Black Spot Cluster Analysis of Road Crash involving Public Utility Vehicles (PUV) along Commonwealth Avenue using Kernel Density Estimation

Jerome BALLARTA [a], Sheila Flor JAVIER [b], Carolyn MERCADER [c]

[a,b] *National Center for Transportation Studies, University of the Philippines, Diliman, Quezon City 1101, Philippines*
[c] *Metropolitan Manila Development Authority, EDSA cor Orense St., Guadalupe Nuevo, Makati City, Philippines*
[a] *E-mail: jnballarta@up.edu.ph*
[b] *E-mail: sdjavier@up.edu.ph*
[c] *E-mail: carolyn.dechino@mmda.gov.ph*

Abstract: The Commonwealth Avenue in Quezon City is known as the "killer highway" in Metro Manila, with an average of 17 fatal road crashes per year from 2017 to 2021. The high occurrence of vehicular road crashes on Commonwealth Avenue has led to several research interests in identifying and analyzing road crash hot spots using Geographical Information Systems (GIS). This study used data from the Metro Manila Accident Reporting and Analysis System (MMARAS) data of the Metropolitan Manila Development Authority (MMDA) and employed kernel density estimation using free open-source software to identify public utility vehicle (PUV) road crash hotspots along Commonwealth Avenue. The study revealed five fatal crash locations along Commonwealth Avenue. High-density road crashes occurred during the period of 7:00 to 10 a.m. and 5:00 to 8:00 p.m., specifically on Fridays at Regalado Avenue. The study's results have significant implications that can be used to identify black spots, develop targeted interventions, and take measures to reduce the severity of PUV crashes.
Keywords: Public Utility Vehicle Road Crash, Black Spot Cluster Analysis, Kernel Density Estimation (max: 6 keywords)

1. INTRODUCTION

1.1 Background

According to the World Health Organization, about 1.2 million people die worldwide due to road traffic crashes every year. It has been a wide-reaching concern because of the high cost associated with it and the negative social and economic repercussions. It is estimated that the cost of road traffic crashes reaches 1% to 1.5% of Gross National Product in low- and middle-income countries like the Philippines. Also, road crashes that are fatal and caused disabilities to put significant strain on families (Department Health, Philippines, 2008).

In the 2021 report of the Metro Manila Development Authority (MMDA), a total of 58,447 road crashes were recorded in Metro Manila. There was at least one fatal road crash per day and 130 of those happened in Quezon City. The Commonwealth Avenue in Quezon City is considered as one of the deadliest thoroughfares in Metro Manila with 23 fatalities recorded in 2021 due to vehicular crashes. Because of this, Commonwealth Avenue is continued to be known as the "killer highway". The high occurrence of vehicular crashes on Commonwealth Avenue has led to several research studies that use Geographical Information

Systems (GIS) to identify and analyze road crash hotspots.

1.2 Statement of the Problem

Commonwealth Avenue is one of the main thoroughfares in Quezon City. It is the widest highway in the Philippines with a length of 12.4 kilometers and spanning 10 to 18 lanes. It starts from the Quezon Memorial Circle inside the Elliptical Road, and passes through the areas of Philcoa, Tandang Sora, Balara, Batasan Hills, and ends in Mindanao Avenue in the Fairview area (Local Government of Quezon City, 2015). Because of its vastness, rowdy traffic behavior is often observed in the area. Several traffic management measures were installed and constructed to control the occurrence of road crashes such as the 60 kph limit, designated U-turn slots, separate lanes for motorcycles, to name a few. Despite these measures, controversial road crashes happened along Commonwealth Avenue and mostly involving public utility vehicles (PUVs). One of which is the death of UP Professor Lourdes Estella-Simbulan in 2011 while on board a taxi that was rammed by a passenger bus. Based on the 2021 statistics of MMDA, of the 3057 recorded road crashes in Commonwealth Avenue about 30% or 973 crashes involved PUVs despite limited operation due to Covid-19. These statistics developed the interest to focus the study in identifying road crash hot spots along Commonwealth Avenue involving PUVs.

1.3 Objectives of the Study

The main objective of the study is to illustrate, using the GIS, the traffic road crash analysis along Commonwealth Avenue involving PUVs. Specifically, the study aims to:

1. Identify road crash hotspots involving PUVs by analyzing the traffic data from the MMDA;
2. Demonstrate clusters of road crashes through Black Spot Mapping and Kernel Density Mapping, describing the specific location and the type of road crashes; and
3. Provide baseline studies for further research and development of traffic and road crashes involving PUVs along Commonwealth Ave., Quezon City.

1.4 Scope and Limitations of the Study

This study focuses on the crash involvement of PUV's (Buses, Jeepneys, FXs/ UV Shuttles) along Commonwealth Avenue through spatial analysis. PUVs comprise a significant 30% share of the reported road crashes along Commonwealth, thus the critical identification of crash hotspots.

Located in the heart of Metro Manila, Quezon City is the largest and most populous city. It is a strategic convergence point for metropolitan roads and transportation networks, making it an ideal distribution hub. Easily accessible from major highways, thoroughfares, and mass rail transit systems of the metropolis; Quezon City has a 37.60% share or 21,978 out of 58,447 total reported road crash incidents in Metro Manila for the year 2021.

Table 1 shows the statistics and road crash classification that occurred in Commonwealth Ave. compared to larger areas such as Quezon City and Metro Manila. The statistics of road crashes involving PUVs along Commonwealth Ave. are also presented.

Table 1. Road Crash Statistics in Metro Manila, Quezon City, and Commonwealth Ave., 2021

Road Crash Classification	Metro Manila (MM)	Quezon City (QC)	Commonwealth Avenue (CW)	PUVs
Damage to Property	42,812	16,624	2,142	767
Fatal	385	130	23	6
Non-Fatal Injury	15,250	5,224	892	200
Grand Total	58,447	21,978	3,057	973

Table 2 presents the percent share of Quezon City and Commonwealth Ave. from Metro Manila's road crash statistics and the disaggregated data on road crashes involving PUVs, while Table 3 presents the percent share of Commonwealth Ave from Quezon City's Crash Statistics. The percent share of road crashes involving PUVs in Commonwealth Ave. is also presented.

Table 2. Percent Share of Quezon City and Commonwealth Ave. from Metro Manila's Road Crash Statistics

Road Crash Classification	Quezon City (QC)	Commonwealth Avenue (CW)	PUVs
Damage to Property	38.83%	5.00%	1.79%
Fatal	33.77%	5.97%	1.56%
Non-Fatal Injury	34.26%	5.85%	1.31%
Grand Total	37.60%	5.23%	1.66%

Table 3. Percent Share of Commonwealth Avenue from Quezon City's Road Crash Statistics

Road Crash Classification	Commonwealth Avenue (CW)	PUVs
Damage to Property	12.88%	4.61%
Fatal	17.69%	4.62%
Non-Fatal Injury	17.08%	3.83%
Grand Total	13.91%	4.43%

This study is limited to the road crashes with PUV involvement that took place in Commonwealth Avenue from Quezon City Elliptical Road intersection up to Mindanao Avenue intersection (Fairview Area). It is also limited to the identification of road crash hotspots per road crash Type (Fatal, Non-Fatal & Damage to property) per time of occurrence (Nighttime or Day time) based on MMDA's MMARAS 2019 up to 2021.

2. REVIEW OF RELATED LITERATURE

2.1 Metro Manila Accident Recording and Analysis System (MMARAS)

The Metro Manila Accident Recording and Analysis System (MMARAS) is created and operated by the Road Safety Unit (RSU) of the MMDA-Traffic Discipline Office – Traffic Engineering Center (MMDA-TDO-TEC). This office operates in cooperation and assistance of the Traffic Enforcement Unit (TEU) of the Philippine National Police (PNP).

The objective of MMARAS is to compile and maintain an on-going database of road crashes. The MMARAS provides MMDA with the capability to monitor and evaluate the impact of road improvement measures. The database of road crashes provides brief information on road crashes that have been recorded by the MMDA-Road Safety Unit through Police Blotter of the PNP. The information is presented in tabular form.

The Road Safety Unit has eight (8) data researchers who gather traffic accident data from different traffic offices and stations of the Traffic Enforcement Units (TEU) within Metro Manila. They started this new scheme in 2005 to increase accuracy or reported road crashes. Previously, they just relied on accident reports submitted by traffic accident investigators.

The MMARAS database classifies road crash severity into Fatal, Non-Fatal and Damage to Property. Fatal crash means at least one person is killed. A non-fatal crash is defined as a crash where at least one person is injured but no fatalities. Damage to property is recorded when nobody is injured in a crash incident, but vehicles or property are damaged.

The existing information in the MMARAS Database includes ID Number, Report Reference, name of the accident investigator, district/city/municipality, time, date, location, classification, junction type, junction control, weather, collision type, mode involved, plate number of involved vehicles and name of the passenger/driver/pedestrian. The location of a road crash only includes street name or establishment name near the area. The coordinates of the incident site are not identified or included in the database.

2.2 Black Spot Analysis

Black spots are often regarded as an effective way to identify high-risk sites or areas. According to Hauer (1996), researchers rank locations by crash rate (crash per vehicle kilometers or per entering vehicles), some use crash frequency (crash per km year or crash per year) and some use a combination of the two. The proportion of road crash types considered susceptible to treatment is also used for ranking in some studies recently. Locations are in general classified as black spots after an assessment of the level of risk and the likelihood of a crash occurring at each location. At certain sites, the level of risk will be higher than the general level of risk in other areas. Crashes will tend to be concentrated at these relatively high-risk locations. Locations that have an abnormally high number of crashes are described as crash concentrated, high hazard, hazardous, hot spot or black spot sites.

According to Yue (2001), the principle in using Black Spot Method is based on the following assumptions:

a. The site/area must have enough road crashes to identify a pattern;
b. The site/area must have enough road crashes of the same type; and
c. The road crashes could be located on a map-based platform.

Once a Black Spot or road crash zone is identified, the proposed engineering treatments can be identified according to their capacity to eliminate or reduce the occurrence of accidents at that location. It is important to identify specific locations of road crashes to come up with reliable black spots.

2.3 The Use of GIS in Black Spot Studies

With the new computer technologies, spatial information can be analyzed on digital maps. A Geographical Information System (GIS) offers a substantial platform for road crash studies. GIS is a method of storing and analyzing spatial data. GIS comes in one of two forms: vector or raster. A vector type GIS is used to assign attributes to points, lines and polygons while a raster type GIS is used to assign attributes to an array of rows and columns. There have been several studies in recent times that have used a GIS to find trends in the occurrence of traffic crashes. In these cases, GIS has been an invaluable tool for visualization of data and has helped researchers to see spatial patterns and black spots (areas of high crash occurrence) which would be difficult to find using statistical methods.

The significance of using Geographic Information Systems (GIS) and Kernel Density Estimation (KDE) to locate road crash hotspots has been focused on by an array of studies. Thipthimwong and Noosorn (2019) concentrated on the spatial density of motorcycle-related collisions in Thailand using similar techniques while Anderson (2008) and Edrogan et al. (2008) used GIS and KDE to identify injury-related hotspots in traffic crashes. Three criteria were utilized by Manap et al. (2021) to analyze heavy vehicle crashes: the quantity of heavy vehicles involved, severity index values, and the quantity of heavy vehicle cases. Loo et al. (2011) discovered that the hot zone approach had a major effect on traffic crash density estimates in Hong Kong.

In addition, Shafabakhsh et al. (2017) used KDE to study traffic crashes in metropolitan networks, Randkavat and Tiwari (2013) developed a KDE technique to identify pedestrian accident-prone areas in New Delhi, highlighting bandwidth as a crucial determinant of density levels. In Tunisia, Ouni and Belloumi (2018) determined collision hotspots for vulnerable road users, and Liu and Lin (2020) used spatial autocorrelation analysis and KDE to analyze traffic crash data from Vietnam. To identify crash hotspots in the UK, Kazmi et al. (2022) used GIS and KDE and offered techniques for ranking crash severities. The importance of KDE and the Weighted Severity Index in helping cities manage multi-modal traffic and address the dominance of two-wheelers in crash-prone areas was highlighted by Pusuluri et al. (2023). The studies demonstrate the various uses of GIS and KDE techniques in analyzing global road safety and the detection of areas that are prone to road crashes.

Furthermore, the collective research of Abdullah and Sipos (2023), Fayaz et al. (2023) and Choudhary et al. (2015) underscores the pivotal role of Geographic Information Systems (GIS), specifically Q-GIS, in enhancing road safety through comprehensive data analysis. Fayaz et al. utilized Q-GIS to visualize road crash data, emphasizing its potential for well-informed decision-making in road safety auditing. Meanwhile, Abdullah and Sipos (2023) employed the QGIS heatmap algorithm, notably Kernel Density Estimation, to identify crash hotspots in Budapest, revealing the city center as a common location for crashes with distinct patterns on weekdays, lanes, and during peak and off-peak hours. Choudhary et al. (2015) applied a heat map plugin to geocode traffic crashes in Varanasi, highlighting the importance of identifying high-risk areas for safety precautions. These studies collectively emphasize the significance of acknowledging and addressing road crash hotspots for promoting road safety, with GIS and heat maps proving valuable for efficient planning and management, ultimately contributing to better traffic conditions and reduced crashes.

The exploratory study of Netek et al. (2018) further recommends using heatmaps for fast previews of spatial data, methods of identifying min/max hotspots, and comparing diverse phenomena with the same parameters (radius and color range). However, heatmaps are not recommended for detecting accurate values and should be used with caution.

GIS is advantageous in black spot studies as it provides both geographical positions and crash details, aiding in the identification of black spots for crash prevention, supporting authorities in directing remedial funding.

3. CONCEPTUAL FRAMEWORK AND METHODOLOGY

3.1 Conceptual Framework

Road crash data were extracted from MMDA's Metro Manila Accident Reporting and Analysis System (MMARAS) database. The individual locations of PUV-related crashes were georeferenced while necessary data such as time and date of crash, crash severity, etc. were recorded. Data formatting and cleaning included the removal of duplicate entries and the assignment of weights in accordance with the classification of crashes: fatal, non-fatal, and damage to property using the Accident Point Weightage (APW). The MMARAS Excel data was formatted and saved as a CSV (Comma-Separated Values) file.

Quantum GIS (QGIS) is a free, open-source platform for spatial data applications, allowing visualization, management, editing, and analysis Netek et al (2018). Its Heatmap plug-in tool is used for Kernel density estimation, calculating road crash density for point and line features.

Install the QGIS and Heatmap plug-in tool if necessary. To install the Heatmap Plugin, navigate to the Plugins menu, select "Heatmap," and click "Manage and Install Plugins."

To import crash data as a point layer, launch QGIS, select "Add Layer," then "Add Delimited Text Layer," and select the CSV file. Configure the coordinate system for precise spatial analysis. After loading the CSV data, activate the Heatmap Plugin from the QGIS toolbar, choose the crash point layer as the input, and configure the settings to estimate kernel density. Modify the layer symbology to create a heatmap by right-clicking on the layer and selecting "Heatmap" from the drop-down menu. Adjust the blur radius, size, and color ramp for improved map visualization.

Create a base map using spatial layers, overlay crash data, and apply symbology techniques. Layer the heatmap with the road network layer to identify crash hotspots. Analyze and interpret data to identify patterns, clusters, and high-intensity areas. Adjust rendering options for improved spatial visualization. Save the heatmap layer in a suitable format like Geo TIFF or PNG or export it as a raster file for further analysis.

The QGIS Heatmap plugin tool will serve as an interpolation technique to spatially determine the locations and patterns of road crashes. The plug-in feature will build a density raster from a point layer and will allow the point clustering and hotspot identification. Furthermore, the generated weights from the APW will help improve the visualization of the map.

The mapped out crash locations are then used to produce kernel density maps. Kernel density calculates a magnitude per unit area from point or polyline features using a kernel function to fit a smoothly tapered surface to each point or polyline. With these maps, we can identify road crash hotspots for further analysis. The process flow of the methodology employed in the study is illustrated in Figure 1.

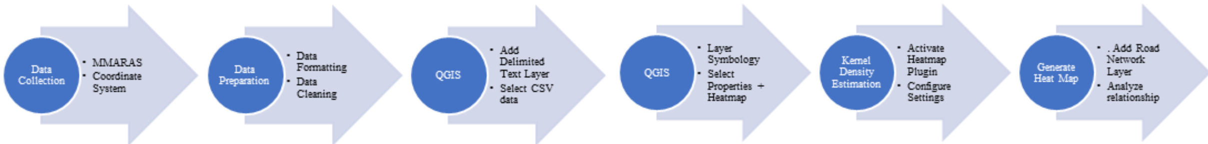

Figure 1. Methodological Framework

4. RESULTS AND DISCUSSION

The MMDA's 2019-2021 MMARAS crash data was used to analyze the occurrences of road crash incidents involving PUVs in Commonwealth Avenue, Quezon City. The statistics of road crashes were manually plotted as point features in QGIS. In the Attribute Table, codes were assigned per category and mode of transportation to easily classify the information in the GIS Database. Maps were subsequently generated showing the crash plots involving PUVs. The PUVs that were considered in the study are bus, jeep, and FX/Taxi. The type of road crashes was categorized into fatal, non-fatal, and damage to property, consistent with the categorization in MMDA MMARAS.

Of the 2,506 total recorded PUV-related crashes reported in the MMARAS, only 2,488 were considered in the study. The data gap of 18 was due to the incompleteness of information in the MMARAS to determine the exact location of the crashes.

It is however important to note that there is a significant number of road crashes underreporting in the Philippines. Not to mention, some data are incomplete and therefore inadmissible for use in this study.

Table 4 provides a summary of the variables to analyze and examine the temporal and spatial distribution or patterns of road crashes along Commonwealth Avenue. The day and time variables are presented in Figure 3 and 4 as calendar heatmaps.

Table 4. Road Crash Collision Analysis of Commonwealth Avenue, 2019-2021

Variables	Categories	Frequency of PUV related Crashes	
		N	%
Years	2019	683	27%
	2020	918	36%
	2021	905	37%
Collision Type	Angle Impact	249	9.6%
	Head On	9	0.3%
	Hit and Run	115	4.4%
	Hit Object	20	0.8%
	Hit Parked Vehicle	8	0.3%
	Hit Pedestrian	33	1.3%
	Multiple Collision	156	6.0%
	No Collision Stated	103	4.0%
	Rear End	622	23.9%
	Self-Accident	29	1.1%
	Side Swipe	1263	48.4%
Accident Factor	Human Error	344	13.7%
	Mechanical Defect	3	0.1%
	Under the Influence of Liquor	1	0.0%
	Vehicle Defect	2	0.1%
	No Accident Factor (based on Police Blotter Book)	2156	86.0%
Vehicles Involved	Car	1365	27.3%
	PUJ	927	18.6%
	Fx / Taxi	781	15.6%
	Bus	751	15.0%
	Motorcycle	485	9.7%
	Van	458	9.2%
	Truck	163	3.3%
	Bike	54	1.1%
	Tricycle	10	0.2%

The calendar heatmap of Commonwealth Avenue in Figure 2 visually suggests that the months of February, January and December are critical months to consider, as they accounted for 14%, 10% and 10% respectively, of the total road crashes recorded.

Consequently, Friday, Thursday and Tuesday are the days of the week that have the highest number of road crashes, accounting for 16.9%, 16.5% and 15.5% respectively.

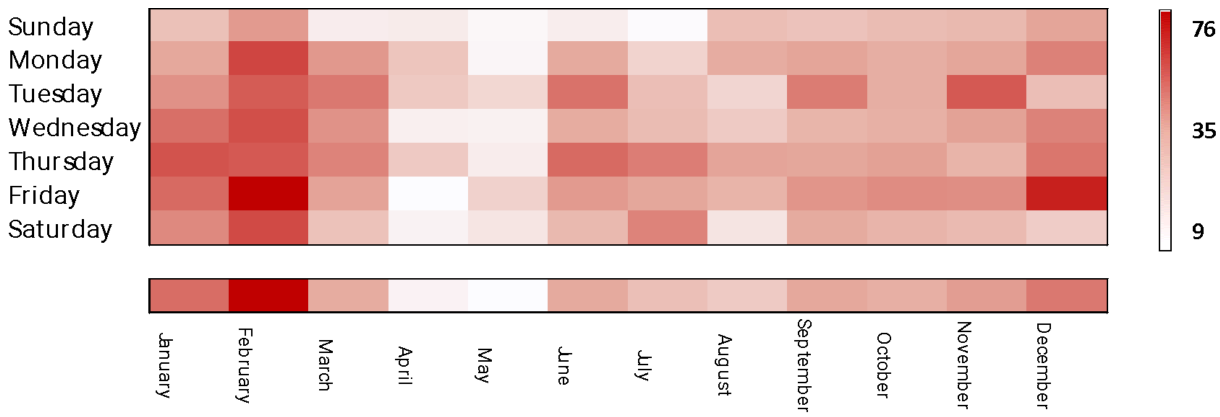

Figure 2. Average number of PUV related Road crashes along Commonwealth Avenue by month and day, 2019-2021

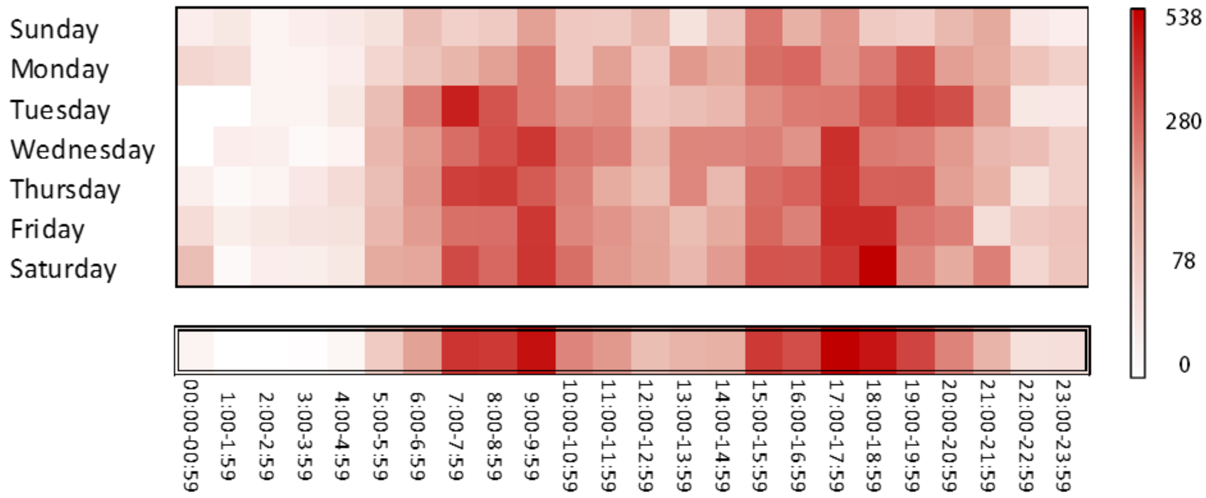

Figure 3. Average number of PUV related Road crashes along Commonwealth Avenue by time of day, 2019-2021

Figure 3 above demonstrates that the peak hours for the occurrence of road crashes along Commonwealth Avenue from 2019 to 2021 were between 7:00 am up to 10:00 am, and 17:00 pm up to 20:00 pm. A large part, accounting for 20.6%, was attributable to the morning peak, while the afternoon peak accounted for 21.4%.

Table 5. Time of Crash Occurrence in Commonwealth Ave. 2019-2021

Time of Occurrence	Type of Road Crash			Total	Percentage
	Fatal	NFI	DTP		
Night-Time	5	137	707	849	34 %
Daytime	2	288	1367	1657	66%
Total Crashes	7	425	2074	2056	100 %

Table 5 briefly states that from a total of 2506 total road crashes, more than 82% or 2074 of these crashes resulted in Damage to Property (DTP), 17% or 425 were Non-Fatal, and 7 cases were recorded as fatal.

Figure 4 below depicts the crash points of PUVs in the whole stretch of Commonwealth Ave. Majority of the recorded crashes involved FX/Taxi (35%), closely followed by buses (34%) and vans which comprises 20% of the total record. Jeepney-related road crashes occupied the least percentage at 11%. Concentrations of PUV-related crashes were obvious in the following points: Mindanao Ave. Intersection – (Fairview) Regalado, Fairview Center Mall – East Fairview Area, Litex Area, Sandigan Bayan/ Batasan Area, St. Peter's Church/ Ever Gotesco Mall Area, North Susana Area, Luzon Area, and Elliptical Road/ Philcoa Area. Strips of commercial establishments or a mass of housing settlements and commuters' convergence points are common to these areas.

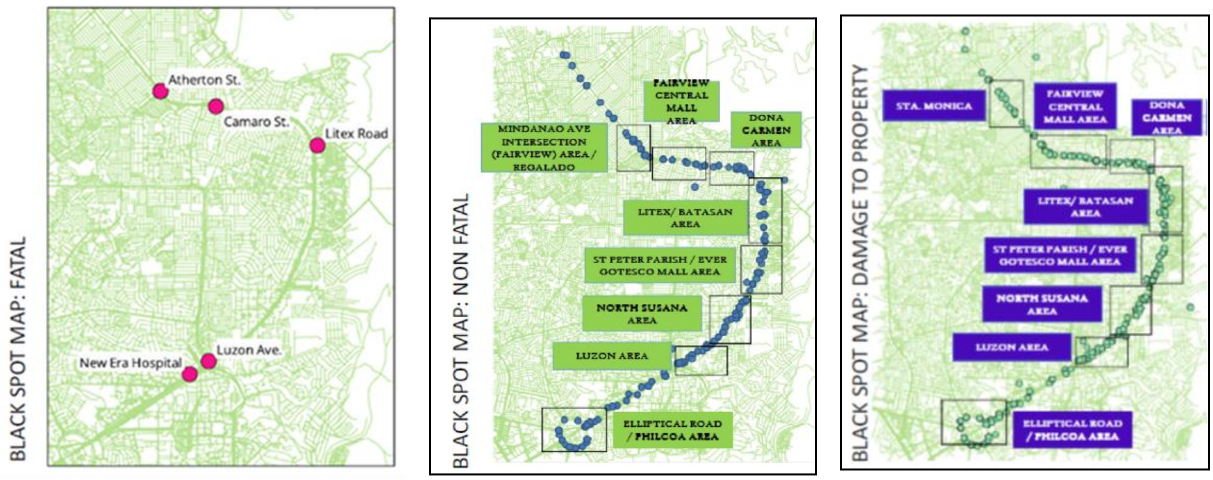

Figure 4. Black Spot Map of PUV-Related Fatal, Non-Fatal Injury and Damage to Property Road Crashes along Commonwealth Ave., 2019-2021

The specific area where each type of road crash occurred is exemplified. The deadly points where fatal road crashes happened. Three (3) fatal road crashes occurred in Atherton St while other fatal crashes were observed to be present in the following areas: Luzon / Tandang Sora Area, Camaro St and Litex Area.

The illustration also depicts the concentrations of non-fatal injury road crashes along East Fairview, Litex Area, Sandigan Bayan/ Batasan Area, St. Peter's Church/ Ever Gotesco Mall Area, North Susana Area, and Elliptical Road/ Philcoa Area.

Concentrations of Damage to Property of road crashes is observed in Mindanao Ave. Intersection – (Fairview) Regalado, Fairview Center Mall – East Fairview Area, Litex Area, Sandigan Bayan/ Batasan Area, St. Peter's Church/ Ever Gotesco Mall Area, North Susana Area, Luzon Area, and Elliptical Road/ Philcoa Area. Most of these locations were almost similar where Non-Fatal Injury crashes occurred.

After manually plotting and taking note of longitude and latitude coordinates of the crash sites, the QGIS Heatmap plug-in tool was utilized to provide visualization of the spatial significance or clustering of road crashes in the specific road segment. Using the Kernel density function the magnitude per unit area was calculated from the point feature.

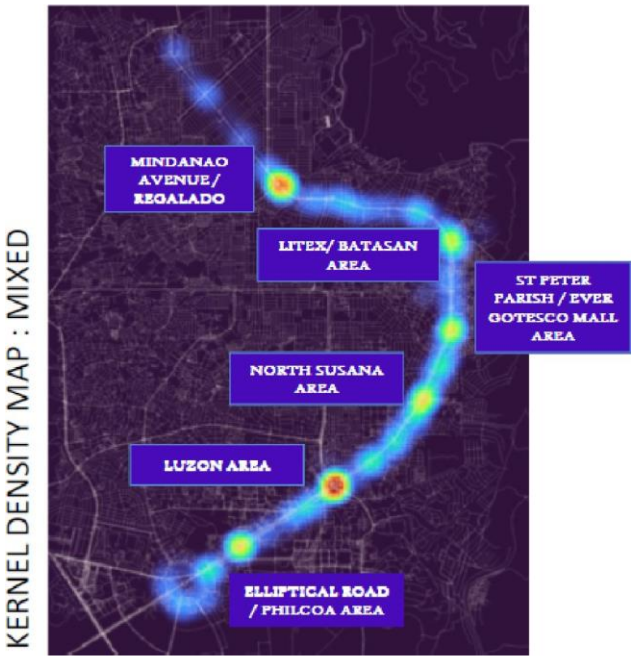

Figure 5. Kernel Density Map of All PUV-related road crashes along Commonwealth Ave., 2019-2021

The result of the interpolation process illustrated that high density of PUV related road crashes are clustered in the Tandang Sora/ Luzon Area Road segment. Medium density is attributed to the Fairview-Regalado Road segment. Low density on the other hand is concentrated along the road segments of Elliptical Circle-Philcoa and Ever Gotesco Mall - St. Peter Parish Area.

Furthermore, Kernel density maps of road crashes involving each type of PUV were considered. As illustrated in Figures 6, road crashes involving FX/ Taxi/ Shuttles clustered mostly in Tandang Sora and Luzon Avenue road segments, areas along St. Peter Parish Church/ Ever Gotesco Mall, Technohub and Elliptical Road/ Philcoa. Bus-related road crashes were prevalent along the road segments of Regalado/ Fairview Center Mall and Batasan / Litex Area.

Conversely, high density of road crash clustering involving public utility jeepneys were present along Tandang Sora / Luzon Avenue, North Susana area, St. Peter's Church/ Ever Gotesco Mall Area and Regalado/ Fairview Center Mall. Road crash concentration were also visible along Dona Carmen Area and Elliptical Road/ Philcoa Area

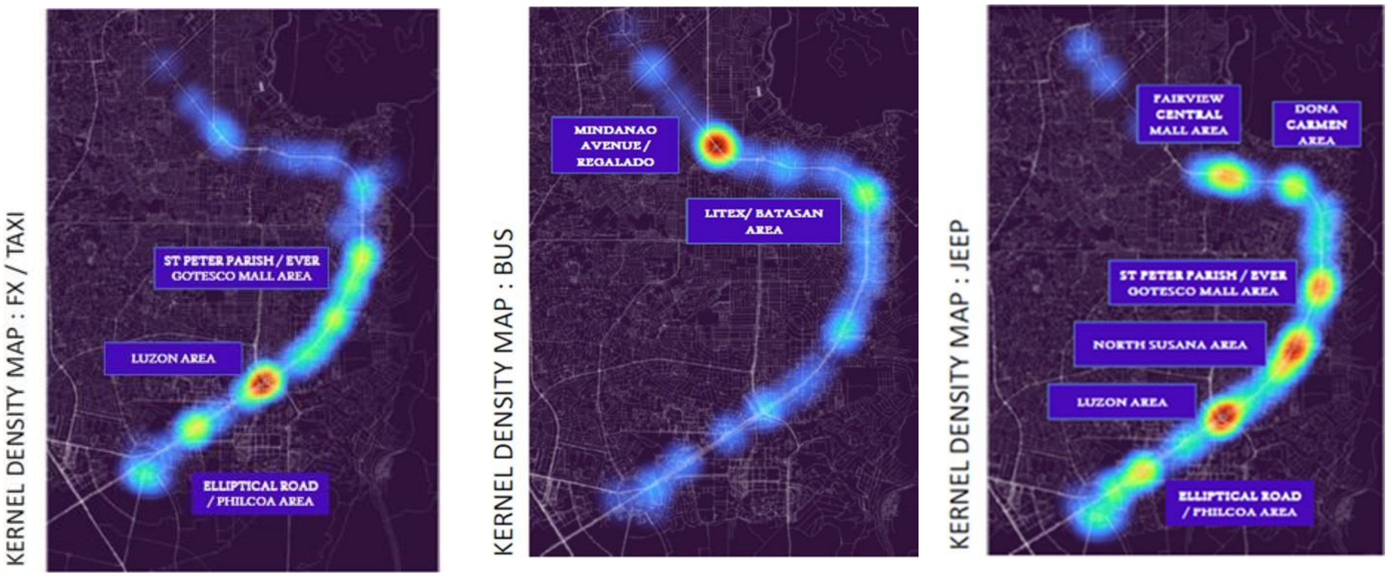

Figure 6. Kernel Density Map of PUV-related road crashes along Commonwealth Ave.

PUV- related road crash maps in relation to the time of occurrence exhibited concentrated clustering along Luzon Area, North Susana Area and Regalado Area for both Daytime and Night-Time period. Figure 7 below also indicated clustering along Elliptical Road/ Philcoa Area, St. Peter's Church/ Ever Gotesco Mall Area, Fairview Center Mall and Dona Carmen Area.

Figure 7. Kernel Density Map of PUV-related road crashes along Commonwealth Ave. by time of day, 2019-2021

Figure 8. Kernel Density Map of PUV-related road crashes along Commonwealth Ave. during peak hours, 2019-2021

Figure 8 illustrates that the peak hours of high number of road crash occurrences are between the time 7:00 am - 10:am and 17:00 pm -20:00 pm. Figure 8 highlighted the aggregation of road crashes during the said peak hours. The rendered AM peak map illustrated high density around the elliptical road specifically on converging points near the North Avenue, Visayas Avenue and Quezon Avenue road segments and along Luzon / Tandang Sora Area. The PM peak map showed densification in the North Susana area.

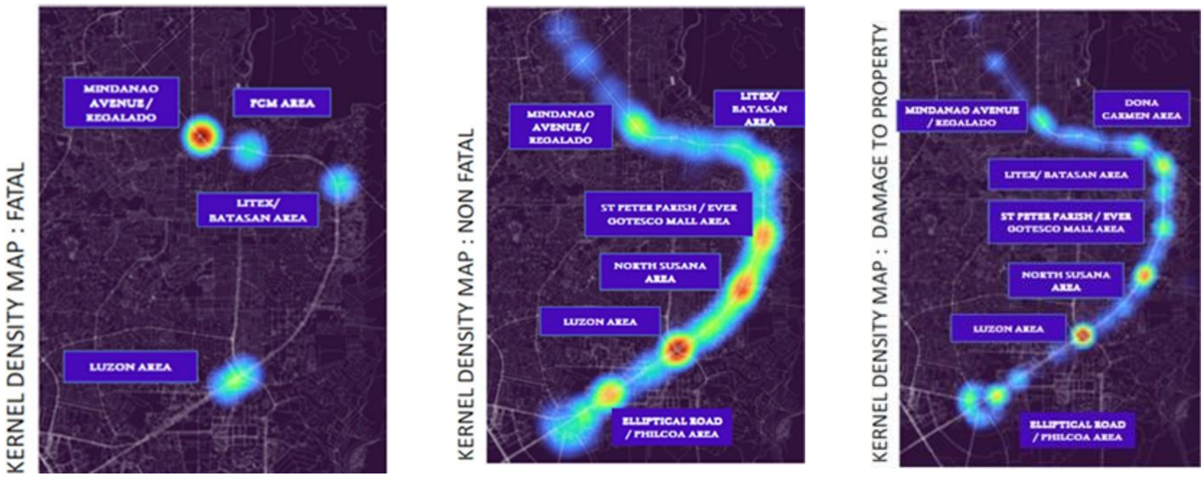

Figure 9. Kernel Density Map of PUV-related Crashes along Commonwealth Ave. by Crash Classification, 2019-2021

Figure 9 presents the clustering of crash points classified according to the type of road crash. It provides visualization of the 7 recorded fatal road crashes that occurred in 4 road locations. High density fatal road crashes are clustered in the Fairview-Regalado road segment, followed by Luzon / Tandang Sora area, Camaro St and Batasan-Sandigan Bayan road segments. Non-fatal road crashes on the other hand are exhibited in four concentrated locations. The recorded 425 non-fatal type is significantly clustered in Tandang Sora-Luzon- road segment and Elliptical Road, North Susana Area.

Furthermore, a large percentage or 78% of the PUV related road crashes that led to Damage to Property were also observed in the Fairview-Regalado, Tandang Sora-Luzon; Q.C. Circle-Philcoa; and Ever-Gotesco-St. Peter Parish road segments.

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Figure 10. Kernel Density Map of Collision Type along Commonwealth Ave., 2019-2021

As indicated in Table 4, Sideswipe collisions and Rear end collisions accounted for 48% and 24% of the total collision type recorded during the study period. As shown in Figure 10 Side Swipe and Rear end collisions were dominant along Luzon Ave / Tandang Sora Area. and North Susana.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study found that the utilization of the spatial capabilities of the Quantum Geographic Information System (QGIS) and the statistical power of Kernel Density Estimation (KDE) can assist in carrying out a comprehensive analysis of road crashes. The heatmap plug-in tool in QGIS can provide an enhancement through the visualization of crash concentration maps and the identification of areas with a high density of crashes. The study has specifically identified that public utility vehicle (PUV) related road crashes are most prevalent in specific locations along Commonwealth Avenue, including Luzon Avenue/Tandang Sora Area, Regalado/Fairview Center Mall, North Susana Area / Ever Gotesco Mall, and Elliptical Road / Philcoa area. Transportation planners, traffic engineers, and decision makers can gain a better understanding of the causes of road crashes, identify prevailing patterns, key factors, and identify crashes based on type and site conditions for further investigation. Most importantly, visual assessment provided by the KDE can aid in devising effective countermeasures aimed at reducing crash rates along Commonwealth Avenue.

5.2 Recommendations

The results of the study arrived at the following recommendations:

- Accurate data collection methods and recording of road crashes need to be ensured. A manual on data collection and recording must be developed. Personnel doing the groundwork should be properly trained in the method.
- Information in MMARAS should also include coordinates of the specific road crash

location. The existing information in the MMARAS does not identify if the road crash happened in the north or south bound of Commonwealth Avenue.

- Also, in the long term, a police officer or crash investigator should be equipped with proper equipment to accurately plot the details of road crash incidents, particularly in identifying the accident factor.
- MMDA to conduct a road safety audit on the identified hotspots; and
- Future research should carefully assess crash-related factors such as the time of day, land use, road conditions and traffic volume to determine the cause of road crashes and the remedial measures needed.

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