Characteristics of pedestrian crashes on different road types in Metro Manila, Philippines

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Abstract : Pedestrians are the most vulnerable road users, hence understanding factors that lead to pedestrian crashes is one of the primary concerns in road safety. In the Philippines, limited studies were conducted that investigate the characteristics and trends of pedestrian crashes specifically on different road types. Using the 3-year data (2016 - 2018) of road crashes involving pedestrians in Metro Manila, this study examines the trends of pedestrian casualties and its proportions to different road types considering different influencing factors. The result shows that higher hierarchy roads (primary) have higher number of fatal casualties compared to lower hierarchy roads (local) while the trend of casualties involving child pedestrians are increasing from primary to local roads, and decreasing for adult and senior pedestrians. Furthermore, this study provides initial insights on the characteristics of pedestrian crashes on different road types to help identifying proper countermeasures in the future.

Key Words : *pedestrian safety, road types, road crashes,*

1. INTRODUCTION

More than half of all road traffic deaths in the world are among vulnerable road users: pedestrians, cyclists and motorcyclists[1)]. In the Philippines, pedestrians and motorcycle riders continue to be the most vulnerable road users specifically in Metro Manila[2)]. Although, several institutional frameworks and policies towards safer roads and mobility have already been made throughout the country, yet pedestrians still have a major share in the total casualties (fatalities and injuries) from road crash. In fact, an annual average of 180.7 pedestrian fatality (46.2% of the total road crash fatalities) is reported in Metro Manila in the period between 2005 to 2016[2)]. Hence, pedestrians make up the biggest chunk of road user deaths at 19% after motorcycles (53%) followed by drivers of four-wheeled vehicles (14%) and passengers (11%)[1)].

In general, road traffic crash results from a combination of different factors including road user behavior, road geometry, road environment, vehicle characteristics, ambient conditions and other[3)]. The role of these factors is different from country to country based on the local traffic and road conditions. In the Philippines, especially in Metro Manila, most of the roads lack a complete segregation of motorized vehicles specifically motorcycles, which is one of the leading vehicles involved in a pedestrian collision. In addition, the urban road network in Metro Manila, has been increasingly becoming crowded with an overwhelming number of motorized vehicles and pedestrians sharing the roadways that consequently result to collisions. Therefore, in order to develop effective countermeasures, it is imperative to identify possible risk factors resulting to crashes. Thus, this study analyzes the proportions and characteristics of pedestrian casualties in Metro Manila for the period from 2016 to 2018 on different road types considering various parameters such as characteristics of pedestrians (e.g. gender, age), severity of the crash, type of vehicle involved, time of day, day of week, location, and district/city. This study provides an overview on the characteristics of pedestrian casualties in Metro Manila including their spacial and temporal disctributions.

Basically, higher hierarchy roads (e.g. arterials) have higher mobility level but with lower degree of access while lower hierarchy roads (e.g. locals) have lower mobility level but with higher degree of access[4]. In this sense, pedestrian access is considerably lesser to higher hierarchy roads compared to lower ones. Thus, this study assumes that there may be significant differences on pedestrian crash characteristics on different road types that could be influenced by their functional differences.

2. LITERATURE REVIEW

Several studies related to pedestrian crashes involve examining factors that contribute to injury severity. The study of Eluru et al.[5] categorized several risk factors that have been considered in several studies into six categories: (1) pedestrian characteristics (e.g. age, gender, state of soberness), (2) motorized vehicle driver characteristics (e.g. state of soberness, age), (3) motorized vehicle characteristics (e.g vehicle type, speed), (4) roadway characteristics (e.g. speed limit, road system), (5) environmental factors (e.g. time, weather conditions), and (6) crash characteristics (e.g. vehicle movement before the accident).

Whereas, Ukkusuri et al.[6] analyzed the relationship between the frequency of pedestrian-vehicle accidents according to injury severity types and built environment variables, such as demographics, land use patterns, transit and road network characteristics. While, Moudon et al.[7] examined the correlates of injury severity using police records of pedestrian-motor-vehicle collisions on state routes and city streets in which the characteristics of individual pedestrians and road environment were considered on the levels of influence on collision outcome.

There are limited studies examining road crashes involving pedestrians in various road and highway classifications. Moudon et al.[7] included state routes and city streets for comparative purposes because they differed in terms of transportation facilities as well as their road environments. While, Hu and Cicchino[8] examined if the increase in pedestrian fatalities by various roadway, environmental, personal, and vehicle factors changed significantly and Shinstine et al.[9] analyzed crash severity for rural highways including interstates, state highways and rural county local roads.

While, Pei and Fu[10] identified several factors affecting crash severity and concluded that crash severity could be associated with the predictors such as road conditions, collision types, and highway classification in which the third-class highway found to result in the increased probability of serious injuries. It states that the possible reason could be that drivers are more likely to speed up on account of lack of surveillance and the traffic police patrol on the third-class highways compared to upper class highways. Thus, also probably the reason for an increase in the likelihood of serious injury in crashes occurring at the intersections with traffic signs or markings on the third-class highways.

The study of Chen et al.[11] considered four roadway class (interstate, US route, NC route, and local street) as one of the potential contributing factors at different severity levels including fatality. It found out that Interstates may increase the likelihood of fatal crashes compared to other roadway class because interstates are associated with higher vehicular speed which could increase the injury severity. The results further reveal that roadway class may significantly increase other injury types (e.g. disabling, evident).

Some of the identified statistical methods are appropriate to use in identifying the causes and severity of the crashes considering various categories of factors as indicated by Eluru et al.[5]. However, this study does not focus in identifying what factors can contribute to collisions as what regression analysis normally does, but rather to investigate the proportions of pedestrian casualties occurred on each of the road type considering the identified characteristics and analyze if these proportions change significantly per road type. Hence, this study, aside from descriptive statistics, uses basic statistical tests such as chi-square test[12] and the test of proportions.

Essentially, the study that focuses on the characteristics of pedestrian crashes on different road types has not been widely explored specifically in developing countries such as the Philippines.

A study conducted by Asian Development Bank[13] reveals that the extent of the road network in the Philippines, when measured in terms of road km per square km, road km per capita, and road km per dollar of GDP per capita, is comparable with or better than many neighboring developing member countries. However, when the quality of the road system is considered, the Philippines lags well behind nearly all of its regional neighbors and competitors. It shows that the major cause of the overall low quality of the road network is poor and inadequate maintenance. Hence, it stresses that the poor quality of the road network is a contributing factor to the rising number of road accidents including pedestrians.

3. DATA AND METHODOLOGY

(1) Road classification

This study focuses on the characteristics of pedestrian casualties on different road types. Thus, functional classifications of the road types should be carefully examined. Basically, road networks in the Philippines are administered by national and local governments. **Fig. 1** shows the road network of national roads (e.g. primary, secondary and tertiary) in Metro Manila. However, local roads were not included on the network map due to unavailability of the data.

In this study, road types refer to the functionality of a road in relation to the road network: primary, secondary, tertiary and local roads. National primary roads are roads that connect major cities (at least around 100,000 population) comprising the main trunk line or the backbone of the national road system; national secondary roads connect cities, major ports & airports, and other significant infrastructures to national primary roads; tertiary roads are other existing roads under the Department of Public Works and Highways (DPWH) which perform local function; and local roads include provincial, municipal/city and barangay roads[14)].

Although there is an existing functional classification for national road types, there is still no definite and specific design parameters or features that separate one national road type to another. This means that the highway design guidelines used for national roads are applicable to all national road types (primary, secondary and tertiary). For example, in setting speed limits, 60 kph is normally set for both primary and secondary specifically for major roads such as circumferential and radial roads which consist of either primary or secondary roads or both. Generally, all national roads are designed to be provided with sidewalk and pavement markings which are not commonly observed in most of the local roads.

Fig. 1. Road network of national roads in Metro Manila

(2) Crash database

Like most of the pedestrian crash-related studies where data was taken from the country level crash database[7,8,9,15,16,17)], the data of road crashes involving pedestrians in this study was mainly provided by the Metro Manila Development Authority (MMDA) through the Metro Manila Crash Reporting and Analysis System (MMARAS) database. This database was created and managed by the Road Safety Unit of the MMDA-Traffic Discipline Office-Traffic Engineering Center in cooperation and assistance of the Police Traffic Investigation Department of the Philippine National Police. It contains information of each crash in an Excel file, such as: report reference number, name of the accident investigator, district/city, time, date, street, location, classification (fatal or non-fatal), junction type, junction control, weather, collision type, classification of road users (drivers, passengers, and pedestrians), accident factor, vehicle type involved in the crash, details of the vehicle (plate number), gender, age and name of pedestrians involved.

A 3-year period of road crashes involving pedestrians (from 2016 to 2018) were considered in this study. A total of 12,080 incidents were officially considered after eliminating all the cases with missing information such as street and basic pedestrian characteristics (e.g. age and gender). About 6.29% or 760 crashes involved more than one pedestrians. Thus a total of 13,107 pedestrian casualty were considered for final analysis.

(3) Limitation of the database

The location information of MMARAS database is limited to the narrative descriptions. It contains two separate column information on the location of the crash: “street” (name of road) and “location” (either name of road section, barangay (district or ward), city or even landmark). Therefore, it is not possible to identify the exact locations of each crash while only the street names are available. The road type of the location of the crashes are classified by matching these street names with the national road classification database of DPWH. Since there is no available data on the “local roads”, the classification for local road was done in such a manner that if the name of the "street" or "road section" of each crash is not included in the list of national roads (i.e. primary, secondary and tertiary), it is considered as a "local road".

The MMARAS database has no direct information on whether the crash occurred at the "intersection" or along the "road section". Meanwhile when the crashes occur at intersections between national roads, the name of the crossing national roads are given in the "location" column. Therefore, the authors assumed that if the information indicated in the "location" column is the name of a road section, the crash is considered occurring at the "intersection", if not, such as barangay (or ward)/city or landmark, it is considered as a crash occurring along "road section". It should be noted that the "road section" in this definition may contain the intersections between national road and local road. In total, about 30% and 70% occurred at intersection and road section, respectively.

Regarding weather information, it was generally classified as either fair or rainy and almost all of the pedestrian casualties occurred with a fair weather (99.53%) while only 0.45% occurred on a rainy condition. This is quite interesting considering that the Philippines, as a tropical country, is frequently experiencing rainy season with an average annual amount of 136 rainy days. Due to this strong biase of weather information, it was not included in the analysis.

(4) Statistical analyses

Due to the limited information provided on the nature and characteristics of pedestrian crashes, only eight variables were considered in this study: road types (primary, secondary, tertiary, local roads), severity (fatal or non-fatal), location (intersection or road section), gender, age, vehicle type, time of the day, and day (weekend or weekday). Most of these variables have been considered in several pedestrian crash related studies in other countries.

Aside from descriptive statistics, this study uses the chi-square test (χ^2) for independence to check the significant relationship of these variables to different road types in Metro Manila. The formula is shown below where $O_{r,c}$ is the observed frequency count at level r of Variable A and level c of Variable B, and $E_{r,c}$ is the expected frequency count at level r of Variable A and level c of Variable B.

$$\chi^2 = \Sigma\left[\frac{(O_{r,c}-E_{r,c})^2}{E_{r,c}}\right] \qquad (1)$$

In order to normalize the distribution, the number of casualties on each variable were divided by the length of each road type per km. However, the values would become small, in this case, they will be multiplied by 1000 so the resulting values are "*1000 casualties per km of road". Due to the absence of data on the total length of local roads in Metro Manila, local road was not included in this analyses.

On the other hand, a test of proportion using z-test statistic was used for testing the difference in proportions on each road type, that is, for testing the null hypothesis. A null hypothesis proposes that no significant difference exists in a set of given observations. In this case, the proportion of casualties of each variable per road type. The formula is shown below where $\widehat{p_1}$ is the proportion from sample 1, $\widehat{p_2}$ is the proportion from sample 2, and the denominator is the standard error of the sampling distribution where $\hat{p}$ is the pooled sample proportion, n_1 is the size of sample 1, and n_2 is the size of sample 2.

$$z = \frac{(\widehat{p_1}-\widehat{p_2})-0}{\sqrt{\hat{p}(1-\hat{p})(\frac{1}{n_1}+\frac{1}{n_2})}} \qquad (2)$$

Aside from the proportion of the total pedestrian casualties on each variable, the proportion of pedestrian casualties with fatal injury was also examined using this test to see if there is a significant difference across different road types.

4. RESULTS AND DISCUSSIONS

(1) General statistics

As shown in **Fig. 2**, of the 13,107 pedestrian casualties, about one third or 34.0% occurred on local roads; 25.5% on tertiary roads; 25.0% and 15.5% on secondary and primary roads, respectively. The total length of national roads is about 1,167.17 km which comprises of primary (169.68 km), secondary (396.61 km) and tertiary roads (600.88 km). Although the primary road has the smallest road length among national roads, it registered a high number of pedestrian casualties per km compared to secondary and tertiary roads. The number of pedestrian casualties per km for primary road is about 11, while 8 and 5 for secondary and tertiary roads, respectively.

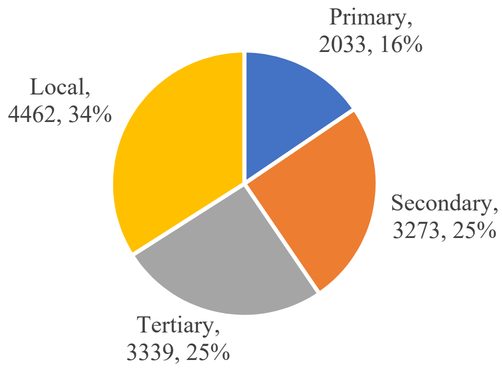


Fig. 2 Proportion of pedestrian casualties by different road type

As shown in **Fig. 3,** this study covers the entire Metro Manila which is comprised of 16 cities and 1 municipality. Overall, almost a quarter of the pedestrian casualties occurred in Quezon City and, as expected, it recorded the highest proportion of crash casualties involving pedestrians because it has a bigger land area among other cities with 171.71 km^2 or 27.72% of the total land area housing 22.80% (2,936,116) of the entire population in Metro Manila[18)]. Also, the major road networks are present in this city such as EDSA, C5 road and Commonwealth Avenue. Whereas, the Municipality of Pateros has the lowest pedestrian crashes because it has smaller land area and with lesser national roads compared to other cities[2)].

However, in terms of the number of pedestrian casualties per km^2 (land area) as also shown in **Fig. 4**, cities of Mandaluyong, Manila, Makati, Pasay, Marikina and Navotas got the highest proportions with more than 30 casualties/km^2. These cities, aside from being considered as one of the Central Business Districts (CBDs), they also have a high social and economic activities.

Although Quezon city has the highest number of pedestrian casualties, it has smaller number of pedestrian casualties per km^2 due to its larger area compared to other cities. In the case of Manila City, although its land area is only 24.98 sq. km. (4.03% of the total land area), it has 43 pedestrian casualties per km^2. This is probably because several universities and colleges, ports and harbors, aside from government institutions, are located in the city. In the same way with other cities with high number of pedestrian casualties per km^2 such as Mandaluyong and Makati cities which are high-commercial areas, while Pasay City is where the major domestic and international airport is located.

(2) Severity

Fig. 5. shows the number of pedestrian casualties by road type and severity (fatal or non-fatal). Overall, majority of the pedestrian casualties were non-fatal (96.38%) and only 3.62% were considered as fatal. This proportion is the same to different road types.

The number of pedestrian casualties with fatal or non-fatal outcome is found to have a significant relationship to different road types by chi-squared test ($p<0.05$). However, the difference on the proportions of pedestrian casualties was only significant between primary to local road, secondary to tertiary and secondary to local road. The results may be influenced by the proportion of fatal and non-fatal crashes.

Although the secondary road has the highest number of fatality followed by the local road, in terms of fatality density (1000 fatal casualty per km of road type), as shown in **Table 1**, higher hierarchy roads

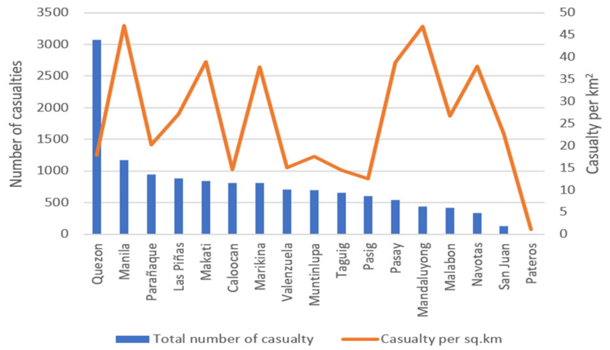


Fig. 3. Number of pedestrian casualties/km^2 in 16 cities and 1 municipality in Metro Manila

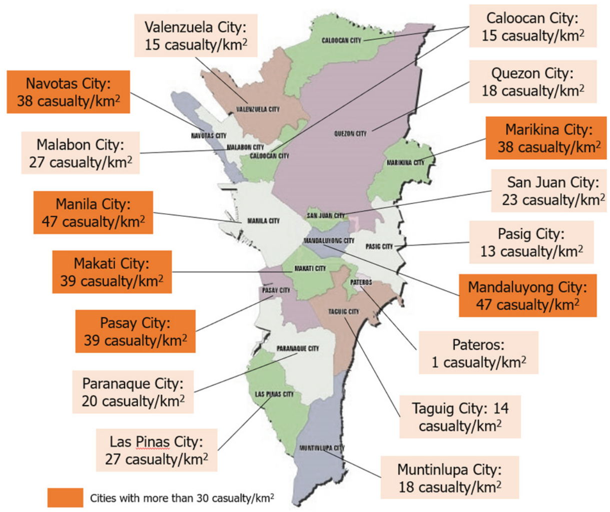
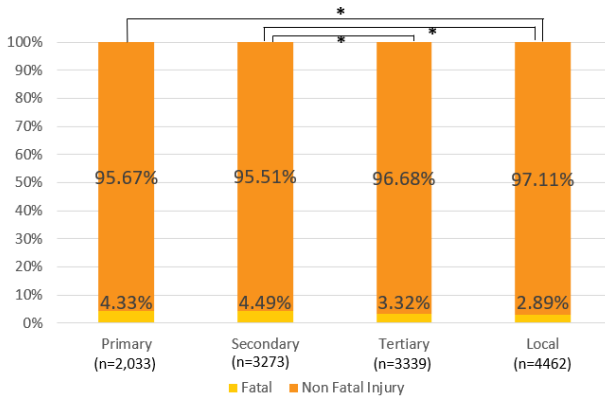


Fig. 4. Location map of 16 cities and 1 municipality in Metro Manila with corresponding number of pedestrian casualty/ km^2



* significant at p<0.05

Fig. 5. Number of pedestrian casualties by road type and severity (fatal or non-fatal)

Table 1. Fatality density (1000 fatal casualty per km) per road type

	Primary	Secondary	Tertiary	Local
Number of fatality	88	147	111	129
Road length	169.68	396.61	600.88	*
*1000 casualties/km	519	371	185	

** Length of local road is not available*

have higher number of fatal casualty compared to lower hierarchy roads. This result corresponds to the fact that national roads are typically multilane roads with higher speeds and traffic volumes in which vehicle speed can be an issue for pedestrians on all road types[8] especially when it comes to severity. The same proportion is observed to different road types in terms of non-fatal casualties.

(3) Pedestrian characteristics (age and gender)

Overall, majority of the pedestrian casualties are adult (18-59) pedestrians which comprises of 62.40% of the total number, while 26.30% and 11.30% for child (0-17) and senior (60 and above) pedestrians, respectively. The number of pedestrian casualties with respect to age of pedestians is found to have a significant relationship to different road types by chi-squared test ($p<0.00001$). Moreover, the difference on the proportion of casualties involving child (0-17 years old) and adult (18-59 years old) pedestrians have a significant difference among various road types ($p<0.05$), while for senior pedestrians (60 years old and above), the difference on the proportion between national roads and local roads are statistically significant ($p<0.05$).

As shown in **Fig. 6**, as expected, the trend of casualties involving child pedestrians is increasing from higher hierarchy road (primary) to lower hierarchy road (local). This is probably because local roads have a direct access to pedestrians especially children, who typically use the road for recreational purposes and routes going to schools nearby. Whereas, the trend of casualties involving adult pedestrians is decreasing as it goes from primary to local roads. Adult pedestrians are basically comprised of college students and working individuals, hence, most of them are likely using national roads going to their respective destinations (either to work or school).

In terms of fatality, exactly half of the casualties involving child pedestrians occurred on local roads while adult pedestrians involved in a fatal casualties are the most dominant in all various road types. Moreover, as shown in **Table 2**, in terms of fatality density (1000 fatal caualties per km), casualties involving adult and senior pedestrians followed the increasing trend from lower to higher hierarchy roads. This is expected because higher hierarchy roads are normally designed for heavy vehicles and high-speed movement, hence, tend to result in a fatal injury on a pedestrian-vehicle collision.

However, unlike in the previous studies which found that older pedestrians are more likely to have fatal outcome compared with young pedestrians[11,17,18], the result shows that adult pedestrians have high fatality rate compared to senior pedestrians across different road types. It is unclear why fatality rate is high among this age range, but a possible reason could be that there is more walking among adults in this age range[8].

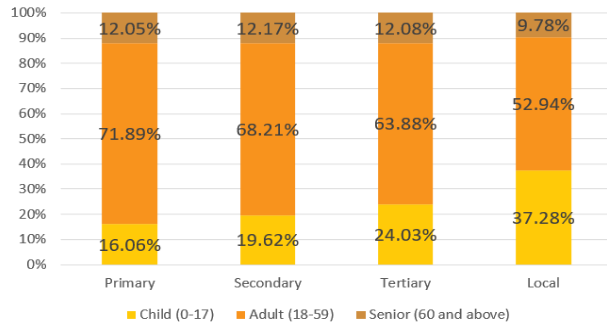


Fig. 6 Pedestrian casualties by age category on different road types

Table 2. Fatality density (1000 fatal casualty per km of road type) by age category

*1000 fatal casualty/km	Primary	Secondary	Tertiary	Local*
Child (0-17)	41	45	28	-
Adult (18-59)	265	189	98	-
Senior (60 and above)	124	66	32	-

* *Length of local road is not available*

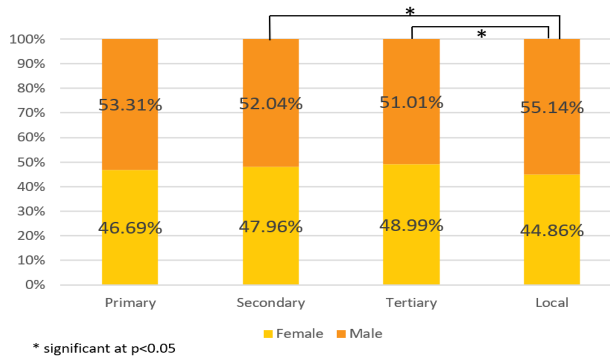


Fig. 7. Proportions of pedestrian casualties on different road types with respect to gender of pedestrians

Table 3. Fatality density (1000 fatal casualty per km of road type) by gender and age category

*1000 fatal crashes/km	Primary	Secondary	Tertiary	Local*
Female				
Child (0-17)	18	23	12	-
Adult (18-59)	94	55	38	-
Senior (60 and above)	94	28	10	-
Total	206	106	60	
Male				
Child (0-17)	24	23	17	-
Adult (18-59)	171	129	60	-
Senior (60 and above)	29	38	20	-
Total	224	189	97	

* *Length of local road is not available*

More than half of the pedestrian casualties involved male pedestrians (53.03%) while 46.97% involved female pedestrians. As shown in **Fig. 7,** the number of pedestrian casualties with respect to gender of pedestians is found to have a significant relationship to different road types by chi-squared test ($p<0.05$) and the difference on the proportion of casualties involving either male or female is significant between secondary to local ($p<0.05$) and tertiary to local roads ($p<0.05$) and this proportion is almost the same across different road types.

Moreover, as shown in **Table 3**, the number of fatality (1000 fatal casualty per km. of road type) of female adult and senior pedestrians increased from tertiary to primary roads in the same manner for male child and adult pedestrians. Generally, this suggests that higher hierarchy roads, despite a supposed limited access for pedestrians, are indeed prone to fatal injury when involved with either female and male pedestrians across different age groups.

(4) Vehicle type

The type of vehicles involved was categorized into five groups, namely: motorcycle, car, van, heavy vehicle and multiple modes. Multiple modes include two or more vehicles (either same type of vehicles or not) involved in a collision with a pedestrian which is comprised of about 6.88% of the total number. Overall, motorcycle is the leading vehicle type involved in a pedestrian casualties (45.75%) followed by car (34.58%) and heavy vehicle (7.16%). This is not surprising as the average annual sales growth of motorcycles in the Philippines is around 20%, and already reached 18.8 million or 71% of the total motor vehicles in the country[20].

As shown in **Fig. 8**, all vehicle types have a significant relationship to different road types in terms of the distribution on the number of pedestrian casualties by chi-squared test ($p<0.00001$). However, only the difference on the proportions of motorcycle and car are statistically significant among different road types ($p<0.05$), while the difference on the proportions of van and heavy vehicle are only significant between primary and other road types ($p<0.05$).

Almost one-third (32.47%) of the total pedestrian casualties involving motorcycles occurred on primary roads and this comprises of 64.94% of all pedestrian casualties on this road type. This is due to the fact that unlike other vehicle types which have some limited access to other road sections, motorcycle can just traverse any paths wherever is preferred, hence, the proportion of pedestrian casualties as well as fatality is higher across different road types specifically among national roads. As a result, pedestrians and motorcycle riders are the most vulnerable road users in Metro Manila[21].

Moreover, local road has the highest number of pedestrian casualties involving car which comprises of 41.15% of its total number. Furthermore, as expected, in terms of fatality density (1000 fatal casualties per km), the trend is increasing from a lower hierarchy road to higher hierarchy road across different vehicle types. Normally, higher hierarchy roads, specifically primary and secondary roads, cater larger and heavier vehicles including bus and trucks. Thus, when involved in a collision with a pedestrian, the resulting injury is most likely to cause fatal or severe injuries[5,17].

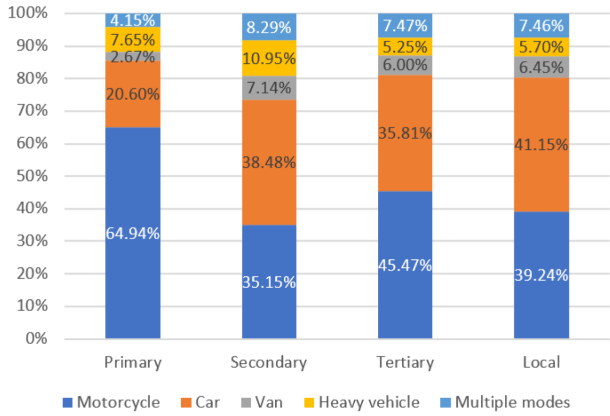


Fig. 8. Proportions of vehicle type involved in pedestrian casualties on different road types

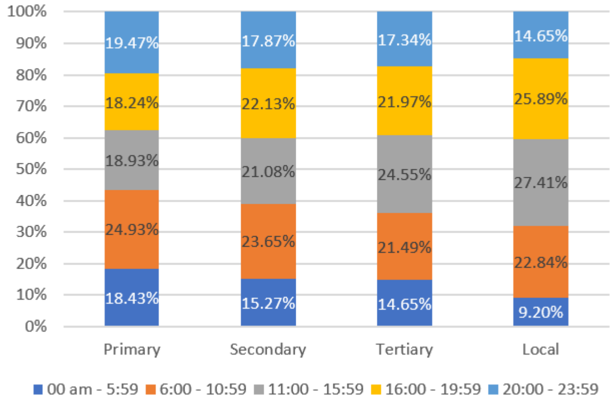


Fig. 9. Proportions of pedestrian casualties on different road types with respect to time

(5) Time of day

The time of a road crash involving pedestrian was divided into five categories, namely: 00am-5:59, 6:00-10:59, 11:00-15:59, 16:00-19:59, and 20:00-23:59. Overall, pedestrian casualties are somewhat uniformly distributed aross time of the day: 00-5:59 (13.54%), 6:00-10:59 (23.02%), 11:00-15:59 (23.78%), 16:00-19:59 (22.77%), and 20:00-23:59 (16.89%).

As shown in **Fig. 9,** the number of pedestrian casualty across time of the day is found to have a significant relationship to different road types by chi-squared test ($p<0.00001$). However, only the difference on the proportions of pedestrian casualties occurring at 11:00-15:59 is statistically significant among all road types. While the difference on the proportions at 00am-5:59 and 16:00-19:59 are only significant between primary and other road types ($p<0.05$).

Interestingly, during morning peak hour (6:00-10:59), only the difference on the proportions of pedestrian casualty between primary to tertiary and secondary to tertiary are significant ($p<0.05$). Unlike tertiary roads, the proportion of pedestrian casualties are higher in both primary and secondary roads notably because they are mostly high in traffic volume (morning peak hour) as most of the road sections are major thoroughfares, hence, a high potential of pedestrian casualties. Whereas during non-peak hour (11:00-15:59), a decreasing trend of pedestrian casualties was observed from primary to local roads. The results may be influenced by the road usage that during non-peak hour, unlike on primary or secondary roads, local roads are mainly used by short trips like going from and to schools (elementary or high school with half-day schedule), markets and other working and non-working related trips (outside the peak hour schedule).

Moreover, in terms of fatality density (1000 fatal casualty per km of road type), majority occurred during late night (00-5:59) as shown in **Table 4**. The result confirms the study of Verzosa et al.[16] that the odds of a fatal outcome on a pedestrian crash is almost three times higher during late night compared to daytime and this applies across different road types. Additionally, the result might also suggest that compared with day light (during daytime), bad visibility of pedestrians is more likely to increase the possibility of a fatal crash[17]. Hence, provision of appropriate lighting and necessary safety measures for pedestrians and motorists alike is necessary on all different road types.

(6) Location

The location of the pedestrian casualty was categorized either at intersection or road section. Due to a limited information, intersection is not determined whether it is signalized or not. Generally, majority of the casualties occurred along road section (70.73%) while only 29.27% occurred at intersection.

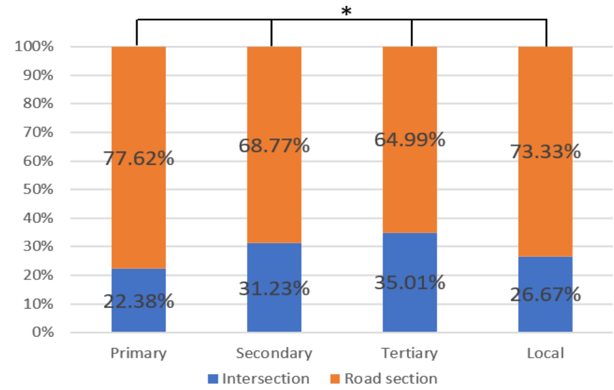
As shown in **Fig. 10,** the number of pedestrian casualties occurring either at intersection or along road section is found to have a significant relationship to different road types by chi-squared test ($p<0.00001$) and the difference on the proportion of casualties is statistically significant among different road types ($p<0.05$). The proportions of pedestrian casualties occurring at intersection is increasing from primary to tertiary and consequently decreasing if the casualties occurred along road section.

However, in terms of fatality density (1000 fatal casualty per km of road type) as shown in **Table 5**, pedestrian casualties occurring along road section are still dominant among different road types. The result is consistent with the study of Guttenplan et al.[25] showing that the probability of a fatal outcome was higher for collisions occurring at non-intersections, or in this case “road section”. Although the intersection design and risk of severe injury severity were not significantly associated for city streets[7], intersections along national roads are most likely signalized compared to that of local roads.

Table 4. Fatality density (1000 fatal crash per km of road type) by time of day

*1000 fatal casualty/km	Primary	Secondary	Tertiary	Local*
00 am - 5:59	212	103	70	-
6:00 - 10:59	88	55	30	-
11:00 - 15:59	71	48	42	-
16:00 - 19:59	35	55	17	-
20:00 - 23:59	112	83	25	-

** Length of local road is not available*



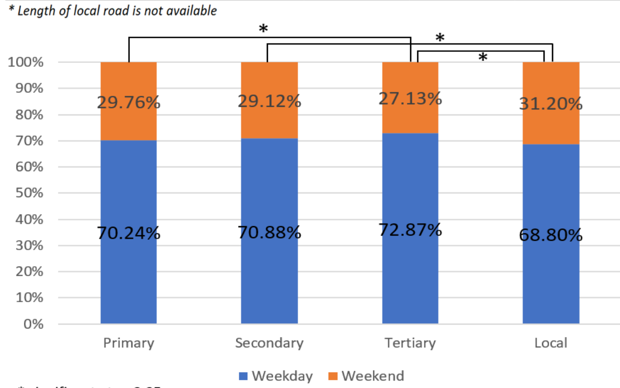
** significantly different to each other at p<0.05*

Fig. 10. Proportions of pedestrian casualties on different road types with respect to location

Table 5. Fatality density (1000 crash per km of road type) by location (intersection or road section)

*1000 fatal casualty/km	Primary	Secondary	Tertiary	Local*
Intersection	124	139	75	-
Road section	395	232	110	-

** Length of local road is not available*



* significant at p<0.05

Fig. 11. Proportions of pedestrian casualties on different road types with respect to location

(7) Day of the week

The day of the week was categorized either on weekday or weekend to see how the proportion of pedestrian casualties differ among different road types. As expected, majority of the pedestrian casualties occurred during weekday (70.58%) while only 29.42% occurred during weekend.

As shown in **Fig. 11,** the number of pedestrian casualties occurring either on weekday or weekend is found to have a significant relationship to different road types by chi-squared test ($p<0.05$). Moreover, the difference on the proportions of pedestrian casualties occurring either during weekday or weekend is statistically significant between primary to tertiary, secondary to local, and tertiary to local roads ($p<0.05$). The proportion of the number of pedestrian casualties during weekday and weekend is most likely similar across different road types.

However, in terms of fatality density (1000 fatal casualty per km of road type) as shown in **Table 6**, majority of the fatal casualties occurred during weekend across different road types which is consistent to the result of Chen et al.[11] showing that weekend is more likely to increase the crash severity or the likelihood of fatal crashes. The possible reason could be that during weekends traffic volume is typically lower than that in weekdays, which in effect results in higher speeds and thus the likelihood of fatal crashes. Notably, the fatality trend is increasing from lower hierarchy to higher hierarchy roads.

5. CONCLUSION AND LIMITATIONS

This study examined the characteristics and proportions of pedestrian casualties on different road types in Metro Manila, Philippines using 3-year road crash data. Based on the analysis conducted, the key findings are as follows:

- Higher hierarchy roads (primary), which are typically have higher speeds, have higher number of pedestrian fatal casualties compared to lower hierarchy roads (local).
- The trend of casualties involving child pedestrians are increasing from primary roads to local roads, while decreasing for adult and senior pedestrians.
- The proportion of casualties involving male or female pedestrians are almost the same across different road types, while male pedestrians tend to be more involved in a fatal casualty per km across different road types than female pedestrians.
- During morning peak hour (6:00-10:59), the trend of pedestrian casualties are higher in both primary and secondary roads compared to tertiary roads, whereas during non-peak hour (11:00-15:59), a decreasing trend of pedestrian casualties was observed from primary to local roads.
- Majority of the pedestrian casualties occurred along road section on all different road types and the trend of pedestrian casualties is increasing from primary to tertiary roads for casualties occurring at intersection while decreasing for casualties along road section.
- The proportion of pedestrian casualties occurring either during weekday or weekend is almost the same across different road types, while weekend tends to have a higher fatal casualty rate per km with an increasing trend from higher hierarchy to lower hierarchy roads.

Table 6. Fatality density (1000 crash per km of road type) by day of the week (per day)

*1000 fatal casualty/km	Primary	Secondary	Tertiary	Local*
Weekday	66	49	25	-
Weekend	94	62	31	-

** Length of local road is not available*

Furthermore, the casualty figures may underestimate the exact number of fatalities because the MMARAS only defines deaths as occurring at the scene of the crash, whereas the internationally accepted definition is death occurring within 30 days of an accident[13].

For future work, several parameters will be considered in order to further explore the pedestrian crashes in the road network of Metro Manila. This includes effect of land use, road geometry and specific road parameters that can be used to further explain and understand the underlying causes of road crashes involving pedestrians as a prerequisite in developing proper countermeasures.

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REFERENCES

1) Global Status Report on Road Safety 2018, World Health Organization (WHO), https//www.who.int/.
2) Metro Manila Development Authority (MMDA) Annual Reports, 2011-2018.
3) World report on road traffic injury prevention 2004, World Health Organization (WHO), https//www.who.int/.
4) Safety Effectiveness of Highway Design Features, Volume I, Access Control, FHWA, 1992.
5) Eluru, N., Bhat, C.R., Hensher, D.A.: A mixed generalized ordered response model for examining pedestrian and bicyclist injury severity level in traffic crashes, *Accident Analysis and Prevention*, Vol. 40, pp. 1033-1054, 2008.
6) Ukkusuri, S.V., Miranda-Moreno, L.F., Ramadurai, G., Isa-Tavarez, J.: The role of built environment on pedestrian crash frequency, *Safety Science*, Vol. 50, pp. 1141-1151, 2012.
7) Moudon, A.V., Lin, L., Jiao, J., Hurvitz, P., Reeves, P.: The risk of pedestrian injury and fatality in collisions with motor vehicles, a social ecological study of state routes and city streets in King County, Washington, *Accident Analysis and Prevention*, Vol. 43, pp. 11-24, 2011.
8) Hu, W., Cicchino, J.B.: An examination of the increases in pedestrian motor-vehicle crash fatalities during 2009-2016, *Journal of Safety Research*, Vol. 67, pp. 36-44, 2018.
9) Shinstine, D.S., Wulff, S.S., Ksaibati, K.: Factors associated with crash severity on rural roadways in Wyoming, *Journal of Traffic and Transportation Engineering (English Edition)*, Vol. 3, pp. 308-323, 2016.
10) Pei, Y., Fu, C.: Investigating crash injury severity at unsignalized intersections in Heilongjiang Province, China, *Journal of Traffic and Transportation Engineering (English Edition)*, Vol. 1 (4), pp. 272-279, 2014.
11) Chen, Z. and Fan, W.D.: A multinomial logit model of pedestrian-vehicle crash severity in North Carolina, *International Journal of Transportation Science and Technology*,

Vol. 8, pp. 43-52, 2019.
12) Kouabenan, D., Guyot, J.: Study of the causes of pedestrian crashes by severity, *Journal Psychology Afr.*, Vol. 14 (2), pp. 119–126, 2004.
13) Philippines: Transport Sector Assessment, Strategy, and Road Map, 2012. https//www.adb.org/
14) Department Order No. 133, series of 2018. Department of Public Works and Highways (DPWH).
15) Ballesteros, M.F., Dischinger, P.C., Langenberg, P.: Pedestrian injuries and vehicle type in Maryland, 1995-1999, *Accident Analysis and Prevention*, Vol. 36, pp. 73-81, 2004.
16) Verzosa, N. and Miles, R.: Severity of road crashes involving pedestrians in Metro Manila, Philippines, *Accident Analysis and Prevention*, Vol. 94, pp. 216-226, 2016.
17) Kim, J.K., Ulfarsson, G.F., Shankar, V.N., Kim, S.: Age and pedestrian injury severity in motor-vehicle crashes: a heteroskedastic logit analysis, *Accident Analysis Prevention*, Vol. 40 (5), pp. 1695-1702, 2008.
18) Census of Population (POPCEN) 2015, National Capital Region, Philippine Statistics Authority.
19) Tay, R., Choi, J., Kattan, L., Khan, A.: A multinomial logit model of pedestrian-vehicle crash severity, *International Journal of Sustainable Transportation*, Vol. 5 (4), pp. 233-249, 2011.
20) Land Transportation Office (LTO), 2019. https//www.lto.gov.ph/.
21) Sigua, R.G., Vulnerable road users in the Philippines. https//www.unece.org/.
22) Guttenplan, M., Chu, X., Siddiqui, N.A.: Crossing locations, light conditions, and pedestrian injury severity, *Transportation Research Record 1982*, pp. 141-149, 2006.

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