Analysis of Transport and Vehicular Road Crash Cases in Metro Manila from 2016 to 2020

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ABSTRACT

Introduction. Metro Manila, the metropolitan center and seat of the national government, is composed of 16 cities and 1 municipality, and considered as the second-most populous region in the Philippines. Transport is a key sector that is needed for accessibility and economic progress. Yet, the question on safety of the roads of Manila remains as road crashes continue to be reported.

Objective. The study aims to determine the trend of road crashes in Metro Manila, and the factors associated with both fatality and injury among three types of road users – the drivers, the passengers, and the pedestrians.

Methods. A retrospective analysis of 523,059 road crash data between 2016 to 2020 was done. Using descriptive statistics, the road crash variables analyzed in the study were (1) crash classification according to damage to property, fatal, and non-fatal crash, (2) road user type according to driver, passenger, and pedestrian, (3) vehicle type, (4) junction type, and (5) risky road user behavior. Logistic and multinomial regression models were used to determine whether these variables were significant with road user fatality and injury.

Results. The analysis of the MMARAS database (n=523,059) showed an increasing trend of road crashes occurred since 2016 and peaked in 2019, and declined in 2020. Majority (436,367, 83.426%) were damage to property, followed by non-fatal or injurious cases (84751, 16.203%) and fatal outcomes (1941, 0.371%). Drivers have the greatest number of fatalities and injuries compared to passengers and pedestrians. Cars (513482 52.322%) and motorcycles (136641, 13.923%) remain the major types of vehicles involved in road crashes. The factors that were significantly associated with increased odds ratio for driver death were involvement of pedicabs (OR=10.937, p=0.000), motorcycles (OR=55.061, p=0.000), bus (OR=5.835, p=0.000), truck (OR=7.073, p=0.000), hit object (OR=11.007, p=0.000), self-accident (OR=6.149, p=0.000), and collisions in bridges/flyovers (OR=2.713, p=0.010)). The factors that were significantly associated with increased odds ratio for passenger fatality were the involvement of motorcycle (OR=3.75, p=0.021), angle impact (OR=42.01, p=0.002), multiple collision (OR=18.42, p=0.040), self-accident (OR=32.66, p=0.010), and lost control (OR=82.98, p=0.001). The factors significantly associated with pedestrian fatality were hit and run (OR=56.04, p=0.000), hit pedestrian (OR=1085.17, p=0.000), and crashes in bridges/flyover (OR=4.20, p=0.025). Meanwhile, multinomial regression showed that classification of crash and vehicle type were significantly associated with fatal and non-fatal crashes.

Conclusion. The study showed the trend of fatality and injury among drivers, passengers, and pedestrians from 2016-2020, and factors of road crashes in Metro Manila including vehicle type, road behaviors, collision type and junction type.

Keywords: road crash, transport vehicular accident, driver, passenger, pedestrian, Metro Manila

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INTRODUCTION

Metro Manila is considered the metropolitan center of Luzon and the Philippines composed of 16 cities, namely, the cities of Manila, Quezon City, Caloocan, Las Piñas, Makati, Malabon, Mandaluyong, Marikina, Muntinlupa, Navotas, Parañaque, Pasay, Pasig, San Juan, Taguig, Valenzuela, and the municipality of Pateros.[1] Registering a population of more than 13 million in 2020, Metro Manila contributed the biggest share of 42.6% in the country's Gross Domestic Product (GDP) in 2020.[2,3] As the second-most populous region with the greatest economic contribution, transport is a key sector that is needed for accessibility and economic progress. Yet, the question on safety of the roads of Manila remains as road crashes continue to be reported.

Road crashes continue to kill and injure approximately 1.3 million and 20 to 50 million people globally, and costs an estimated 3% of the country's Gross Domestic Product.[4] There is limited data on the impact of road crashes in the Philippines. Road crash costs the Philippines at least 1.86 billion USD yearly, divided into 100.3 million USD for medical treatment and 1.76 billion USD for other losses, and this amount could have been used for infrastructure projects and road safety programs.[5]

A study identified that independent variables that were significantly associated with fatal crashes were crash type, injury severity, spatial cluster-ID, and crash time (hour).[6] Further, junction type, crash type, and number of vehicles involved were found to be significant variables with small effect size to road crash.[7] Sheykhfard et al.[8] determined that road users' features, especially risky behavior, and road characteristics were the major causes of road crashes and conflicts. The factors that affected road crash-related mortality between countries during the pandemic were road infrastructure, environment, vehicle size and speed, road user behavior, road traffic mobility and congestion, and empty roads.[9,10]

Understanding the factors contributing to road crashes are key to mitigating the impact of road crashes to public health. Using the Metro Manila Accident Recording and Analysis System (MMARAS) between 2016 to 2020, the study aims to further determine the trend and factors that contribute to road crashes, and how these factors are associated with the type of road user from 2016-2020.

METHODS

This study involved analysis of the database on road crashes in Metro Manila from the Metro Manila Development Authority (MMDA). Metro Manila Accident Recording and Analysis System (MMARAS) is created and operated by the MMDA in cooperation with the Philippine National Police (PNP).

The MMARAS records the following data: tally of road crashes, crash classification (fatal, non-fatal, and damage to property), road user type (driver, passenger, and pedestrian), vehicle type, junction type, and risky road user behaviors. This study will explore analysis of road crash variables in the Metro Manila setting which is among the most densely populated places in the world.

The MMARAS three road users: (1) "driver is a person driving a mechanically propelled vehicle or pedal cycle"; (2) "passenger is anyone carried-in or on a mechanically propelled or pedal cycle"; and (3) "pedestrian is anyone travelling on foot". MMARAS counts the number of fatalities and injured persons for every road user for each road crash incident.

Other risk factors were also extracted from the database such as - 1. vehicle type; 2. road behaviors; 3. collision type; and 4. junction type. Vehicle types included cars, motorcycles, vans, trucks, jeepneys, buses, taxis or FXs, tricycles, and bicycles or pedicabs. Road behaviors, generally categorized as Human Error, included 11 sub-categories, which are "fallen passenger", "falling asleep", "fell down deep hole", "lost control", "open door", "over turned", "passenger fell down from bus", "pothole", "slide", "slipped", and "victim fell". MMARAS classified 11 collision types into angle-impact, head-on collision, hit and run, hit object, hit parked vehicle, hit pedestrian, multiple collision, rear-end collision, self-accident, no collision, and side swipe. MMARAS classified 12 junction types, which were bridge or flyover, crossroads, K junction, "not at junction", "other", parking area, rotunda, skew junction, t-junction, tunnel or underpass, u turn slot, and y junction.

The 5-year database of road crash cases from 2016 to 2020 with 532,059 road crash records were clustered into categories and analyzed using descriptive statistics, logistic and multinomial regression.

The study focuses in determining the trend and factors that contribute to road crashes, and the relationship of these factors with road user type in Metro Manila from 2016 to 2020. Descriptive statistics were used to describe the trend of road crashes, and crash characteristics, specifically the classification of crash according to fatality, injury and damage to property; type of victim, collision, vehicle, risky road user behavior, and junction. Inferential statistics, specifically logistics and multinomial regression were performed. Using multiple logistic regression, the fatality and injury of drivers, pedestrians, and passengers were used as dependent variables and explored of their significant associations with the type of vehicle involved, type of crash, risky behavior, and type of junction. Last, multinomial regression was performed to determine whether fatal and injurious crashes were significantly associated with vehicle and collision type.

After securing an approval from the Department of Health-Single Joint Research Ethics Board (DOH-SJREB), the researchers were cleared for implementation. The researchers requested and were given a copy of the MMARAS database.

RESULTS

The study looked into the trends of road crash in Metro Manila from 2016 to 2020, and described road crash variables, which are (1) crash classification according to damage to property, fatal, and non-fatal crash, (2) road user type according to driver, passenger, and pedestrian, (3) vehicle type, (4) junction type, and (5) risky road user behavior.

The MMARAS database records each road crash incident as one (1) observation despite involvement of more than one victim. The cases are the incidents, and not the victims, hence, there is no socio-demographic profile indicated.

The total number of road crash cases is 523,059 from January 2016 to December 2020. Of all the total road crashes from 2016-2020, 0.37% of cases are fatal cases. 83.43% of the cases are damage to property only, while 16.2% of cases are non-fatal (Table 1).

Human error is the most common reported risk factor with 7849 recorded cases, followed by losing control (228) and alcohol intoxication (183). Vehicle defect also is among the most common risk factors with 170 cases. 98.3% of the whole database however has no recorded risk factor.

For collision types, the most common are side-swipe collisions (29.6%) followed by rear-end collisions (22.14%). 24.04% of collision types are "No collision stated in the blotter reports". For junction types on the other hand, most road crashed doesn't happen in junctions (4.57%), while 1.06% of the road crashes happen in crossroads and 1% happen in T-junctions. 91.7% have no data on junction type.

0.2% of all road crashes have at least one driver killed, 0.04% have at least one passenger killed, while 0.13% have at least one pedestrian killed. On the other hand, 10.26% of road crashes have at least one driver injured, 3.43% have at least one passenger injured, and 3.86 have at least one pedestrian injured.

At least one private car is involved in 73.13% of road crash incidents, while at least one motorcycle is involved in 23.59% of all road crash incidents (Table 1).

The number of crashes recorded per year increased by 11.38% from 2016 to 2019. On the average, there is an increase of 3.68% annually from 2016 to 2019**.** Road crashes in 2020 decreased by 46.59% in 2019 due to the lockdowns induced by the pandemic. Road crashes gathered in MMARAS rose from 109,324 in 2016 to 121,770 in 2019, and dipped to 65,032 in 2020 (Figure 1).

Damage to property crashes are constantly increasing until 2019, then decreased by more than 50% from 100,932 in 2019 to 50,230 in 2020. On the other hand, non-fatal injuries decreased from 16,424 in 2016 to 15,505 in 2017, then rose to 20,466 in 2019 (Figure 2).

Fatal crashes are on a declining trend from 426 in 2016 to 337 in 2020 (Figure 3).

The number of drivers being killed as a result of road crash incidents is continuously increasing despite the lower number of total cases in 2020. Pedestrian fatality is on a declining

Table 1. Frequency Distribution of Road Crash Variables in MMARAS (N = 523, 059)

	Frequency	Percent
Classification of Crash		
Fatal	1941	0.37
Non-Fatal (Injurious)	84751	16.20
Damage to Property	436367	83.43
Risky Road Behaviors		
Alcohol suspected	183	0.03
Human Error	7849	1.50
Lost Control	228	0.04
Road Defect	46	0.01
Vehicle Defect	170	0.03
Missing	400	
Collision Type		
Angle Impact	28992	5.54
Head-on	3684	0.70
Hit and Run	22492	4.30
Hit Object	12234	2.34
Hit Parked Vehicle	12509	2.39
Hit Pedestrian	19806	3.79
Multiple Collision	13487	2.58
Rear-end	115828	22.14
Self-Accident	12647	2.42
Side Swipe	154969	29.63
Missing	1	
Junction Type		
Bridge/Flyover	1977	0.38
Crossroads	5529	1.06
Not at junction	23905	4.57
Parking Area	2173	0.42
Rotunda	1636	0.31
T-junction	5157	0.99
Tunnel/Underpass	714	0.14
U-turn slot	1833	0.35
Missing	479829	
Road User Fatality		
A driver is killed	1064	0.20
A passenger is killed	234	0.04
A pedestrian is killed	679	0.13
Road User Injury		
A driver is injured	53667	10.26
A passenger is injured	17941	3.43
A pedestrian is injured	20177	3.86
Vehicle Type		
A cycle/pedicab is involved in crash	9134	1.75
A motorcycle is involved in crash	123368	23.59
A tricycle is involved in crash	16703	3.19
A car is involved in crash	382487	73.13
A jeepney is involved in crash	42634	8.15
A taxi/FX is involved in crash	29287	5.60
A bus is involved in crash	38932	7.44
A van is involved in crash	91342	17.46
A truck is involved in crash	78119	14.94
A train is involved in crash	112	0.02

trend (Figure 4). The number of drivers being injured as a result of road crash incidents is on an increasing trend, similar to passenger injuries.

This has dropped in 2020 due to the pandemic induced lockdowns (Figure 5).

Cars are the most commonly involved vehicle in road crash, followed by motorcycles. Cars contribute to 52.32% of the total of vehicles involved in crash. Motorcycles contribute to 13.92% of the total, while vans contribute to 10.35% (Figure 6).

Logistic regression was used to look into the risk factors associated with driver fatality, driver injury, passenger fatality, passenger injury, pedestrian fatality and pedestrian injury.

Driver Fatality and Injury

For driver fatality, 43,230 cases are considered in this model due to missing data in the MMARAS database. Nagelkerke R-square shows that the model explains up to 24.6% of the variance in the dependent variable. Independent variables are selected through forward selection within vehicle types, collision type, risky road user behavior, and junction type. Results show that involvement of pedicabs, motorcycles, bus, and truck significantly increases the odds ratio of driver death. For collision type, hit object and self-accident significantly increase the odds ratio for driver death, while side-swipe decreases the odds ratio of driver death. Collision in bridges/flyovers also increases the odds ratio of driver death (Table 2).

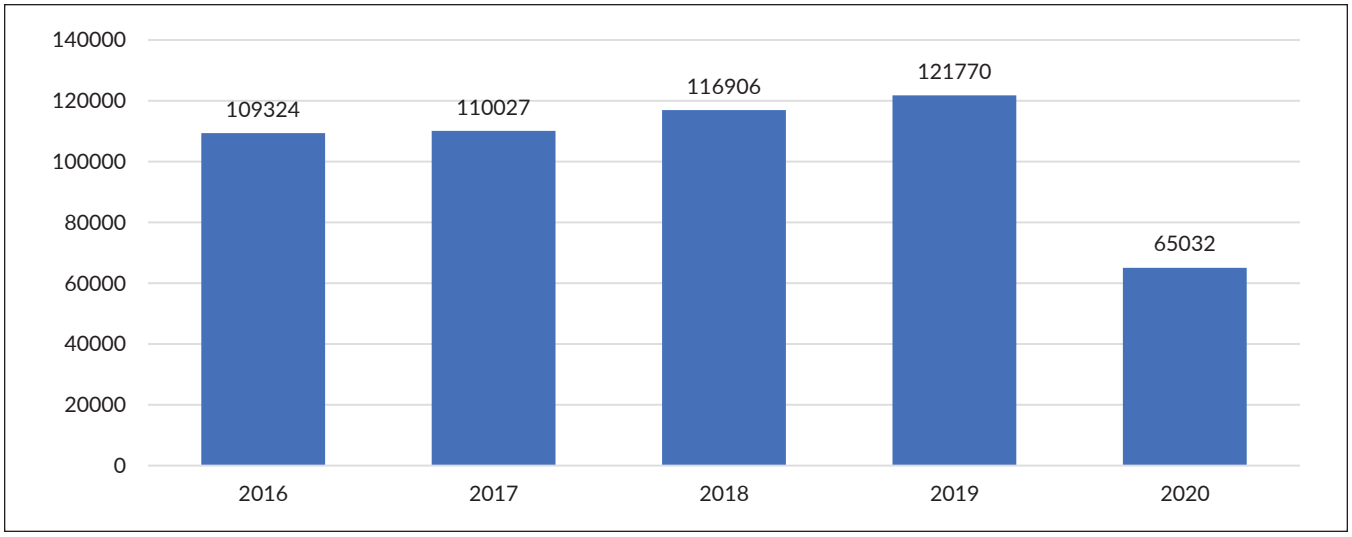

Figure 1. Road Crash Reporting from 2016-2020.

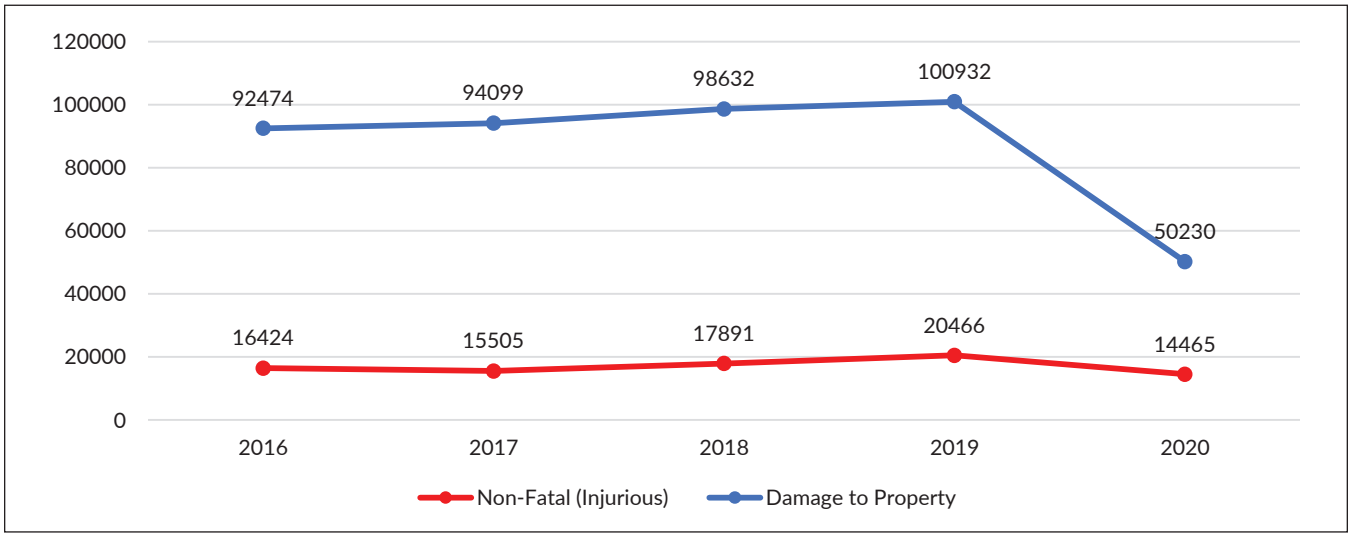

Figure 2. Trends of Non-Fatal and Damage to Property Crash.

For driver injury, 43,230 cases are considered in this model due to missing data in the MMARAS database. Nagelkerke R-square shows that the model explains up to 47.5% of the variance in the dependent variable. Results show that involvement of pedicabs, motorcycles, tricycle, car, jeepney, bus, and van significantly increases the odds ratio of driver injury. For collision type, head-on collision, hit-object, multiple collision, and self-accident significantly increase the odds ratio for driver injury, while hit parked vehicle, and hit pedestrian decreases the odds ratio of driver injury. Collisions in crossroads, parking areas, and T-junctions also decrease the odds ratio of driver injury (Table 2).

Passenger Fatality and Injury

For passenger fatality, 43,230 cases are considered in this model due to missing data in the MMARAS database. Nagelkerke R-square shows that the model explains up to 14.3% of the variance in the dependent variable. Results show that involvement of motorcycles in crash significantly increases the odds ratio of passenger death. Angle impact, multiple collision, self-accident and lost control increase the odds ratio of passenger death (Table 3).

For passenger injury, 43,230 cases are considered in this model due to missing data in the MMARAS database. Nagelkerke R-square shows that the model explains up to 17.8% of the variance in the dependent variable. Results show that for vehicle type, involvement of motorcycles, tricycle, jeepney, and bus increases the odds ratio of passenger injury, while involvement of car, taxi/FX, van, and truck decreases the odds ratio of passenger injury. For collision types, only multiple collision significantly increases the odds ratio of passenger injury, while hit and run, hit parked vehicle, hit

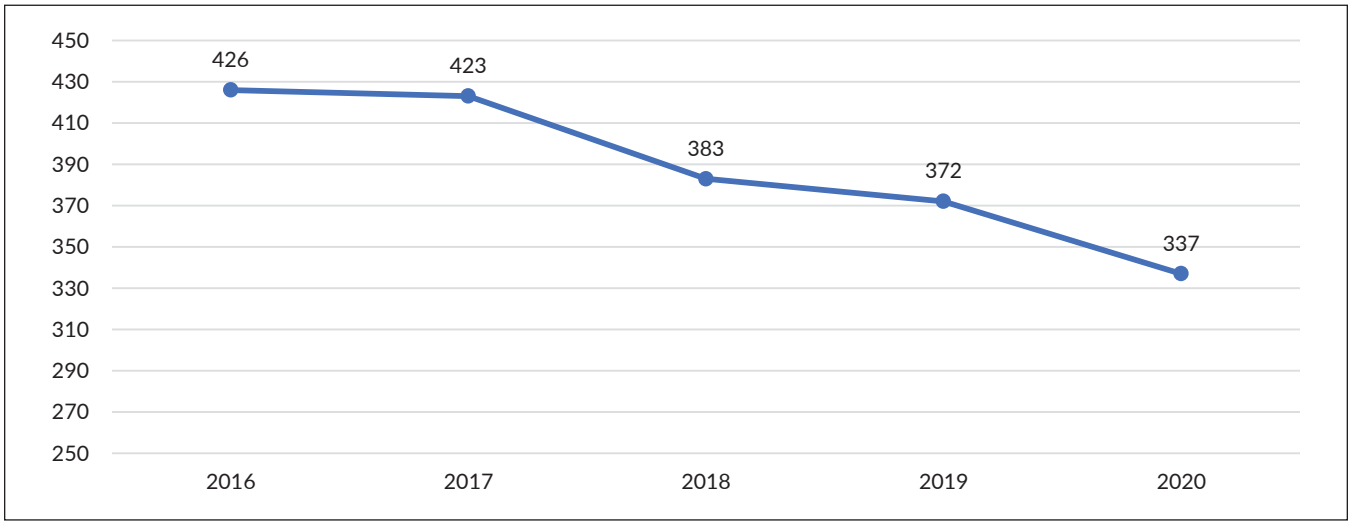

Figure 3. Trends of Fatal Crash.

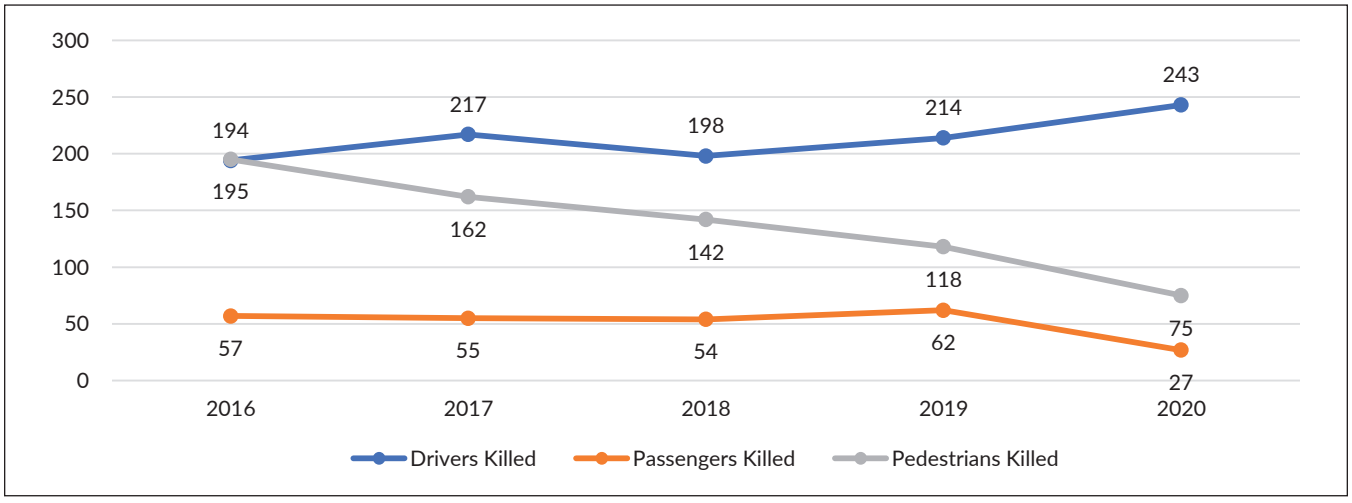

Figure 4. Trends of Total Deaths per Road User.

pedestrian, rear-end, and side swipe collision decreases the odds ratio of passenger injury. For risky road user behavior, suspected alcohol intoxication, and human error significantly increases the odds ratio of passenger injury. Collisions in parking area and T-junctions decrease the odds ratio of passenger injury (Table 3).

Pedestrian Fatality and Injury

For pedestrian fatality, 43,230 cases are considered in this model due to missing data in the MMARAS database. Nagelkerke R-square shows that the model explains up to 39.5% of the variance in the dependent variable. Results show that involvement of motorcycle decreases the odds

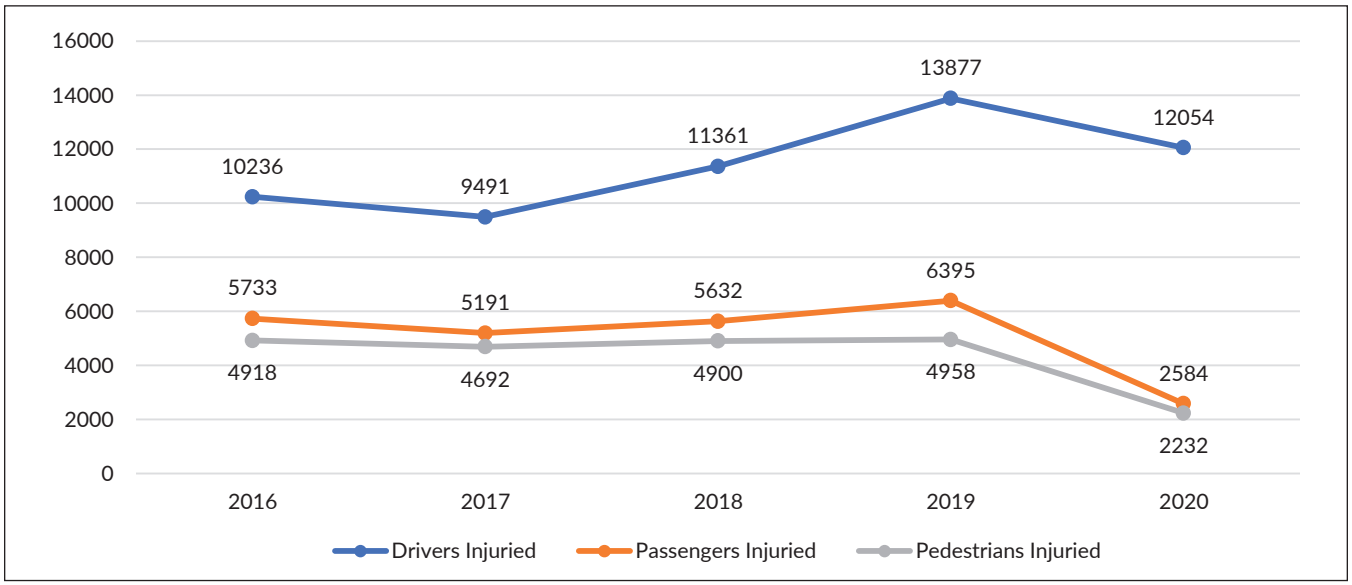

Figure 5. Trends of Total Injuries per Road User.

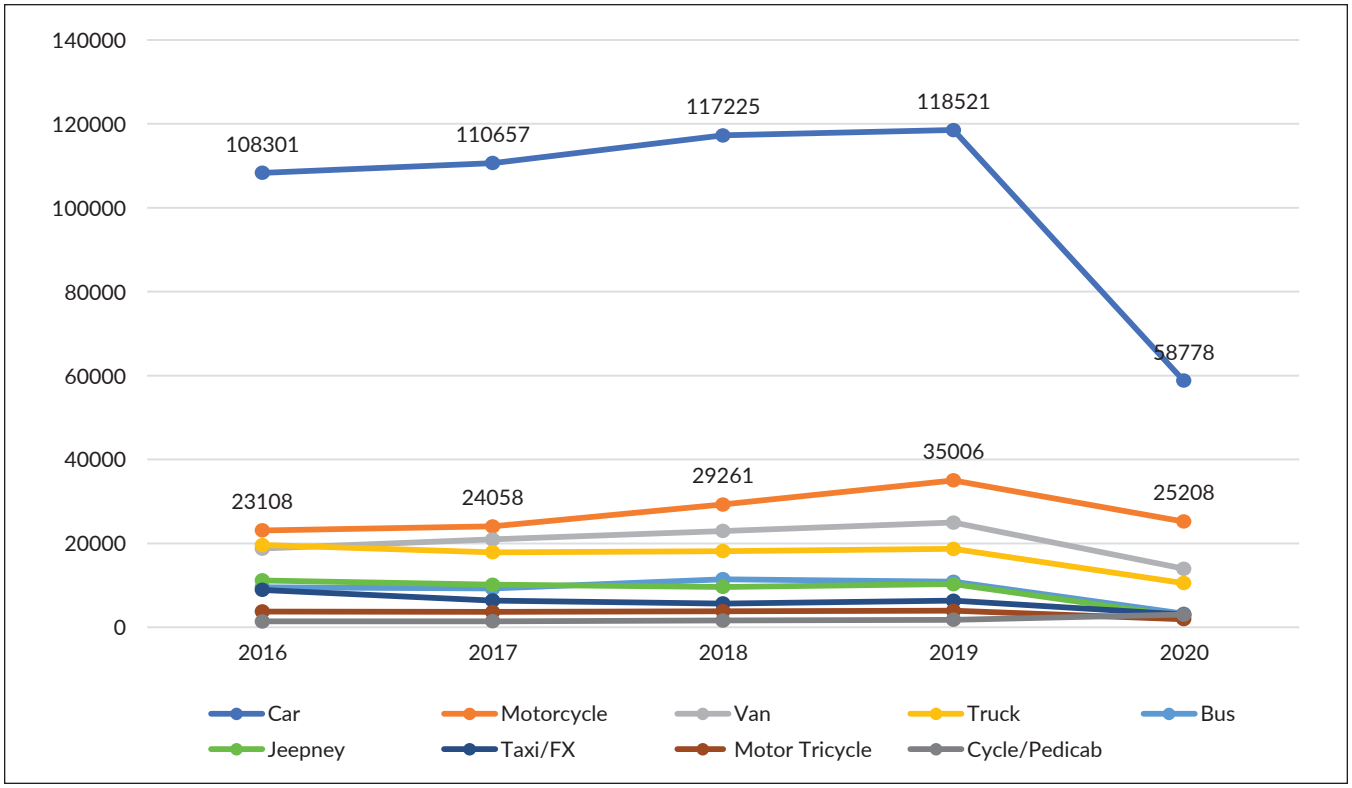

Figure 6. Trends of Involvement of Each Vehicle Type.

ratio of pedestrian death, but involvement of bus and truck increases the odds ratio of pedestrian death. Hit and Run and Hit Pedestrian collision type increases the odds ratio of pedestrian death. Crashes in Bridges/flyover increase the odds ratio of pedestrian death (Table 4).

For pedestrian injury, 43,230 cases are considered in this model due to missing data in the MMARAS database. Nagelkerke R-square shows that the model explains up to 34.9% of the variance in the dependent variable. All of the variables significantly associated with pedestrian injury only decrease the odds ratio of pedestrian injury. Cycle/pedicab, motorcycle, tricycle, car, jeepney, taxi/FX, bus, van and truck involvement are significantly associated vehicle types. Bridge/Flyover, crossroads, parking area, rotunda, T-junction, Tunnel/Underpass, and U-turn slot are significantly associated junction types (Table 4).

Multinomial Regression for Classification of Crash

Multinomial regression analysis was done on the dependent variable "Classification of Crash", which has three categories: Fatal, Non-Fatal (Injurious), and Damage to Property. This was done to explore what factors affect the severity of road crash incidents. The variable "Classification of crash" serves as the measurement of crash severity. Logistic regressions on driver, passenger, and pedestrian fatality and injury address the question "how are road crash factors associated with the type of road user?". On the other hand, the multinomial regression on the classification of crash explores what factors affect the severity of road crash incidents.

Here Damage to Property is set as the reference category. 64609 cases are included in the analysis. Nagelkerke R-Square suggests that this model can explain up to 51.8% of the variance in the dependent variable. Variables included in the

Table 2. Logistic Regressions for Driver Death and Driver Injury

Driver Fatality	Parameter Estimate	Standard Error	p-value	Odds Ratio	95% CI for OR	
					Lower Bound	Upper Bound
A cycle/pedicab is involved in crash	2.392	0.496	0.000	10.937	4.141	28.890
A motorcycle is involved in crash	4.008	0.413	0.000	55.062	24.527	123.612
A bus is involved in crash	1.764	0.464	0.000	5.835	2.349	14.492
A truck is involved in crash	1.956	0.337	0.000	7.073	3.652	13.698
Hit Object	2.399	0.505	0.000	11.007	4.093	29.598
Self-Accident	1.816	0.398	0.000	6.149	2.819	13.413
Side Swipe	-1.383	0.525	0.008	0.251	0.090	0.701
Lost Control	2.245	1.149	0.051	9.440	0.993	89.757
Bridge/Flyover	0.998	0.389	0.010	2.713	1.265	5.815
Constant	-9.525	0.449	0.000	0.000		
Driver Injury	**Parameter Estimate**	**Standard Error**	**p-value**	**Odds Ratio**	**95% CI for OR**	
					Lower Bound	**Upper Bound**
A cycle/pedicab is involved in crash	4.00	0.13	0.000	54.68	42.01	71.18
A motorcycle is involved in crash	3.70	0.06	0.000	40.39	35.66	45.75
A tricycle is involved in crash	1.38	0.14	0.000	3.96	3.02	5.19
A car is involved in crash	-0.59	0.05	0.000	0.55	0.50	0.62
A jeepney is involved in crash	0.28	0.09	0.002	1.32	1.11	1.57
A bus is involved in crash	0.22	0.10	0.032	1.25	1.02	1.53
A van is involved in crash	-0.32	0.09	0.000	0.73	0.61	0.86
Angle Impact	0.73	0.12	0.000	2.08	1.66	2.62
Head-on	1.12	0.24	0.000	3.07	1.91	4.94
Hit Object	1.28	0.17	0.000	3.60	2.58	5.04
Hit Parked Vehicle	-0.89	0.33	0.007	0.41	0.22	0.78
Hit Pedestrian	-2.64	0.21	0.000	0.07	0.05	0.11
Multiple Collision	0.52	0.11	0.000	1.68	1.35	2.08
Self-Accident	0.98	0.12	0.000	2.67	2.10	3.39
Human Error	0.60	0.19	0.000	1.83	1.26	2.66
Crossroads	-0.40	0.08	0.002	0.67	0.58	0.77
Parking Area	-1.27	0.25	0.000	0.28	0.17	0.45
T-junction	-0.55	0.09	0.000	0.58	0.49	0.68
Constant	-4.24	0.09	0.000	0.01		

model are selected through stepwise selection. Results show that for Fatal crashes, involvement of cycle/pedicab (OR = 28.82), involvement of motorcycles (OR = 8.18), involvement of tricycles (OR = 3.34), and involvement of trucks (OR = 1.55) significantly increase the odds ratio for fatal crashes, while the rest of the variables significantly decrease the odds ratio of fatal crashes in favor of damage to property crash (Table 5). On the other hand, for injurious crashes, involvement of cycle/pedicab (OR = 26.98), involvement of motorcycle (OR = 16.42), involvement of tricycle (OR = 5.52), and involvement of jeepney (OR = 1.46) significantly increase the odds ratio for injurious crashes. The rest of the variables significantly decrease the odds ratio of injurious crashes in favor of damage to property crash (Table 5).

DISCUSSION

For the five-year data, road crashes in Metro Manila steadily increased and peaked in 2019. The increase in urbanization and steady increase of registered vehicles may have contributed to road congestion and increasing number of recorded road crash cases. Metro Manila is the national capital region of the Philippines and has the largest population with approximately 13 million Filipinos, while Metro Cebu and Metro Davao are the second- and third-largest urban areas in Visayas and Mindanao with 2.8 million and 2.5 million Filipinos, respectively.[2] Aside from increasing population, the steady increase in road crashes may be attributed to the increased traffic volume in Metro Manila, which is considered as the 4th most congested city in the world with commuters losing an average of 257 hours or 10 days and 17 hours during rush hour in 2019.[11,12]

Based on the results, road crash classified as damage to property continued to be the major type of road crash classification, while fatal crash steadily showed a declining trend since 2016. Drivers and pedestrians were the vulnerable road users. The increasing trend of road crash in Metro Manila for 5 years started to decline by the year 2020, where reductions in both fatalities and injuries were reported primarily due to the decreased road traffic volume

Table 3. Logistic Regressions for Passenger Fatality and Injury

Passenger Fatality	Parameter Estimate	Standard Error	p-value	Odds Ratio	95% CI for OR	
					Lower Bound	Upper Bound
A motorcycle is involved in crash	1.32	0.57	0.021	3.75	1.22	11.46
Angle Impact	3.74	1.23	0.002	42.01	3.79	465.08
Multiple Collision	2.91	1.42	0.040	18.42	1.14	297.48
Self-Accident	3.49	1.35	0.010	32.66	2.33	458.63
Lost Control	4.42	1.33	0.001	82.98	6.16	1117.33
Constant	-10.60	1.03	0.000	0.00		
Passenger Injury	**Parameter Estimate**	**Standard Error**	**p-value**	**Odds Ratio**	**95% CI for OR**	
					Lower Bound	Upper Bound
A motorcycle is involved in crash	0.93	0.08	0.000	2.53	2.17	2.95
A tricycle is involved in crash	1.76	0.11	0.000	5.80	4.64	7.27
A car is involved in crash	-1.31	0.08	0.000	0.27	0.23	0.32
A jeepney is involved in crash	0.63	0.09	0.000	1.87	1.58	2.23
A taxi/FX is involved in crash	-0.31	0.12	0.008	0.74	0.59	0.92
A bus is involved in crash	0.30	0.10	0.003	1.35	1.11	1.65
A van is involved in crash	-1.00	0.12	0.000	0.37	0.29	0.46
A truck is involved in crash	-0.53	0.11	0.000	0.59	0.47	0.73
Hit and Run	-1.16	0.18	0.000	0.31	0.22	0.45
Hit Parked Vehicle	-1.09	0.42	0.010	0.34	0.15	0.77
Hit Pedestrian	-2.15	0.23	0.000	0.12	0.07	0.18
Multiple Collision	0.84	0.13	0.000	2.32	1.80	2.99
Rear-end	-0.51	0.09	0.000	0.60	0.51	0.71
Side Swipe	-0.92	0.09	0.000	0.40	0.33	0.47
Alcohol suspected	2.20	0.74	0.003	8.99	2.11	38.30
Human Error	0.52	0.23	0.026	1.68	1.06	2.66
Parking Area	-1.96	0.45	0.000	0.14	0.06	0.34
T-junction	-0.53	0.13	0.000	0.59	0.46	0.76
Constant	-2.62	0.10	0.000	0.07		

and limited mobility caused by the COVID-19 pandemic. Similarly, there was a significant decrease in the number of reported road crash cases globally when the COVID-19 pandemic emerged due to decreased congestion and more open and empty lanes, reduced enforcement, risky road user behaviors.[9]

Although the drivers were the most frequent fatality and injury based on this study, pedestrians and passengers were also significantly affected. In a study, pedestrians and motorcyclists have higher mortality compared to other road user type and vehicle due to their association with speeding and being vulnerable road users.[9]

Logistic regression was used by Wu et al.[10] in analyzing vehicle and crash type and their association with crash injury severity. In this study, we use logistic regression to explore the factors increasing the odds of suffering injury or fatality among road users. Using logistic regression, the vehicle types that were found to have a significant association with road user fatality and injury were cars, motorcycles, vans, trucks, jeepneys, buses, taxis or FXs, tricycles, and bicycles or pedicabs. Metro Manila accounted 24.2% of the 12.7 million motor vehicle registrations in the country, and steadily increased. In 2019, a 10.1% (3.1 million) increased in registered vehicles from 2018 were reported, which were divided into: motorcycles and tricycles by 47.8%, utility vehicles by 21.6%, and passenger cars by 16.1%. It is worth noting that the vehicle type involved in road crashes are cars, even if only 16.1% are passenger cars out of 3.1 million registrations (both new and renewals) in 2019.[12]

In this study in the Philippines, motorcycles were next to cars with the highest involvement in road crashes. Results show that involvement of motorcycles increases driver fatality by 55 times, driver injury by 40.4 times, passenger fatality by 3.75 times, and passenger injury by 2.5 times. Study results in Indonesia showed that motorcycles accounted to 74.6% of road crashes, as motorcycle taxis are considered the staple means of transport in Indonesia to avoid traffic jams.[13] Motorcyclists also have higher mortality compared with other vehicle types due to the high-energy transfer from a bigger vehicle. Motorcyclists were found to have a 3-fold risk for death and higher fatality compared to car occupants.[14] Having a separate lane for motorcyclists may be

Table 4. Logistic Regressions for Pedestrian Fatality and Injury

Pedestrian Fatality	Parameter Estimate	Standard Error	p-value	Odds Ratio	95% CI for OR	
					Lower Bound	Upper Bound
A motorcycle is involved in crash	-1.00	0.41	0.014	0.37	0.17	0.81
A bus is involved in crash	1.16	0.40	0.004	3.19	1.46	6.95
A truck is involved in crash	1.05	0.42	0.012	2.86	1.26	6.48
Hit and Run	4.03	0.84	0.000	56.04	10.79	291.19
Hit Pedestrian	6.99	0.74	0.000	1085.17	256.72	4587.04
Bridge/Flyover	1.43	0.64	0.025	4.20	1.20	14.71
Constant	-10.39	0.74	0.000	0.00		
Pedestrian Injury	**Parameter Estimate**	**Standard Error**	**p-value**	**Odds Ratio**	**95% CI for OR**	
					Lower Bound	**Upper Bound**
A cycle/pedicab is involved in crash	-1.92	0.28	0.000	0.15	0.08	0.26
A motorcycle is involved in crash	-1.23	0.08	0.000	0.29	0.25	0.34
A tricycle is involved in crash	-1.20	0.16	0.000	0.30	0.22	0.41
A car is involved in crash	-3.92	0.09	0.000	0.02	0.02	0.02
A jeepney is involved in crash	-1.49	0.10	0.000	0.22	0.18	0.28
A taxi/FX is involved in crash	-2.52	0.16	0.000	0.08	0.06	0.11
A bus is involved in crash	-2.81	0.14	0.000	0.06	0.05	0.08
A van is involved in crash	-2.95	0.14	0.000	0.05	0.04	0.07
A truck is involved in crash	-2.85	0.14	0.000	0.06	0.04	0.08
Bridge/Flyover	-1.94	0.26	0.000	0.14	0.09	0.24
Crossroads	-1.01	0.12	0.000	0.36	0.29	0.46
Parking Area	-1.18	0.20	0.000	0.31	0.21	0.45
Rotunda	-1.54	0.29	0.000	0.22	0.12	0.38
T-junction	-1.53	0.16	0.000	0.22	0.16	0.29
Tunnel/Underpass	-1.47	0.37	0.000	0.23	0.11	0.48
U-turn slot	-1.39	0.26	0.000	0.25	0.15	0.41
Constant	0.61	0.08	0.000	1.84		

an effective strategy to mitigate motorcycle-involved road crashes. A study showed that separate lane for motorcyclists was associated with reduced road crash accident and injury.[15] By 2019, in the Philippines, the MMDA considered exclusive motorcycle lanes with 2 lanes exclusive for buses and 3 lanes for private vehicles in EDSA in their proposal; however, this has not pushed through primarily due to the pandemic.[16]

This study in the Philippines showed that jeepneys are significantly associated with increased driver injury ($p<0.001$, OR=1.32), and passenger injury ($p=0.000$, OR=1.87). Jeepneys are an icon of Metro Manila, and are among the most commonly used mode of transportation for the working class and student population. In recent years, the new "modernized jeepneys" are implemented in the Philippines, which in theory should make commutes safer for Filipinos. The MMARAS must update its category to be able to monitor road crashes involving traditional and modern jeepneys in order to see if the modern jeepneys

Table 5. Multinomial Regression for Classification of Crash (N = 64609)

Classification of Crash	Independent Variables	Parameter Estimates	Standard Error	p-value	Odds Ratio	95% CI for OR	
						Lower Bound	Upper Bound
Fatal	Intercept	-1.765	0.169	0.000			
	A cycle/pedicab is involved in crash	3.326	0.327	0.000	27.820	14.662	52.787
	A motorcycle is involved in crash	2.101	0.169	0.000	8.177	5.868	11.393
	A tricycle is involved in crash	1.205	0.345	0.000	3.338	1.697	6.568
	A car is involved in crash	-2.117	0.182	0.000	0.120	0.084	0.172
	A jeepney is involved in crash	-0.313	0.275	0.255	0.731	0.427	1.253
	A taxi/FX is involved in crash	-0.986	0.340	0.004	0.373	0.192	0.727
	A van is involved in crash	-1.380	0.294	0.000	0.252	0.141	0.448
	A truck is involved in crash	0.436	0.190	0.022	1.547	1.065	2.245
	Angle Impact	-3.317	0.471	0.000	0.036	0.014	0.091
	Head-on	-1.577	0.548	0.004	0.207	0.070	0.605
	Hit and Run	-3.328	0.319	0.000	0.036	0.019	0.067
	Hit Object	-2.663	0.376	0.000	0.070	0.033	0.146
	Multiple Collision	-1.992	0.335	0.000	0.136	0.071	0.263
	No Collision Stated	-3.453	0.191	0.000	0.032	0.022	0.046
	Rear-end	-4.627	0.360	0.000	0.010	0.005	0.020
	Self-Accident	-2.025	0.272	0.000	0.132	0.078	0.225
	Side Swipe	-4.688	0.310	0.000	0.009	0.005	0.017
Non-Fatal (Injurious)	Intercept	1.003	0.052	0.000			
	A cycle/pedicab is involved in crash	3.295	0.104	0.000	26.979	22.002	33.083
	A motorcycle is involved in crash	2.799	0.037	0.000	16.423	15.284	17.647
	A tricycle is involved in crash	1.708	0.083	0.000	5.521	4.692	6.495
	A car is involved in crash	-1.421	0.038	0.000	0.242	0.224	0.260
	A jeepney is involved in crash	0.381	0.054	0.000	1.463	1.317	1.626
	A taxi/FX is involved in crash	-0.397	0.059	0.000	0.672	0.598	0.755
	A van is involved in crash	-0.960	0.057	0.000	0.383	0.342	0.428
	A truck is involved in crash	-0.569	0.056	0.000	0.566	0.508	0.631
	Angle Impact	-2.813	0.089	0.000	0.060	0.050	0.071
	Head-on	-2.306	0.199	0.000	0.100	0.068	0.147
	Hit and Run	-3.246	0.077	0.000	0.039	0.033	0.045
	Hit Object	-2.747	0.113	0.000	0.064	0.051	0.080
	Multiple Collision	-2.464	0.091	0.000	0.085	0.071	0.102
	No Collision Stated	-2.966	0.052	0.000	0.052	0.047	0.057
	Rear-end	-3.555	0.061	0.000	0.029	0.025	0.032
	Self-Accident	-2.695	0.114	0.000	0.068	0.054	0.084
	Side Swipe	-3.752	0.059	0.000	0.023	0.021	0.026

a. The reference category is: Damage to Property.

are an improvement over the previous models in terms of safety. There is limited study on the crashworthiness of jeepneys.[17] Aside from safety, the modernization of jeepneys allow decreased air pollution and greenhouse gas emissions reduction.[18]

The results showed that involvement of buses in road crashes increases the odds ratio of driver fatality be 5.84 times, driver injury by 1.25 times, passenger injury by 1.35 times, and pedestrian fatality by 3.19 times. The passenger injury may be due to overcrowding in buses. In July 2020, when Metro Manila was placed under general community quarantine, the EDSA Busway or EDSA Carousel, which is a Bus Rapid Transit (BRT) line, was made available to prevent overcrowding in buses.[19] Accordingly, Bus Railway Transit in Metro Manila was also implemented as a separate and dedicated lane for buses only except emergency vehicles, to aid in reducing road traffic volume and road crashes. The Metro Manila BRT Line 1 Project which stretches from Quezon Memorial Circle to Manila City Hall with 12.3 kilometers is expected to be constructed at the end of 2022 or early 2023, and serve at least 290,000 commuters per day.[20,21]

Multiple collision increases the odds ratio of driver injury by 1.68 times, passenger fatality by 18.42 times, and passenger injury by 2.32 times. Head-on collision was significantly associated with an increase in the odds ratio of driver injury by 3.07 times. In other studies, head-on collisions were also found to be significantly associated with increased odds for a crash to be fatal.[22]

Hit and run collision was significantly associated with an increase in the odds ratio of pedestrian fatality by 56 times.[23] Pedestrians are the most vulnerable road users, but up until now, there are still not enough measures to protect pedestrians. In the Philippines, sidewalks are being utilized as parking and stalls for informal sellers, making pedestrians displaced and forced to walk in the road with vehicles.

The results of this study showed that human error was found to significantly increase the odds ratio of driver injury by 1.83 times, and passenger injury by 1.68 times. Human errors, specifically loss of control, speed violation, risky driving, route violation, and wrongful overtaking, were statistically significant with road crashes.[24] According to Payani et al., among young and novice drivers, emotional condition and social norms such as peer pressure contributed to their risk-taking behavior.[25] Suspected alcohol intoxication was found to significantly increase the odds ratio of passenger injury by 8.99 times. Despite existing road traffic laws on drunk-driving, alcohol-intoxicated driving is still persistent in Metro Manila.

The study is limited on the available road crash factors based on MMARAS dataset. Another limitation in this study are several missing data. The MMDA must evaluate its data collection methodologies to aid researchers and policy makers in identifying and preventing the cause of road crashes. Since its first report in 2005, the missing data maybe due to the incidences of under reported cases, complex mechanism of collecting road accident data, and large number of Traffic Accident Investigators involved. Addressing the missing cases of the MMARAS database should be performed for a complete baseline data.

CONCLUSION

The increase in global road accidents and fatalities primarily affects developing countries. This study used the MMARAS database to look into road crashes and the factors affecting the severity of crashes in Metro Manila, Philippines. The trend of road crashes and the severity of crashes in Metro Manila are generally increasing, except for 2020 due to the lockdowns and community quarantine from the pandemic.

The study has also elucidated data on both the fatality and injuries incurred by three types of road users – driver, passenger and pedestrian. These outcomes of road crash were also correlated with known major categories of factors – vehicle types, road user behavior, collision type, and junction type.

The presence of preventable accident causations shows the need for stricter enforcement and review of road traffic laws, policies, and regulations to address risky driving behaviors, and license requirements for road users and vehicles. There is also a need to educate road users on safe road utilization to decrease their involvement in risky driving behaviors.

Further research and funding are needed to obtain data from the cities of Metro Manila and determine the road crash factors, how these existing road traffic laws, policies, and regulations are being implemented, and the availability and utilization of equipment for enforcement. There is a need for a complete and accurate data providing the major contributing factors to road crash that will translate to safety programs and road safety policies.

Statement of Authorship

JLL contributed in the conceptualization of work, drafting and revising, and final approval of the version to be published; TJH contributed in the conceptualization of work and acquisition of data; SFL contributed in the conceptualization of work, acquisition and analysis of data, drafting and revising, and final approval of the version to be published.

Author Disclosure

All authors declared no conflicts of interest.

Funding Source

This study was funded by the Emerging Interdisciplinary Research Program of the University of the Philippines System through the National Institutes of Health, University of the Philippines Manila.

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