

Analysis of Road Traffic Accident Distribution in Tagaytay City Philippines

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Abstract

The study proposed a tool that will determine the distribution of road traffic accidents in the city. Specifically, the Geographical Information System was introduced. GIS able to analyze a high density of road traffic accidents of 1276 RTA cases in Tagaytay City. The tool able to specify areas of the city that has a high concentration of RTA; furthermore, the tool also provided information that the distribution of RTA is in a dispersed pattern. SEM makes the statistical analysis. Where the relationship of factors is determined. The tool was able to verify that young ages have the risk of being the victim that will add to the victim's count and high risk of fatality. Weather condition also shows as factors in the increase of RTA. The intense program for driving lessons and strict implementation driving licensure enrolment and proper planning of travel recommended. Also, real-time visualization for weather conditions recommended. Other studies suggest having vehicle technology to monitor real-time weather and safety parameters. A light-emitting diode that serves as a road guide light was indicated in the study.

Keywords

Traffic Accident Distribution, Tagaytay City, SEM, GIS

1. Introduction

A road traffic accident (RTA) is a collision between vehicles, between vehicles and pedestrians, and between vehicles and animals or fixed obstacles that can be resulted in one or more persons being killed or injured (OECD Health Statistics 2019). Road Traffic accident becomes a global public problem, having killed nearly 1.3 million people a year and injuring between 20-50 million people worldwide (WHO, 2013). Associated with the Road Traffic Accident is the widely used road transport (Paden et al., 2004) since the number of vehicles is increasing due to the economy's growth (Huang, Wang, and Hu, 2016).

In the Philippines, having 107 million population as of 2018 (PSA) has 11.6 million motor vehicles registered in 2018 (LTO), thus increase of motorization in a region is also a parallel increase of road traffic accidents which increased casualties, injuries, and property loss (Zhang et al., 2010). With this, the probability of RTA occurrences can be reduced by a systematic analysis of the RTA scenario in an area and by formulation solutions using proper traffic control devices, roadways signs, traffic practices, and roadways design practice. However, formulation solutions require analysis of spatial and temporal patterns in the area of road traffic accidents, which can be achieved through Geospatial Technology Application (Cheng and Washington, 2008). Unlike conventional methods, spatial approaches help to determine the patterns and identify the reasons for the characteristics of the patterns (Prasannakumar et al., 2011). As the GIS technology is popular with various traffic agencies for its visualization feature of RTA data (DeepthiJayan and Ganeshkumar, 2010) and understanding the spatial crash pattern will furthermore help to identify the area having a more significant number of RTA compare to its nearest area for comparison.

Datum from generated traffic accident report in Tagaytay for 2018 was obtained, consisting of 1276 cases of traffic accidents that comprise of Physical Injury - 221 cases, Fatality - 8 cases, and damage to property - 1048 cases (Tagaytay PNP, 2018).

Road Traffic Accident Database of Tagaytay City contains precise GPS location (Longitude, Latitude parameters), which motivates to study possible using GIS (Geographic Information System) as a mode of Spatial-Temporal Analysis.

Several studies have been conducted using Spatial-Temporal Analysis to establish patterns of RTA to identify critical locations. Shafabakhsh, Famili, and Bahadori (2017) analyzed urban traffic accidents in Mashhad Iran using GIS technology and used GIS tools such as Kernel Density Analysis and K-Function. Yamashita (2007) analyzed patterns of pedestrian accidents in Honolulu, Hawaii using K- means clustering techniques. In 2015, Baratian-Ghorghi, Zhou, and Jalayer developed a new methodology to predict the first and second possible entry points based on the crash locations and distance from upstream interchanges. Jones (1996) and Bentham (2015) were able to decrease the number of accidents in an area in Norfolk, the United Kingdom, using the K-function analysis method that identified the presence or absence of hotspot clustered. In 2004, in Mechelen, Belgium, a study was done to find black zones. Researches used linear and planar cluster analysis methods, and by comparing them, they established the location of the hotspots (Steenberghen et al., 2004). In Turkey, research was performed to evaluate accident distribution on the main road, located at the entrance of Afyonkarasiyar City. The researcher used two different methods of kernel density analysis and identified hotspot; the condition of accidents was considered hourly, daily, and seasonal basis.

1.1 Objectives

The objective of the study is to combine the used of several advanced spatial methods using GIS technology that will allow analyzing the distribution of road traffic accidents and will further focus and study on a concentrated area of study. Furthermore, Structural Equation Model (SEM) was used as a statistical analysis to evaluate the analysis of factors contributing to the accidents that will suggest recommendations and solutions to reduce traffic accidents in Tagaytay City.

2. Methods

2.1. Data Source

The study covered Tagaytay City only, located within the Philippines with coordinates of 14°06'N 120°56'E as shown in Figure 1. A total of 1276 Road Traffic Accident data were obtained from Tagaytay City Philippine National Police Traffic Investigation Section. The coverage of traffic report from January 1, 2018, to December 31, 2018. All traffic reports were collected from all the police precincts in Tagaytay and tabulated at their central police station, Tagaytay Component City Police Station as shown in Figure 2. Each accident report has a classification that has been used as a possible factor in the analysis. Each incident has barangays where the RTA happened alongside its coordinates that are valuable to locate using GIS technology, data and time of commission, weather and temperature, offenses, fatality, victim/suspect ages and sex, suspect education, and incident type, etc. These data types were used for statistical analysis using SEM.

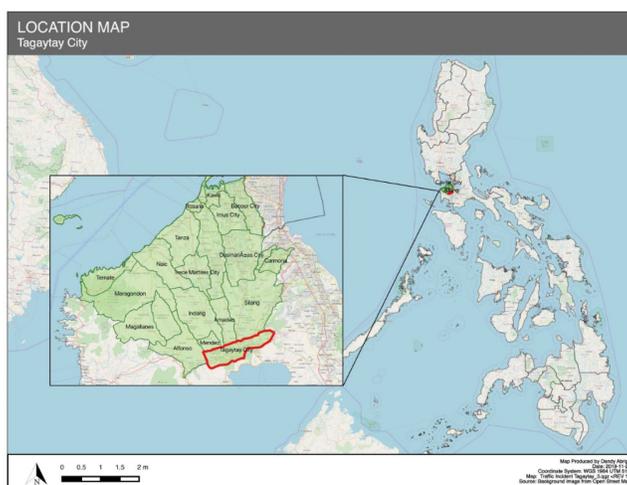


Figure 1. Tagaytay City within Cavite Map

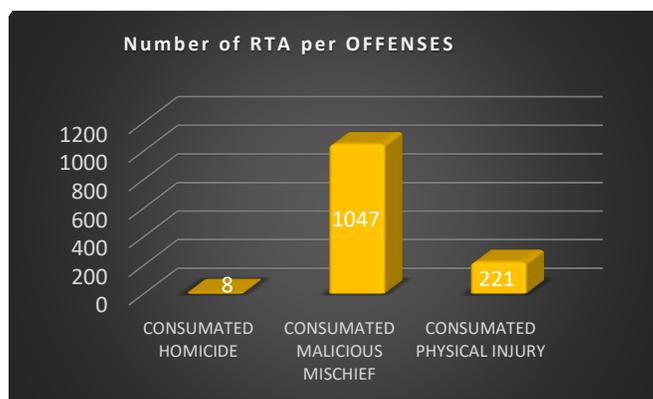


Figure 2. Tagaytay City Traffic Accident per Offense Count (2018)

The methodology started with a macro analysis using Spatial Analysis that determined the concentration and distribution of the road traffic accident in Tagaytay City. From the result of Spatial Analysis, the identified barangay was determined. The identified barangays with a high concentration of road traffic accidents were the focus of Structural Equation Modelling Analysis to analyze factors contributing to road traffic accidents.

2.2. Spatial Analysis

Identification of patterns and inputs on reasons for pattern characteristics can be made through Spatial Analysis (Tortum, Atalay, 2015). In recent studies for RTA, researchers commonly employ the spatial capability of GIS (Geographic Information System) which supports Spatial inquiry by enabling the GIS graphical environment provided by GIS that allows visual analysis of road crashes and the relationship of RTA distribution. Road safety agency like The Iowa Department of Transportation, in cooperation with local law enforcement agencies and Iowa State University, used Spatial Analysis as baseline to developed a GIS-based system accident location and Analysis System that demonstrate the importance of accurate collection of data that allows to enhance the capability of GIS for analyzing RTA locations in a Spatial perspective (Souleyrette et al., 1998).

In this study, the combined function of GIS such analysis of a. Kernel Density Estimation (KDE), b. Nearest Neighbor Analysis, and c. K-function utilized. Nearest neighbor analysis and K-Function will observe and examine the absence and presence of the clustering of accidents. The presence of clustering is an indication that an RTA will likely occur (Shafabakhsh, et al., 2017). For visualization and analysis through geographic representation and data analysis, the study used GIS software such as QGIS and ArcGIS.

The process started by mapping the coordinates from the raw data. In this study, the independent variable used was the “offenses,” there are three categories under offenses such as consummated homicide, consummated malicious mischief, and consummated physical injury, whereas three maps created for KDE.

2.2.1. Kernel Density Analysis (KDE)

To determine a location with a high concentration of RTA, Kernel Density Estimation was used that formed graphical representation through raw data with coordinates. According to (Budiharto, Saido, 2012), KDE is used for determining the risk spread of the RTA. The spread of risk can be identified as the area within the cluster where such risks are most likely increase due to a traffic accident. It is also a range of spatial software for understanding patterns of changing geographic locations (Chainey, Ratcliffe, 2005). In this study, three maps generated per incident scenario (consummated homicide, malicious mischief, and physical injury) to find out the location of the concentration of the accident. The most reddish color will have the high-density value or concentration of road traffic accidents in the area.

Conventional KDE has employed in several studied in safety to identify the crash hazard area. The advantage of the method is that it will estimate the growth rate of accident risk. Risk growth can be identified as an area around the special cluster with the highest accident occurrence determined based on spatial analysis. Another advantage is that it

can define a spatial analysis unit inconsistent form for the whole study area to create criteria for categorizing and comparison (Anderson, 2009).

Kernel Density estimation covered the location where the accident occurs. However, it also shows the point pattern has a density at any location in a region of study. In KDE, the asymmetrical plane placed on each point, and the space from that point to the reference point was assessed based on mathematical function and its total amount of levels for the reference point. The repetition of the process done for the other remaining points.

Kernel Density Function shows a set of points as entry and thus creates a density level. Using their location from the zero point, the density level of each dependent and distinct point can be recognized and define with the highest amount. The density level for a point out of determined radius equals to zero. To create a continuous density level across the study area, each of these separated density levels added to others (Fotheringham et al., 2000).

2.2.2. Nearest Neighbor Distance Analysis (NNA)

Nearest Neighbor Distance Analysis used to measure the increasing number of points against the nearest neighbor distance. If the average distance of the nearest neighbor is significantly smaller than the expected accident pattern, the null hypothesis is rejected in support of the cluster (Shafabakhsh & Famili, 2017).

For RTA pattern analysis, a null hypothesis will be a no spatial pattern or relationship among the road traffic accident data to test the statistical significance (The ESRI Guide to GIS Analysis, Volume 2). Z score helped to decide if to accept or reject the null hypothesis as the P-value helped to know the probability that falsely rejected the null hypothesis (ArcGIS Desktop 9.3 Help).

In Figure 3 shows the Z score as the standard deviation and P-value as the probability to accept or reject the null hypothesis. Where, if Z score is >1.65 and P-value is <0.05 , the null hypothesis is rejected and shows the road traffic accident pattern as “dispersed” pattern, while if z score is <-1.65 and P-value is <0.05 , the patter is likely to be a “clustered” pattern. Else, when the Z score does not meet the two prior conditions, the null hypothesis will consider.

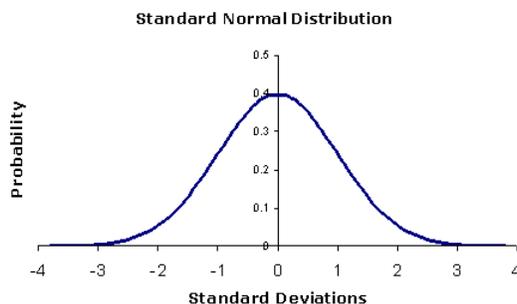


Figure 3. Graph Guide for Nearest Neighbor Analysis

This tool measured the distance between each feature geometric center and its nearest neighbor's geometric center location. The nearest neighbor distances will have the average value. If the average value distance is less than the average for a hypothetical random distribution, the distribution is considered clustered. If the average distance is higher than a hypothetical random distribution, the distribution is considered dispersed (Mitchell, 2005).

2.2.3. K-Functional Analysis

K-Functional Analysis performed after the nearest neighbor analysis is done. The objective was to verify the result from later analysis and analyze the RTA distribution more accurately. The number of RTA with the Shortest distanced assessed for each independent point as an addition for the processes performed in the nearest distance analysis. This method is similar to the analysis of the Nearest Neighbor Analysis. (Shafabakhsh & Famili, 2017). Other studies illustrated the relevance of the method in using for analysis of RTA spatial clustering of unexpected fatality of different road users (Jones et al., 1996).

K-Function Analysis started with a table with field names ExpectedK, ObservedK, and DiffK. ExpectedK is the expected value obtained, while ObservedK is the observed value. ExpectedK will be equal to the distance value. Meanwhile, the DiffK is the value of ExpectedK subtracts from ObservedK. If ObservedK value is larger than the ExpectedK for a specific distance, then the distribution of RTA is clustered than a random distribution at such distance. While if the ObservedK value is smaller than the expected value, the distribution of RTA is dispersed than a random distribution at such distance. Figure 4 shows the understanding of how to specify the pattern distribution using K-Functional Analysis.

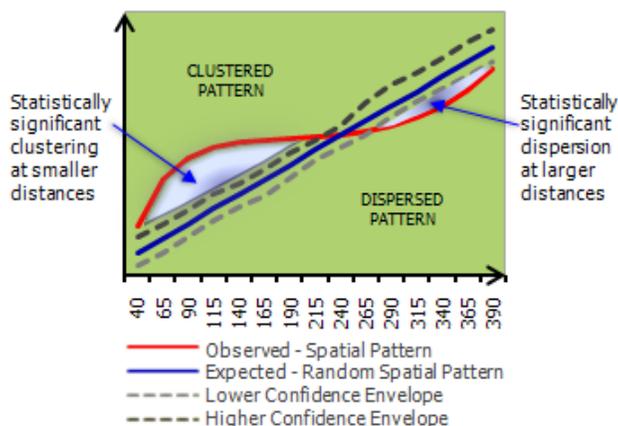


Figure 4. Graph Guide for K-Function Analysis (ArcGIS Pro)

2.3. Structural Equation Modeling

SEM used after GIS identified the location where significant RTA occurs. The data from that area then gathered and analyzed using SEM. Another study suggested that SEM was able to show the relationship between RTA severity and RTA characteristics. Also, SEM has an advantage compare to regression modeling since it allows RTA severity can be described by several indicators simultaneously.

In this study, SME showed the relationship of RTA counts to different variables such as Victim count, Victim age, RTA time, and type of weather conditions. Three-step of the SEM model made. First, a model of the hypothesis formed as such, 13 hypotheses developed based on the given data. This model defined the relationship between unobserved variables such as endogenous and exogenous variables. This will represent by schematic diagrams which include interrelated ellipses.

Second, the initial SEM model shows the relationship between latent variables and the observed variables. And last, the final model formed based on the estimation of AMOS software.

SEM can simultaneously handle a sizeable data population of observed endogenous and exogenous variables. Also, it can handle latent or unobserved variables, which specified as a linear combination for the observed variables. Special cases of SEM capability includes a type of Correlation (Simultaneous equation), whether with or without error term correlation or canonical correlation, regression, path analysis, and factor analysis.

3. Results and Discussion

3.1. Spatial Analysis

Raw data includes its coordinates, such as the coordinates used to start the mapping of the GIS. In Figure 5, shows the data points of 1276 road traffic accidents scattered in Tagaytay maps based on their coordinates. The map used on creating the Kernel Density Estimation Mapping.

Figure 8 represents the category of consummated physical injury that shows the high-density value of RTA at barangay Barangay Kabagal South, San Jose, Silang Crossing East, and Mendez Crossing West.

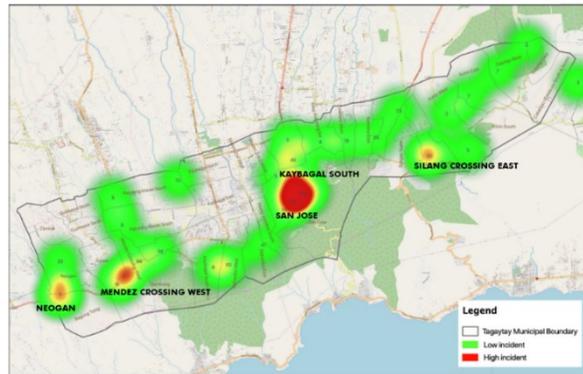


Figure 8. Consummated Physical Injury with High-Density Value of heat map

It also observed that Figure 7 and 8 have common high-density value in which found barangay Kaybagal South, San Jose, and Silang Crossing East.

The identified barangay does have several road accident counts that occurred. See Table 1.

Table 1. Identified Barangay with High-Density Value of heat Map

Area	# of RTA	Consummate Homicide	Consummated Malicious Mischief	Consummated Physical Injury
Kaybagal South	209	1	176	32
San Jose	126	0	104	22
Neogan	43	2	35	6
Silang Crossing East	192	0	167	25
Mendez Crossing West	72	0	68	4

From the data given by heat map analysis, the result of the NNA as seen in Figure 9 shows a bell curve wherein three particular areas have a different interpretation. A clustered, random, and dispersed output.

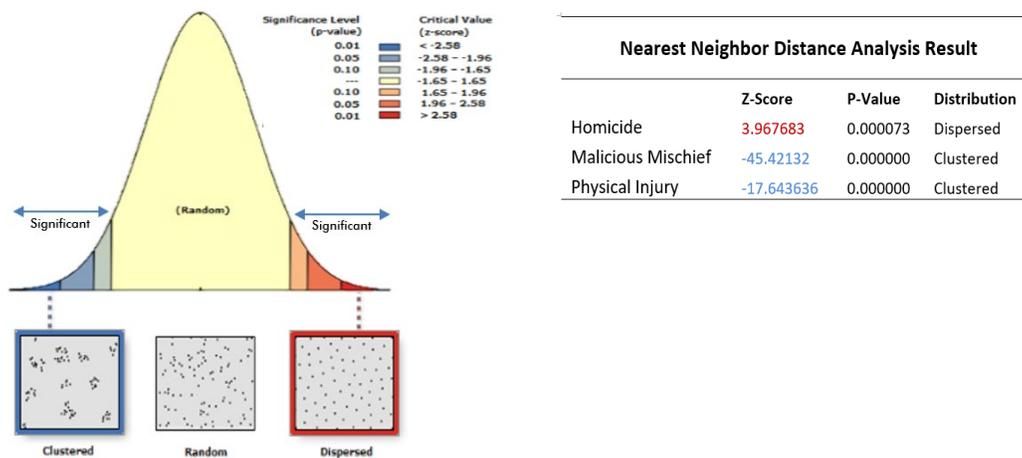


Figure 9. Nearest Neighbor Analysis (NNA) Result

Based on the result, with a z-score of 6.118932 and a p-value of 0.00, it will reject the null hypothesis of being a random pattern. The result falls on the side of the dispersed pattern over a particular area of the study, and it means that the Road Traffic Accident for those areas has pattern uniformly far from each road traffic accidents. In other words, the distribution of road traffic accidents for those identified barangays is more dispersed than the expected random distribution or null hypothesis. The result suggests that the road traffic accident shows only the concentration of incidents for those areas but did not show any clustered data pattern.

3.3. K-Function Analysis

The K-function results for Homicide, Malicious Mischief, and Physical Injury are shown in figure 10-12 respectively. Based on the reference graph, the majority of the result verified the findings of Nearest Neighbor Analysis, and the K-function Analysis suggested the distribution pattern in more specific way that corresponds with its distance band, the distance band default value is 10 in which was sued to compute the value of distant increment of the table (ArcGIS Pro).

The result suggests that the RTA distribution pattern falls on a dispersed pattern that signified that the RTA is more scattered than the expected random pattern in which tells the road traffic accidents are far from each other, and no clustering was formed.

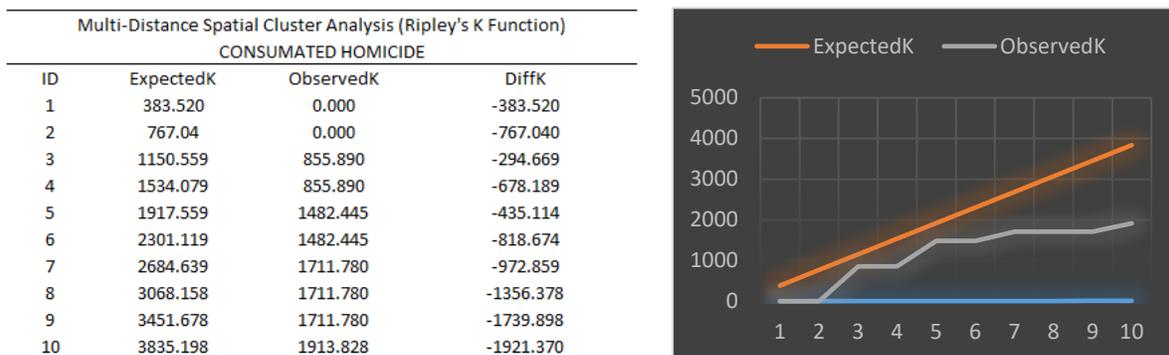


Figure 10. Ripleys K-Function for Homicide

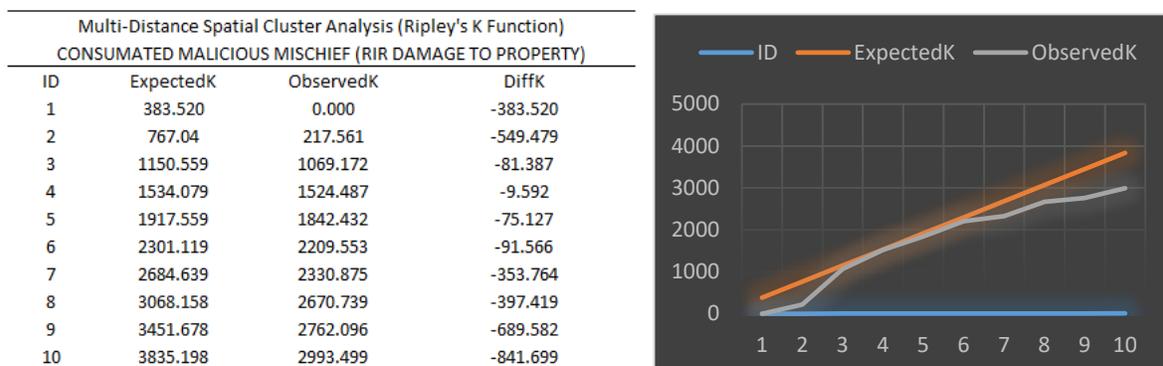


Figure 11. Ripleys K-Function for Malicious Mischief

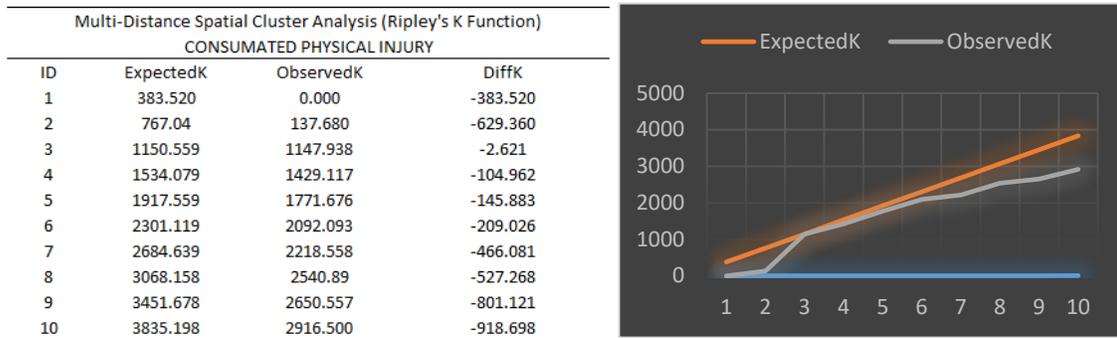


Figure 12. Ripleys K-Function for Physical Injury

3.4. Structural Equation Modeling

After identification of high-density area during Kernel Density Estimation of GIS, all identified barangay and its road traffic accident data ran in SEM analysis. From data of 1276 incidents, it went down to 642 RTA data based on the identified barangay.

The indicators of the road traffic accident severity, which are the suspect count, victim age, victim counts, and suspect age. The only latent variable from the model hypothesis is the Weather condition that is linked to weather intensity, gustiness, wind intensity, victim count and fatality intensity.

As the AMOS 22.0.0 began calibration and analyze the model, it shows that the regression weight estimation where it can identify variables that are statistically significant with a P-value of <0.05 . The variables with >0.05 are statistically insignificant, thus will remove from the model.

In the Final Model, the remained related variables linked to another variable shown in Figure 13. The list of its remained variables shown in Table 2. With the corresponding estimation of regression weights.

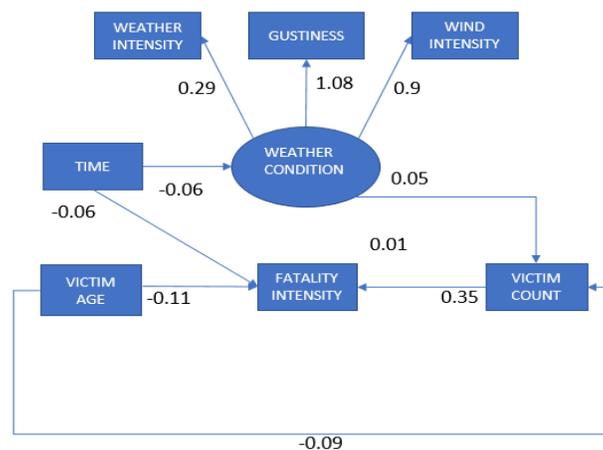


Figure 13. Final SEM Model

Table 2. Goodness of Fit Indexes

Indexes	Values
Chi-Square	103.87
Goodness of Fit Index	0.992
Comparative Fit Index	1.000
Adjusted Goodness of Fit Index	0.982
Root Mean Square Residual	0.000

The test of goodness of fit indexes shows minimum discrepancy function is at 103.87, which statistically significant for chi-square. The goodness of fit index (GFI) is at 0.992, adjusted goodness of fit index (AGFI) is 0.982 and the comparative fit index (CFI) is 1.0. The value can get from a good model is unit or 1. Therefore, the present model is good.

SEM result in Table 3 shows that Victim Age has an inverse relationship with Victim Counts and Fatality Intensity. It means that as the victims get much older, the victim counts to Road traffic accidents will reduce. The victim was described as the driver without other involved in accident and pedestrian.

Table 3. Parameter estimation and levels of statistical significance

		No Stand. Weight	S.E.	C.R.	P Value	Stand Weight
VICTIMS_COUNT	<-- SUSPECT_AGE	0.001	0.002	0.575	0.566	0.026
VICTIMS_COUNT	<-- VICTIM_AGE	√ -0.005	0.002	-2.333	0.020	-0.092
VICTIMS_COUNT	<-- Educational Attainment	-0.006	0.009	-0.610	0.542	-0.027
VICTIMS_COUNT	<-- Weather Condition	-0.005	0.005	-1.062	0.288	-0.038
Fatality Intensity	<-- Date	0.000	0.000	0.375	0.708	0.013
Fatality Intensity	<-- VICTIM_AGE	√ -0.002	0.001	-2.104	0.035	-0.076
Fatality Intensity	<-- SUSPECT_AGE	0.000	0.001	0.203	0.839	0.008
Fatality Intensity	<-- Educational Attainment	0.006	0.004	1.245	0.213	0.051
Fatality Intensity	<-- VICTIMS_COUNT	√ 0.217	0.018	11.789	***	0.422
Wind Intensity	<-- Weather Condition	√ 1.000				0.911
Gust Intensity	<-- Weather Condition	√ 1.586	0.049	32.068	***	1.066
Weather Intensii	<-- Weather Condition	√ 0.142	0.015	9.428	***	0.328
Fatality Intensity	<-- Weather Condition	0.001	0.002	0.345	0.730	0.012
Fatality Intensity	<-- Time	0.022	0.031	0.702	0.483	0.026
Fatality Intensity	<-- SUSPECTS_COUNT	0.029	0.331	0.087	0.930	0.003

(√) Statistically Significant (Pvalue : <0.05)

The study suggested that contributing road traffic accidents can be associated with young drivers and traffic users. Factors such as inexperience, lack of skill, and risk-taking behaviors are characteristics of younger ages. Also, according to (Tefft BC. 2017), younger drivers have a higher risk of road traffic accidents, the risk decreases rapidly with age go through the 20s, and continues to fall when the age reaches the 30s, 40s, and until 50s. Road traffic accident involvement for the fatality of people outside the driver’s vehicle also has a similar trend. Table 4 shows the demographics of the data.

Table 4. Demographics Data

Barangay	Baby 0-2	Young Adults				Middle-aged Adults		Old Adults			Grand Total
		3-12	13-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	
Kaybagal South		1	5	55	62	40	29	12	5		209
Mendez Crossing West			1	16	17	20	10	8			72
Neogan			4	7	12	6	10	3	1		43
San Jose	1	1	4	30	36	21	27	4	1	1	126
Silang Crossing East	1		10	40	56	43	30	10	2		192
Total	2	2	24	148	183	130	106	37	8	2	642
Grand Total	2		357			236		47			642

SEM shows the direct effect of Victim count in relations with Fatality intensity, SEM suggests if Victim Counts will increase, it is more likely to have severe fatality intensity or injury. Victim counts increase due to road traffic accident increment. According to (World Health Organization, 2015), around 1.2 million of death and a greater quantity of less

severe injury has been caused by a road traffic accident. Non-physical factors are pointing out the factor of young drivers' collision compare to older drivers are probable causes of the road traffic accident. Based on Figure 14, there were 45% of cases with injury-related RTA. Out of 642 RTA, 221 of those suffered major injury and 71 of those were severe.

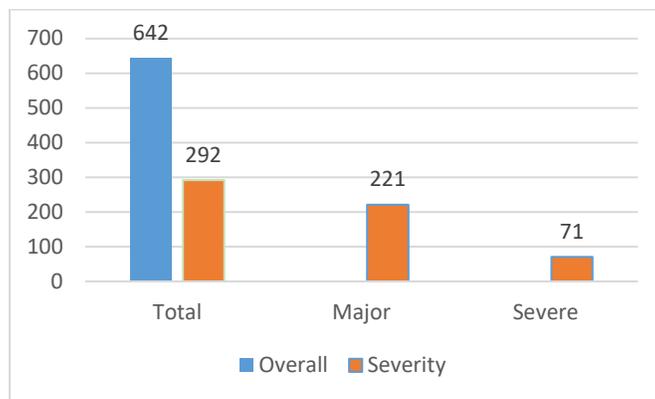


Figure 14. Severity Count

The SEM also found a direct relationship of weather conditions with Wind, Gust and Weather Intensity. As the weather condition goes up or worsen, the three factors will likely to increase. Wind intensity shows a direct impact on road traffic accidents. Strong winds can make the vehicle control difficultly and will cause visibility restriction and road obstruction due to rush of dust, debris, and other materials coming to vehicle and across roadways. Wind intensify may also cause the vehicle to lose its stability which may result in road traffic accidents (Gao, Jinghong, et al., 2016). Gust Intensity also has a direct relationship with the weather condition, when Gust increase, the possibility of a road traffic accident will increase. In other studies, the analysis of a standard bus when hit by a gust of 13m/s will be sufficient to change to route and stability of the bus, and at 20m/s will result in overturning (Brijs, Stiers, 2007).

Bad weather can increase the percentage of road traffic accidents by 20% (Perrels, Votsis, et al. 2015). According to Brijs (2007), q study shows that there was an average RTA risk on normal sunlight, however, there's an increase of 16% when sunlight increase and glare exceedingly increase. Other studies suggest that an increase in precipitation will lead to a rise in road traffic accidents. The study added that the weather condition affects the driver's behavior and pedestrian as well, which can result in a road traffic accident. (Karlaftis, 2011).

During overcast, partly cloudy, and cloudy weather, a chance of formation of fog is likely high, fog is the same with cloud, however fog form at low elevation near a cold surface of Earth (Julita, 2011). The presence of fog will likely change the visibility capability during driving or road usage for the pedestrian. Drivers will probably have difficulty driving handling due to poor visibility, and they may overlook road alignment and roadway layout during the event. Also, the perception of both drivers and pedestrians becomes more complicated once fog becomes denser (Baumberger & Fluckiger, 2004).

4. Conclusion

The study proposed a methodology that suggests a macro to microanalysis of road traffic accidents in Tagaytay. The data gathered from Tagaytay Road Traffic Accident reports then runs through the Geographical Information System, using software such as QGIS and ArcGIS. It generates a visualization of the road traffic accident that focuses on its high-density value utilizing Kernel Density Estimation; furthermore, it locates the area where RTA is more concentrated. Identified barangay specified as a high-density area of RTA. The software also identified the RTA for those barangays as a dispersed distribution pattern rather than an expected random distribution.

The data of identified barangays then ran into a statistical analysis tool of SEM. It proposed a model able to define the various factors' relationship for road traffic accidents. The result shows that Victims Age shows a significant impact on the increase of RTA. The model shows the direct relationship between its victim counts and fatality intensity. The study suggests that young ages tend to have a lack of skill, inexperience, and risk-taking behaviors.

The model also shows the increase in Victim Counts, which reflects with the rise in RTA, will likely have an injury or higher intensity fatality.

Gust Intensity, Wind Intensity, and Weather Intensity have a direct relation with Weather conditions that suggests that an increase of three factors will make weather conditions worsen. The condition affects the drivers' and pedestrian mobility, visibility and stability of vehicle which will lead to RTA.

For young ages, the recommendation is to have an in-depth and strict driving lesson program from driving government agency and strict implementation of driving license enrollment. Other research suggested having a licensing program for a young age that will provide driving experience but with a minimum risk. The system of the program will target young drivers to experience driving integrated with a fully systematic and controlled program such as will be issued license with restriction of night curfew, the limit of passenger age and numbers. As the driver will gain no-accident and violation record, the restriction will gradually remove until gain full privileged of driving license is met (Mayhew, 1987).

For weather condition factors, the study recommends conducting pre-travel planning that will check the weather before traveling to Tagaytay. The use of mobile applications of weather forecast might be helpful. The local government unit of Tagaytay City may recommend having a real-time check of weather conditions. Real-time weather conditions and the possible effects on the vehicle and pedestrian will be shown on a widescreen or in changeable message signs to call the attention of road users that may avoid any road traffic accident. The problem for visibility during the event of fog may reduce by implementing a light-emitting diode on the road that will serve as road guide lights for the drivers to focus and stay on their lane.

It is suggested to have a vehicle technology that has mobile-in technology that will provide real-time traffic and road information. It is also recommended to have a vehicle instrument that measures safety parameters such as friction or visibility monitoring during driving. Such information from vehicle technology it can apply to vehicle speed adjustment technology.

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