Black Spot Cluster Analysis of Motorcycle Accidents

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Abstract: Road accident is now considered as a global problem. It is a cause of concern in the Philippines since road accidents are at present the major causes of fatalities, injuries and property damages. In Metro Manila, majority of the road accidents are incidents involving motorcycles. It is in this context that this study seeks to promote motorcycle safety awareness through the spatial analysis of motorcycle accident locations in Quezon City. The study will show that the clustering of accidents can be inferred from a Kernel Density Map, generated through the use of GIS, after manually plotting its location based on existing traffic accident records. It was found out that the higher density of accidents involving motorcycles in Quezon City are along major corridors such as Commonwealth Avenue, Elliptical Road, Quirino Highway, Mindanao Avenue and EDSA.

Keywords: motorcycle, tricycle, accidents, blackspot analysis, GIS, Kernel Density Map

1. INTRODUCTION

Road accidents are a problem worldwide, wherein in 2004 around 1.2 million people were killed (2.2% of all deaths) and 50 million more were injured in motor vehicle accidents. This translates to 2 lost lives per minute. Developing countries are particularly at a disadvantage as 70% of the fatalities occurring in these states. In 1990, road accident is the 9th leading cause of death. By 2020, it will be the 3rd leading cause of death. Road accident is also the leading cause of injury, with road accident injuries higher than occupational injuries.

The Philippines, being a developing country, unfortunately is an example of rising implications of road accidents. Figure 1 shows that the increase in registration of vehicles in the Philippines follows the trend of its growth in Gross Domestic Product (GDP) and population. This simply means that more Filipino people can now purchase vehicles due to rising disposable incomes. However, the lack of comprehensive road safety program likely will result to the continued increase in road accidents.

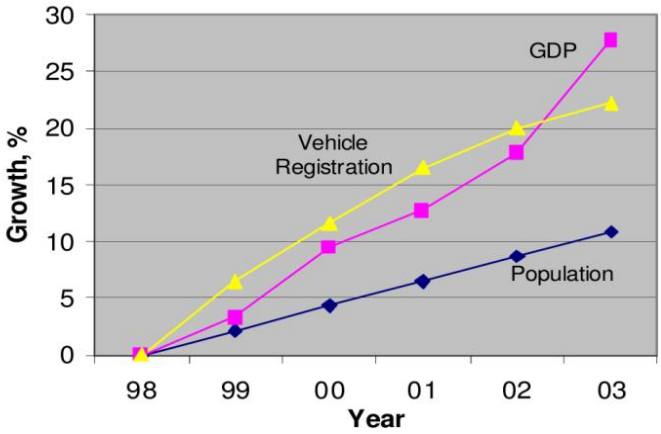
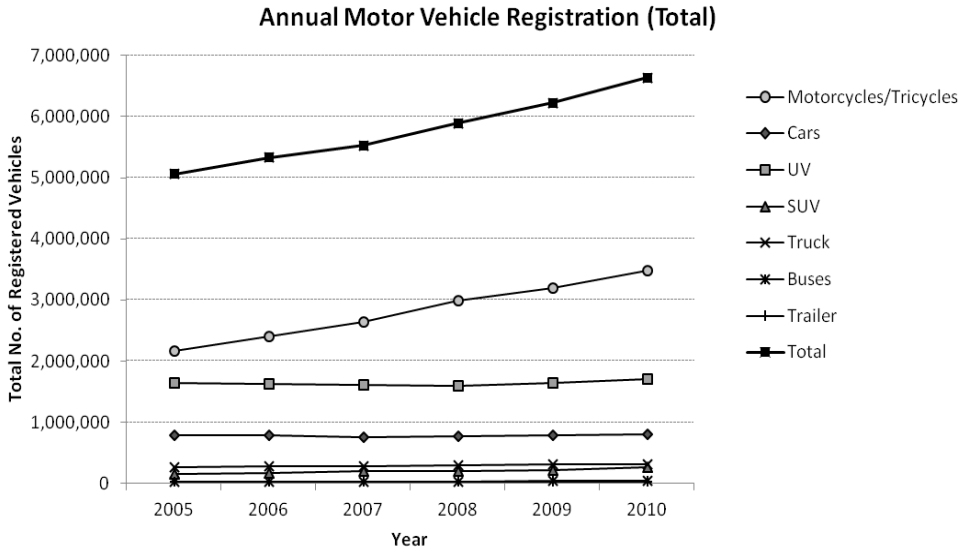


Figure 1. Comparison of Growth Rates (Vehicle Registration, Population and GDP)

Amongst vehicles that are involved in road accidents, motorcycles are the most vulnerable as both the driver and the passenger are highly exposed to the environment. Contributing to the vulnerability is the tremendous increase in motorcycle registration (which includes tricycles) as illustrated in Figure 2. It is noteworthy that the Land Transportation Office do not classify motorcycles and tricycles separately, because the registration of tricycles was delegated to local government units.

Motorcycles, now outnumber other vehicles in a given year starting 2005 (except in absolute total numbers). This increase can be attributed to the fact that motorcycles have become an important mechanism to promote social mobility because of price affordability. Lower income people now have improved mobility and yet it increased their vulnerability to injuries.



Source: Land Transportation Office, 2011

Figure 2. Motor Vehicle Registration by Vehicle Classification

The relative mobility of motorcycles has become the danger for the passengers and riders. Being nimble and having the ability to turn faster, motorcycles can weave in and out of traffic. This makes the likelihood of collision against other vehicles higher. Based on hospital account, motorized two-wheeler users tend to sustain multiple injuries, including to the head, chest and

legs. The majority of the fatal injuries are to the head. Lower-leg injuries – either from direct contact with the impacting vehicle or as a result of being crushed – contribute substantially to more fatal injuries. Motorcycles now have the highest rate of accidents in Metro Manila as demonstrated in Figure 3.

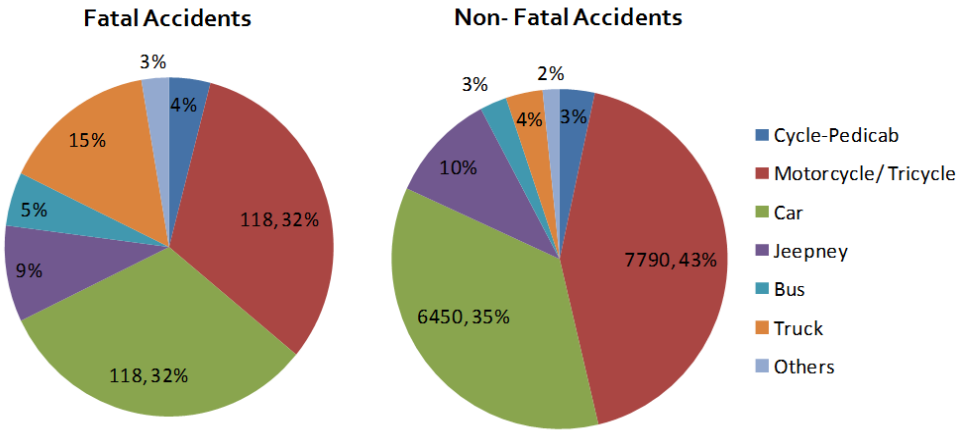


Figure 3. Percentage Share of Fatal Accidents by Vehicle Involvement

Given the scarcity of government resources particularly funding for road infrastructure, it is therefore rational that more research in road safety is needed particularly for motorcycle accidents. However, most researches in the country have focused on statistical analysis of accident rates. Moreover, previous road accident mapping through GIS has general assessment across vehicle types or classifications. A study on motorcycle accidents is thus an additional dimension to the limited literature of road safety in the country.

The main objective of this study is to characterize the spatial profile of motorcycle accidents through the use of GIS. The expected outputs of this research is the (i) Identification of motorcycle accident black spot clusters; and (ii) Spatial profiles of motorcycle accidents.

2. SCOPE AND STUDY AREA

The scope of this study involves the spatial analysis of motorcycle and tricycle accident location, being the highest incidence of road accidents by vehicle involvement.

Quezon City is the largest city in Metro Manila in terms of land area and population. And more importantly, Quezon City major arterial corridors pass through its jurisdiction. The study area is Quezon City since it is has the highest incidence of motorcycle and tricycle accidents across Metro Manila. The total road accidents in Quezon City is 25,519, the highest amongst local government units in Metro Manila. And out of these road accidents, there were 4,485 motorcycle and tricycle accidents in the same city as shown in Table 1.

Table 1. Road Accidents in Quezon City

Category	All Vehicle Type	Motorcycles/Tricycles
Fatal	144	58 (40%)
Non-Fatal	4,797	2,422 (50%)
Property Damage Only	20,578	2,005 (10%)
TOTAL	25,519	4,485

3. REVIEW OF RELATED LITERATURE

Many highway agencies have been using Geographic Information System (GIS) for analyzing accident data. Identification of problematic locations is one of the most important aspects in accident studies. Although there is no accepted international standard definition of an accident blackspot, for the purpose of this study, a blackspot or hazardous road section will be defined as a road section wherein the expected number of accidents is higher than other similar locations (Sorensen and Elvik 2007). The GIS based application combines the information collection capabilities with the visualization. In 2004, The University Putra Malaysia developed a GIS and Road Accident View System and a set of applications developed for managing accident database entries. The developed system was designed based on the Universiti Putra Malaysia (UPM) community area and may be adapted very easily to any other places.

The system was developed using Microsoft Visual Basic 6.0 in Windows XP platform. The database was designed in terms of textual format. The Accident Report from UPM security unit was used as the source for information needed in the database development wherein the location of the accident was recorded on a map. And by browsing on it, the user can perform queries on a particular condition to get the number of accidents.

The research paper of UPM has shown that traffic accidents data can be collected, analyzed and presented in a systematic way through a GIS program. With the proper setup of Accident GIS System, the user or decision maker can retrieve, analysis, and display database on its spatial characteristics. The GIS Software can provide the core functions through entering, searching and retrieving information from database; main supportive functions through Node Analysis and Distribution Plot; and Minor functions through Searching Engine and Accident Ranking. Thus the GIS based application was concluded to improve the accuracy and timeliness in priorities accident location.

In another research paper, Kernel Estimation cluster analysis technique was used to automatically identify road traffic accident ‘black spots’ and ‘black areas’ in Christchurch, New Zealand. GIS and Python scripting was used to implement the technique, using spatial data of recorded accident locations. Kernel Estimation was able to quickly identify the statistically significant accident clusters.

In Flahaut et al (2002) focused on spatial data analysis problem: defining the location and the length of black zones. Two methods are compared: the use of local spatial autocorrelation indices (a decomposition of the global Moran index) and kernel estimation. Both methods differentiate local dangerousness and generate a smoothing of the empirical process. Although each method are different in its conceptual approaches, both provided quite similar results under a specific parameters.

Furthermore, Lu (2000) compared kernel density to other spatial analysis techniques and found out that Kernel density is more reliable and desirable for hot spot analysis. Lu has the following observations: “First, kernel density uses more information about point distribution than virtually all distance view cluster algorithms. A continuous density surface is generated over all locations to let data pattern show itself. Users can visually inspect the variability of density over the whole surface and identify hot spot depending on his/her observation point of view. Second, since density is a measurement of magnitude, in addition to showing spatial clustering, hot spots are comparable over space as well as between studies. Algorithms based on spatial separation of observations are shy to support the quantitative comparison of hot spots. Third, kernel density technique is more arbitrariness free and provides relatively stable analysis results to user.”

It is for this reason that Kernel density is adopted in this study.

4. METHODOLOGICAL FRAMEWORK

Given the experience of previous countries in plotting accident locations, the study team developed its own methodology to present GIS Blackspot mapping in Metro Manila, specifically in Quezon City. Motorcycle and tricycle accidents were extracted from the Metro Manila Accident Reporting and Analysis System (MMARAS) database of road accident reports in Metro Manila, which is being maintained by the MMDA. The MMARAS is operated by the Road Safety Unit (RSU) of the MMDA-Traffic Operations Center (TOC), with the cooperation and assistance of the Traffic Enforcement Group under National Capital Regional Police Office (TEG-NCRPO) Philippine National Police (PNP). The accident data are based from individual report forms for each accident, gathered by Data Researchers Group of the RSU from different stations and Districts Offices of the Traffic Enforcement Group.

However, it is important to note that there is 60 to 70% under-reporting of road accidents in the Philippines (Vibal, 2003). Road accidents reported in hospitals are examined to be higher compared to accidents reported in police stations. Whether there is inherent distrust to the police community or general avoidance of perceived further administration costs, a good reporting system for road accidents is essential to fully understand the implications of road safety.

Upon collection of the data from MMDA, the individual locations of these motorcycle and tricycle accidents are then plotted or place-marked in Google Earth to have geo-referenced accident locations. GIS technicians were hired to facilitate the expeditious plotting of numerous accident locations. The location files from Google Earth were then imported into ArcGIS 9.3, for which these were converted into shape files (point feature). Other attributes of the motorcycle and tricycle accidents from the MMARAS database were "spatially-joined" with the location shape files.

As a further analysis, accident valuation was also done to determine the total costs arising property damages, injuries and fatalities. Each accident was given corresponding socio-economic cost values using the results of the previous study of one of this paper's authors made. However, in the previous study, the author had four (4) classifications of accidents, namely fatal, serious injury, minor injury, and property damage only, which is consistent with internationally used accident classification systems. And yet in MMDA's MMARAS database, there are only 3 classifications; fatal, non-fatal injury, and property damage only accidents. As such, for injury accidents, the cost for minor injury accidents in the previous study was adopted for non-fatal injuries of the MMDA database.

Attributing costs to each accident will enable planners and decision makers to have a grab of the social and economic magnitude of accidents, where each live and property damage are given monetary values to consider loss economic opportunities, medical costs, etc.

The accident locations are then mapped out, for which Kernel Density Mapping is undertaken. 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. Other thematic maps are derived including spatial grid indexing of attributes. Figure 4 shows this methodological framework adopted for this study.

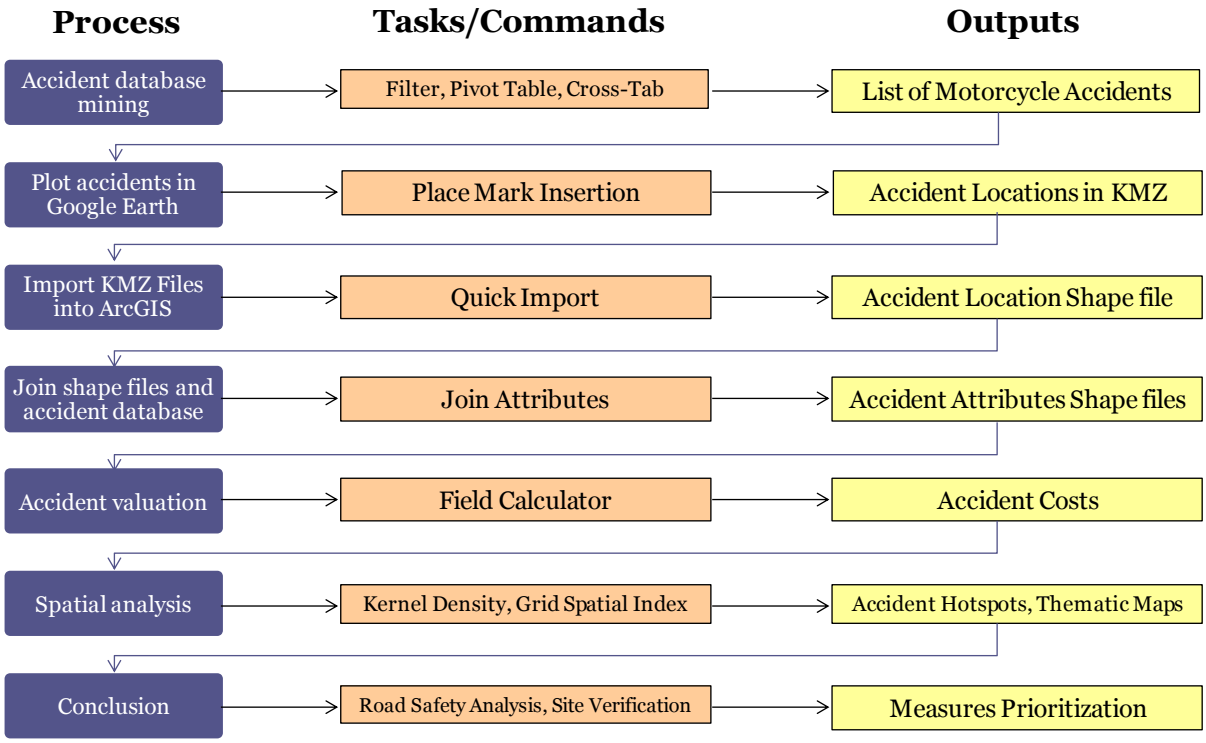


Figure 4. Methodological Framework for the Study

5. SUMMARY OF FINDINGS

The accident data for this study was extracted from MMARAS which is an Accident GIS Database System operated and maintained by the MMDA. However, there are inherent downsides to the MMDA-MMARAS, which are mostly budget related. There is no GIS software. Data collection is manually done by researchers collecting filled-up accident investigation forms from PNP-TEUs. Sometimes, accident investigation forms are not used and instead, the researcher would need to extract information from narrative police blotter reports from logbooks. In the process, important data may have been overlooked either by the police or by the researcher. Furthermore, accident data from accident reports are manually encoded through MS Excel. Based on interviews from MMDA personnel and PNP-TEU police investigators, there is a general inadequacy of training for accident investigation and analysis. In spite of these constraints, a total of 3,697 data points were utilized, which comprised of motorcycle and tricycle accidents in Quezon City for the year 2010. These data points were the usable records that have been imported from the accident plots in Google Earth. Some of the accident data have been identified as invalid because of inconsistent location (i.e. EDSA corner Commonwealth Avenue) or locations which cannot be found using Google Earth, Wikimapia, and or OpenStreetMap (i.e. in front of a sari-sari store).

After plotting in Google Earth, the KMl file was imported into ArcGIS for which these were converted into shape files (point feature). After joining corresponding attributes, the resulting GIS database can be sub-classified according to subject attributes or themes. **Figures 5** to **8** show the accident points of motorcycles and tricycles in Quezon City, for which the accident plots were translated into maps generated through ArcGIS.

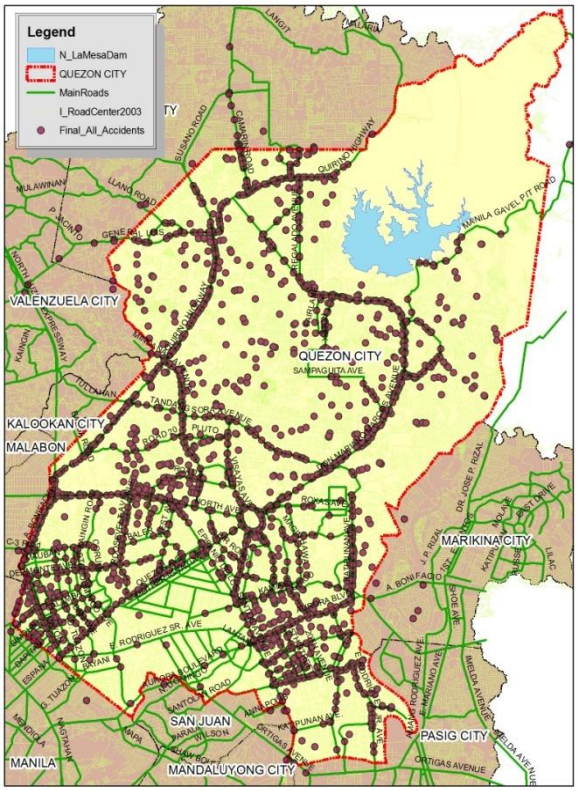


Figure 5. Plot of Motorcycle and Tricycle Accidents in Quezon City

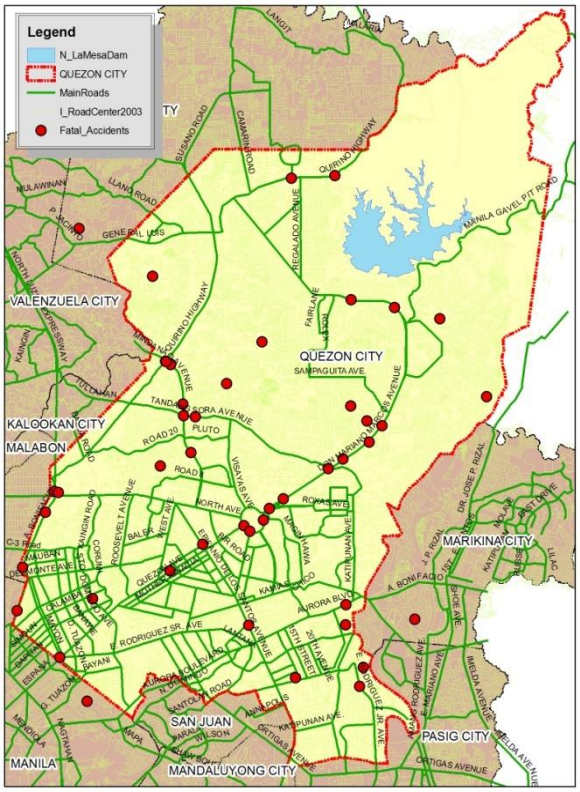


Figure 6. Plot of Fatal Accidents in Quezon City

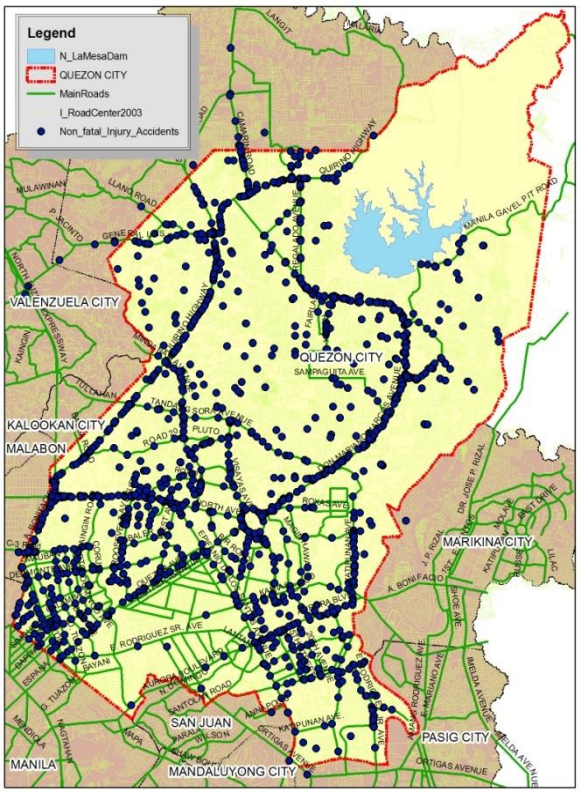


Figure 7. Plot of Non-fatal Injury Accidents in Quezon City

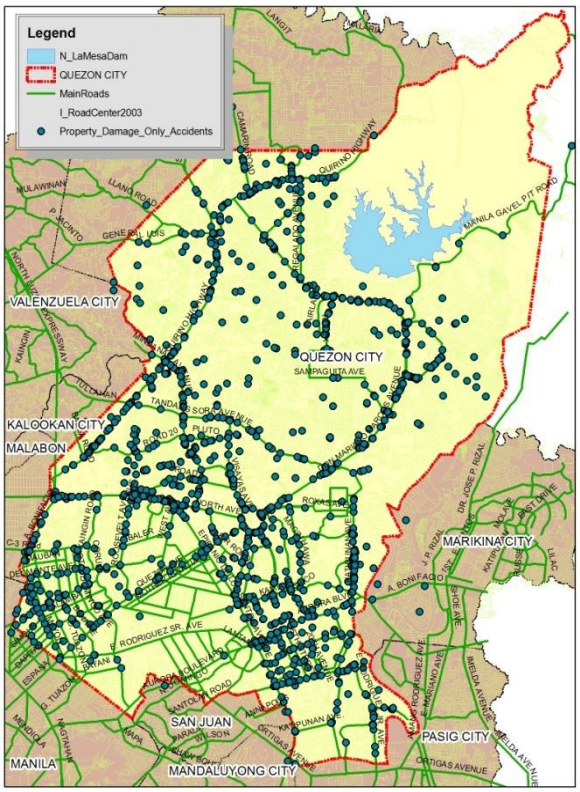


Figure 8. Plot of Property Damage Accidents in Quezon City

The accident plot maps do not show the spatial significance or clustering of accidents in certain road sections. It seems that every road is plotted with accident sites. By using the Kernel Density function of ArcGIS, the density of features is a calculated in a given area around the accident sites. Spatial analysis of motorcycle and tricycle accidents through the Kernel Density Method would show that the spatial density of accidents involving motorcycles and tricycles are heaviest along Commonwealth Avenue, Elliptical Road, EDSA, Quirino Highway and Mindanao Avenue (see Figure 9). Meanwhile, the spatial density of motorcycle and tricycle accidents is lightest in local roads within Quezon City (i.e. city and barangay roads).

Figures 11 and 12 show the densities or clustering of the accident counts in terms of fatal accidents and night time accidents. The Fatal Accident cluster map shows that the most fatal motorcycle accidents occur in Quirino Highway corner Mindanao Avenue and Tandang Sora corner Mindanao Avenue. The stretch of Commonwealth from QC Circle to North Fairview is also littered with fatal accident sites specifically near Philcoa and UP Technohub. And when compared with night time fatal accidents, this map shows little difference as most fatal motorcycle accidents happened at night at a rate of 32 out of total 47 fatal accidents. Further analysis of the fatal accident statistics shows that there are 32 drivers killed, 4 drivers injured; 8 passengers killed, 8 passengers injured; 10 pedestrians killed, 10 pedestrians injured; and Average age of fatalities is 31 years old. Based on these statistics, we can deduct that of the 47 fatal accidents, 32 drivers were killed. This shows that for motorcycle accidents, the most vulnerable victim will always be the driver. The average age of the fatalities is 31years old, which can be considered as productive members of the society. These early deaths can also be treated as an economic loss if we take into account the economic productivity of the fatality if he could have lived much longer.

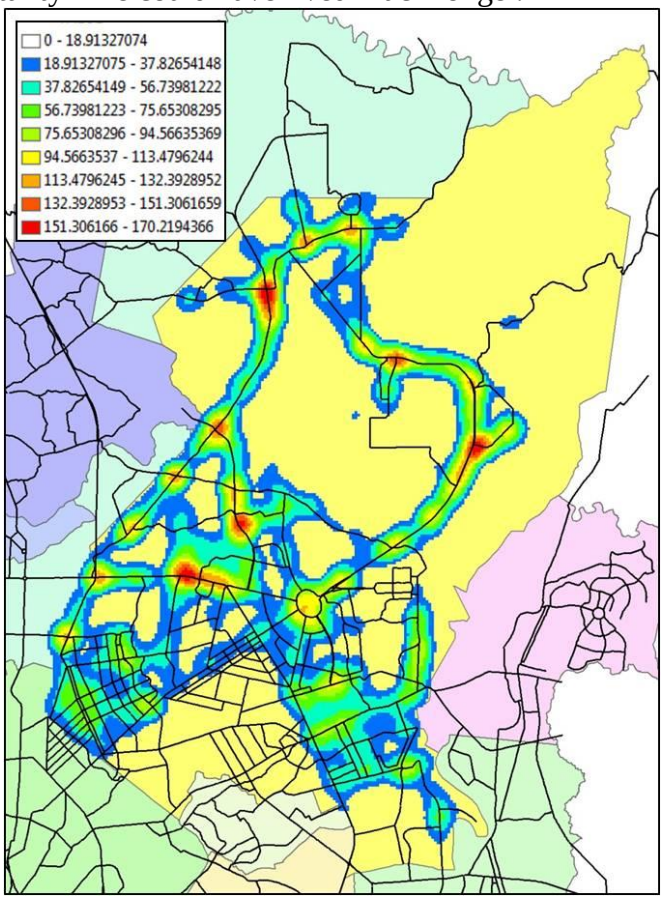


Figure 9. Kernel Density Map of Motorcycle and Tricycle Accidents in Quezon City

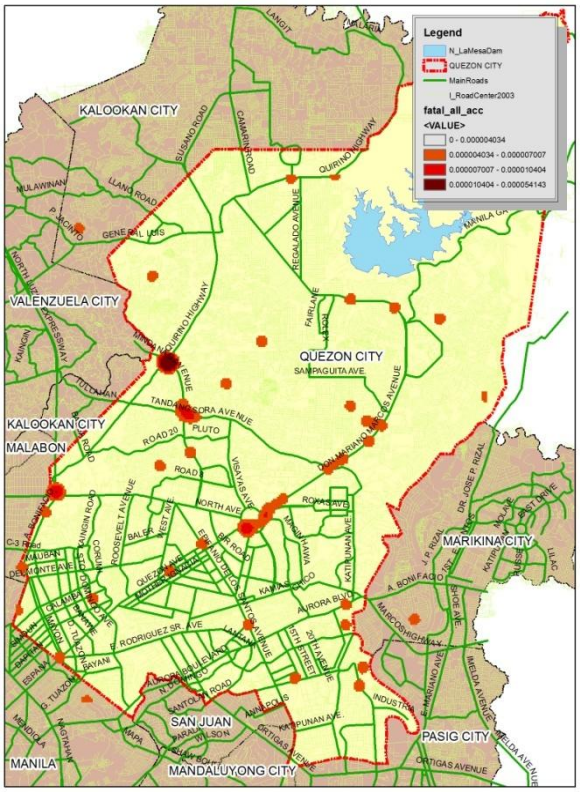


Figure 10. Fatal Motorcycle and Tricycle Accidents Density Map

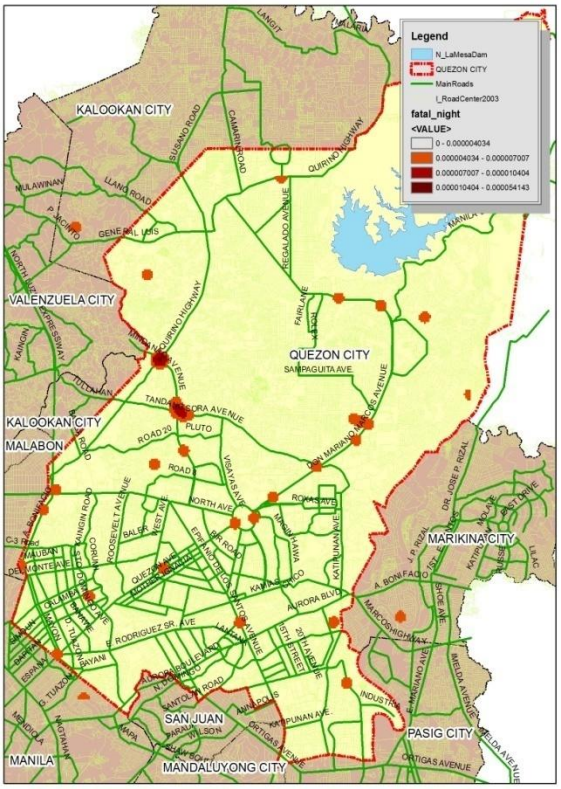


Figure 11. Nightime Fatal Motorcycle and Tricycle Accidents Density Map

In this study, clustering can be viewed as densities or levels of incidences (low or hig). For the high occurrence of injury accidents, there seem to have no single prevailing accident cluster site for this type of accident. The entire stretch of Commonwealth and Quirino Highway and portions of EDSA are considered as hotspots for injury accidents (see Figure 12). Meanwhile, as shown in Figure 13, Property Damage Only Accidents have high incidence rates at Quirino Highway corner Mindanao Avenue; Quirino Highway coner Tandang Sora; Quirino Highway corner Baesa Road; Quirino Highway (Bayan and Regalado, SM Fairview); Stretch of EDSA from North Avenue to Roosevelt; EDSA corners Kamias and Aurora Boulevard; Mindanao Avenue coner Tandang Sora; Quezon Circle; Katipunan Avenue; and Commonwealth (Batasan and North Fairview).

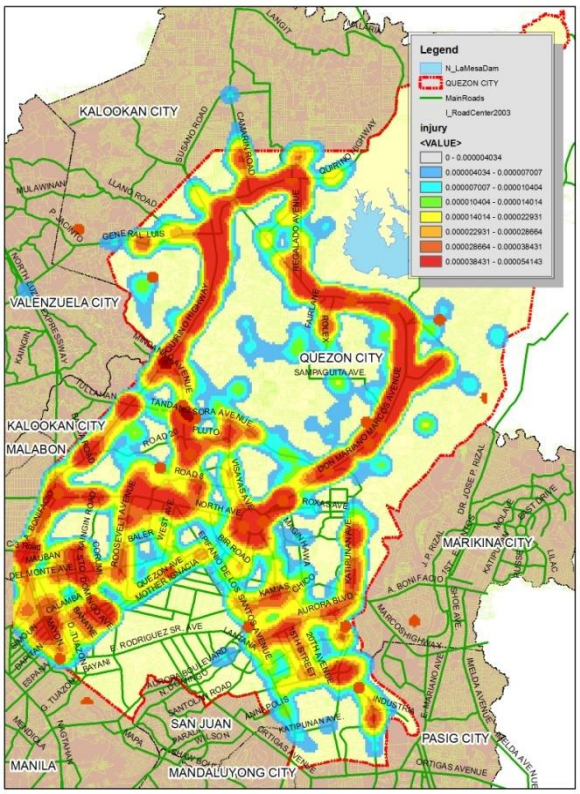


Figure 12. Motorcycle and Tricycle Injury Accident Density Map

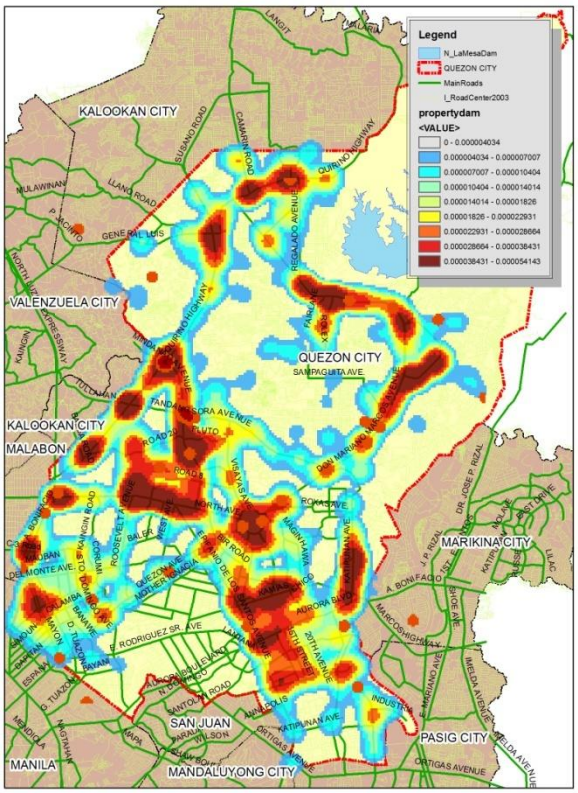


Figure 13. Motorcycle and Tricycle Property Damage Density Map

It can be further examined in the points from the GIS database that these road sections where PDO accidents are dominant are also installed with u-turn slots. Also, there were at least 3,225 vehicles involved in motorcycle accidents. These comprise of 1382 motorcycles, 359 Tricycles, 990 cars among others. Using the results of the study conducted by de Leon (2005), all of these property damage accidents in QC already cost PhP 69 Million pesos.

Figures 14 and 15 show the clustering or density of fatal and injury pedestrian accidents. Figure 14 shows the Kernel Density map of fatal accidents occurring mostly in the QC Circle and Commonwealth Avenue. On the other hand, Figure 15 highlights the large occurrence of pedestrian injury casualties in Quirino Highway (Novaliches Bayan); Quirino Highway (Baesa Road); Quirino Highway (Tandang Sora); Batasan Complex; Commonwealth (Luzon Avenue); and SM Fairview. Commercial establishments at the northern part of QC (SM Fairview) also attract pedestrian and commuter activity thereby exposing more people to motorcycle accidents.

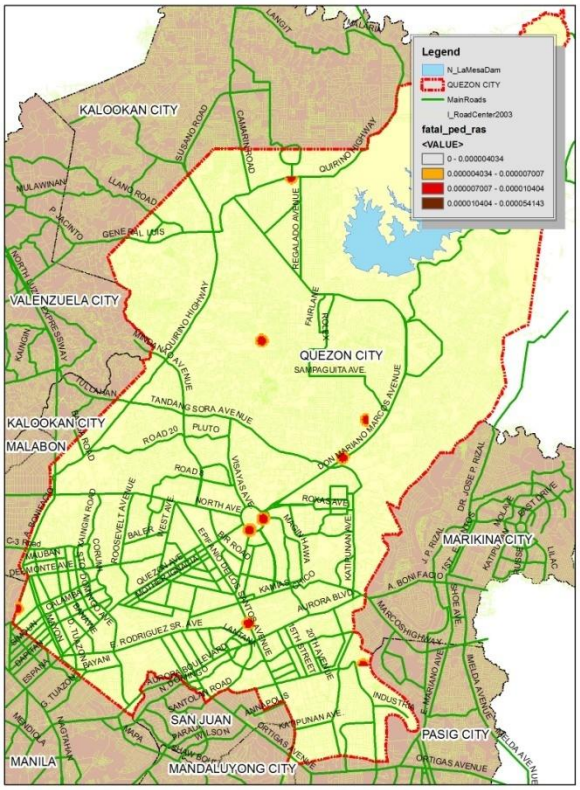


Figure 14. Motorcycle and Tricycle resulting to Fatal Pedestrian Accident Density Map

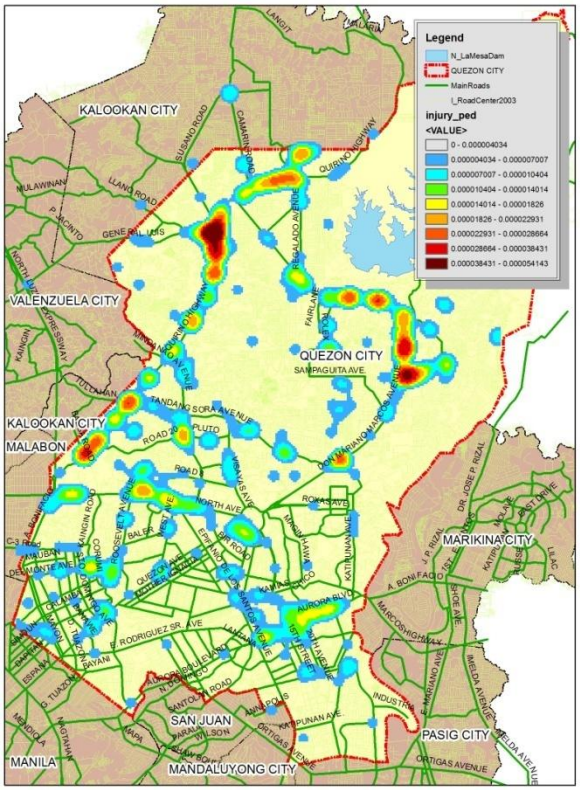


Figure 15. Motorcycle and Tricycle in conflict with Pedestrian Injury Density Map

Alarmingly, based on the statistics of MMDA, pedestrian casualties have an average age of 51 years old. These show a disregard of motorcycle users to the pedestrians especially the elderly. It can be surmised that the driving behaviour of motorcycle riders weaving in and out of traffic and sometimes invading the sidewalks is the cause of these accidents.

Although based on the database, daytime motorcycle accidents (2,466) outnumber night accidents (1,231), it can be said that most of these night accidents are fatal in nature and are mostly resulting to injury accidents. Figure 17 shows the cluster or density of accidents during night time. It shows accidents are numerous at night at: Quirino Highway corner Mindanao Avenue; Quirino Highway coner Tandang Sora; Quirino Highway corner Baesa Road; Quirino Highway (Bayan and Regalado, SM Fairview); Stretch of EDSA from North Avenue to Roosevelt; EDSA corners Kamias and Aurora Boulevard; Mindanao Avenue coner Tandang Sora; Quezon Circle; and Commonwealth (Batasan and North Fairview).

Assigning costs for each accident enables planners and decision-makers to grasp the magnitude of the accident in a given site in terms of pesos and centavos. Although this may seem inhumane, where we assign values to the lives and limbs lost, albeit this is the most straight forward way of evaluating the cost of accidents to the society. This is also useful in determining benefit savings from lives saved because of road safety improvements which are otherwise difficult to justify and difficult to fund with road safety not within the list of priority programs of the government.

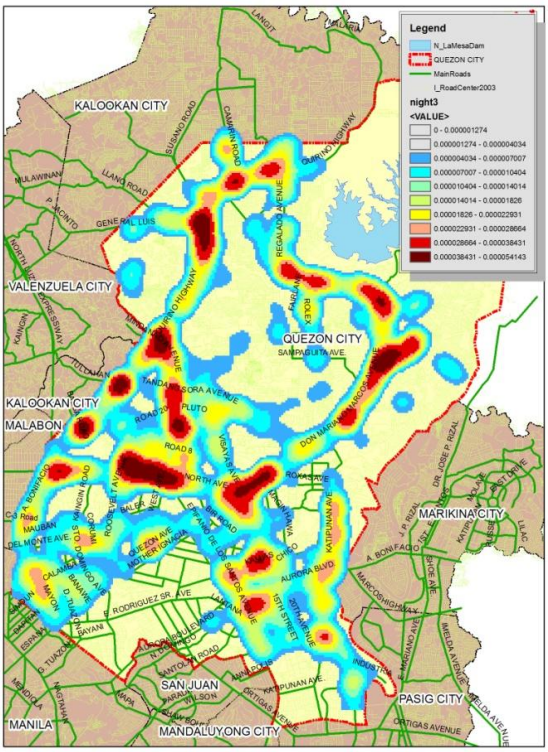


Figure 16. Motorcycle and Tricycle Night Accidents Density Map

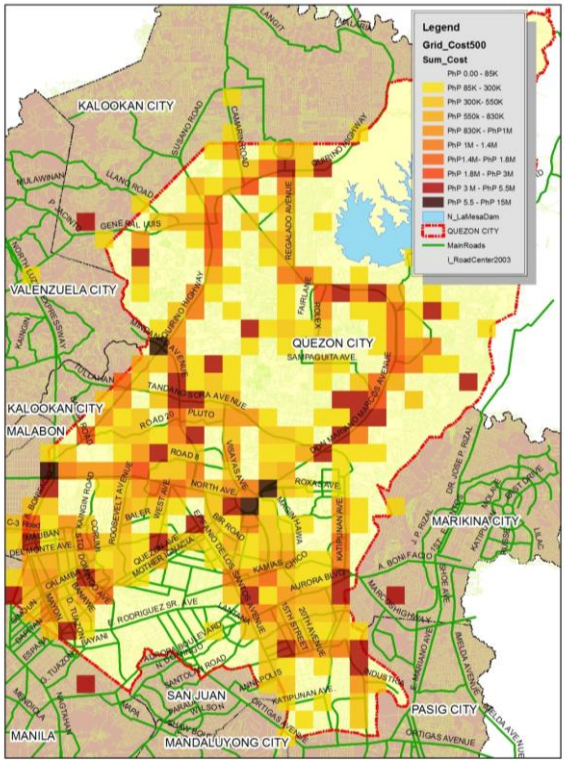


Figure 17. Total Cost of Accidents within a 500 meter Grid

Given this accident cost mapping as shown in Figure 17, it can be seen that motorcycle accidents in QC are most costly in: QC Circle (Philcoa and East Avenue side); Balintawak Interchange; and Quirino Highway corner Mindanao Avenue. The cost of accidents in the above-mentioned sites amount to PhP 5.5 Million to PhP 15 Million for the year 2010. Given this historical cost, it is only just to allot funding for road safety improvements in these areas to avoid future loss of lives and limbs.

In summary, spatial analysis of motorcycle accidents through the Kernel Density Method would show that the spatial density of accidents involving motorcycles and tricycles are heaviest along Commonwealth Avenue, Elliptical Road, EDSA, Quirino Highway and Mindanao Avenue (see succeeding figures) Meanwhile, the spatial density of motorcycle and tricycle accidents is lightest in local roads within Quezon City (i.e. city and barangay roads).

A kernel density map of accident costs would also illustrate that costs are highest in major intersections of the arterial corridors previously identified. The spatial densities of other accident attributes (e.g. accidents by fatalities, injuries, property damage; day-time and night-time accidents; accidents by victims, pedestrians) follow a trend similar to the spatial density of accident counts.

6. CONCLUSIONS

Based from the Black Spot Cluster Analysis, the arterial corridors in Quezon City that are critical for motorcycles are Commonwealth Avenue, Elliptical Road, EDSA, Quirino Highway and Mindanao Avenue. The Quezon City Government, MMDA and the Department of Public Works and Highways (DPWH) might want to prioritize these roads for a general program of road safety measures. There is another enormous set of road accident data points outside of Quezon City that can be plotted and analyzed through GIS. The pattern of accident clustering, however, can still be the same. And these corridors are the abovementioned arterial

roads, which traditionally have higher traffic volumes and pass-through traffic.
This study is a good case for GIS as an important tool for the spatial characterization of road accidents. Despite the need to improvement robustness, MMDA database is a good source of information from which road accidents in Metro Manila can be spatially profiled through GIS. GIS is a good tool in this road safety audit activity as GIS can provide a rapid appraisal of accidents in a site given the adequacy of data.

Furthermore, majority of the cost of accidents are resulting from property damages as these occur most often. The wide occurrence of underreporting especially for property damage accidents should be taken seriously. Accurate reporting could have given the authorities and policymakers factual values on the damages involved thus they have tools to evaluate existing policies and programs on road safety. Without accurate data, more under-reporting and inaccuracy of data for accident will be expected, thus giving the false impressions of roadworthiness and road user safety.

7. RECOMMENDATIONS

Enhancement of MMDA MMARAS. Assessing the data system, the collection of data is hampered by internal administration problems, which are more related to budget constraints. As such, the use of an extensive database system has been downgraded continuously and the personnel of the RSU are now only utilizing Microsoft Excel spread sheets to compile road accident data. This was in sharp contrast to the original intention of coming up with a modern and updated database system that can be used in not only for coming up with measures to address road safety but also for research and analyses.

Further to this, the intention of encoding these data into a GIS database system has been deferred. Moreover, it is perceived that the process of data collection from the individual TEGs of the PNP scattered in the Metropolis is hampered by inconsistencies and omission of important data. This is due to the fact that the researchers of the MMDA-RSU will have to retrieve accident data logged by traffic investigators of the PNP from their logbook and input them to MMDA's database. Likewise, the accident logs of the PNP are perceived to have some degrees of unreliability because of its narrative nature, which relies heavily on the aptitude of the police officer to write a comprehensive accident report. And with the absence of a template, necessary data to be collected are sometimes overlooked.

Given the above shortcomings of the database system of MMARAS, it is imperative that improvement and updating of the system and its collection and management process be proposed. There is a need to further develop the database system so as to ensure a reliable and usable road accident database for Metro Manila will be available.

Implementation and Prioritization of Road Safety Measures. The density maps will show the spatial clustering of black spots. This means that these density maps show the clustering of high incidence of motorcycle accidents in Quezon City. With resources always an issue, government agencies can prioritize the implementation of road safety measures in these black spots or clustering of high incidence of subject accidents. There is a wide spectrum of road safety measures from motorcycle lanes to road safety signs, which are options that government agencies can choose from. However, these measures should be subject for further studies and evaluated for its applicability in the subject road sections.

Use of Mobile GPS Device. Accident reporting can be enhanced by equipping the traffic accident investigators with Mobile GPS devices that can plot the location of road accidents and directly record accident investigation data via a mobile device enabled with accident investigation software. This will ensure faster accident investigation process and will facilitate data processing and retrieval. Having a simple accident investigation software may

also reduce perceived discrepancies derived from encoding of accident investigation forms to the MMARAS database.

More quantitative analysis on Accidents/ Accident Factors. As a further step, research is needed in the statistical risk, spatial, and land use relationship of road accidents. Modelling of the different contributory factors (or attributes) of road accidents can also be a good material for future study. More detailed spatial analysis, can help in coming up with physical mitigating measures and schemes so as to minimize road accidents, notably motorcycle-related ones. Furthermore, spatial analysis may be able to provide any link between land use and accidents and as such, appropriate and responsive land use-related measures can be recommended.

More quantitative data about accident analysis should be pursued for future researches like severity indices and accident exposure rates which would require analysis of MMDA against LTO data i.e. motorcycle-km, vehicle-km traveled, etc.

8. ACKNOWLEDGEMENTS

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