PCEF to account for greater potential disruptions as indicated in the rationale behind the PCEF system from the Highway Planning Manual.

Based on the findings, it is recommended that the PCEF of 2.5 for tricycles be reassessed, particularly for urban local roads, to more accurately reflect traffic conditions. The PCEF of 0.535 derived in this study is a better representation of the impact of tricycles in urban local roads. Traffic capacity models should incorporate this lower PCEF value when applied to these areas. Additionally, localized traffic studies should also be conducted to account for variation in road type and configurations, with the current PCEF of 2.5 potentially remaining valid for national roads, should tricycles be permitted to operate on them again in the future. Finally, adopting a differentiated PCEF for urban local and national roads will allow for a more precise evaluation of traffic dynamics based on road type.

## 7. ACKNOWLEDGMENTS

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