GIS-BASED SPACE AND TIME ANALYSIS OF ROAD ACCIDENTS IN AN URBAN ENVIRONMENT: A CASE STUDY OF THE COLOMBO MC AREA.

H.B.T.P. Jayathilaka (1), V.P.I.S Wijeratne (2)

[1]Postgraduate Institute of Science, University of Peradeniya, Peradeniya, 20400, Sri Lanka.
[2]Department of Geography, Faculty of Arts, University of Colombo, Colombo 7, 00700, Sri Lanka.
Email: tprathibani2014@gmail.com; sandamaliwijeratne87@gmail.com

KEYWORDS: RTAs, GIS, Spatial, Temporal

ABSTRACT: The road transport system is the vital infrastructural system and plays an important role to perform any activities in any country. But its main negative impact was road traffic accidents and it is becoming major economic and social issues in the world. Hence, it is very important to find new ways to handle spatial data related to urban road accidents. In this case, GIS plays an important role in mapping and analysis. It offers a graphical representation of the distribution pattern of RTAs with spatially and temporally.

This research mainly aimed to examine the spatial and temporal trends of urban traffic accidents in the Colombo MC area. This study employed the analysis tool of MS Excel 2013 and Arc GIS 10.5 such as; average nearest neighbor, spatial autocorrelation (Morans I), high/low clustering (Getis-Ord General G), point density, kernel density and tracking analysis to determine the spatial and temporal pattern of the RTAs and research data obtained from 2004 to 2018. More than 76,000 incidences were analyzed.

The findings reveal that the RTA distribution was depicted as a clustered pattern. According to the point density analysis and kernel density analysis, high-density areas can be identified in the middle part of the study area and most of them were located near the road junctions. High population density migration, road junctions, can be identified as the main influencing factors of this pattern. The temporal based analysis of data revealed that most RTAs were reported in 2014. The maximum number of RTAs were reported months of January, February, May, June, July, August and September of this year over fifteen years. In this period, the highest number of road traffic accident reported times were 8.00 a.m. to 10.00 a.m, from 11.00 a.m to 1.00 p.m, 2.00 p.m to 4.00 p.m and 5.00 p.m to 7.00 p.m on weekdays. The minimum number of road traffic accident was reported between 12 midnight to 6.00 a.m on all weekdays.

This study area is the main administrative, business area of Sri Lanka. As well as the capital city of the country and this area has highly inhabitants than other areas and expanded by nearly 500,000 daily floating populations. Hence the prevention and mitigation of road traffic accidents are very important. Therefore, the analytical and theoretical results will undoubtedly lead to enhanced road traffic accident prevention strategies of the Colombo MC area in the future.

1. INTRODUCTION

The road transport system is the most important infrastructural system and plays a vital role to perform any activities in any country. Transport provides a range of benefits to society in terms of mobility, access and economic growth. However, there are negative impacts of transport, not least in terms of environmental degradation, damage to property, traffic accidents and loss of life (Wang *at el.*, 2006). At present, these negative impacts are becoming major economic and social issues in the world. Among these negative impacts of a road traffic accident is one of the most complicated issues over the world. (Le *at el.*, 2019).

According to the World Health Organization data which shows, every year the lives of approximately 1.35 million people are cut short as a result of a road traffic (accident) crash. Between 20 and 50 million more people suffer non-fatal injuries, with many, incurring a disability as a result of their injury (World Health Organization, 2020).

According to the data, the traffic accident rate is higher in number, especially in developing countries because of the negligence of accident prevention (Sivakumar and Amarathung, 2015). Even within high-income countries, people from lower socioeconomic backgrounds are more likely to be involved in road traffic (accident) crashes (World Health Organization, 2020). RTAs contribute to poverty by causing deaths, injuries, disabilities, grief and loss of productivity and material damages. Children, pedestrians, cyclists and older people are among the most vulnerable of road users (Sivakumar and Amarathung, 2015). At present, road accidents are becoming a man-made disaster in the world. Many researchers have come up with various kinds of solutions and recommendations towards preventing road accidents.

Over the years, Geographic Information Systems (GIS) technology has been applied for a variety of purposes within the transportation industry. With this have come many new uses, benefits and challenges. GIS is a powerful tool for analyzing road traffic accidents. GIS has been applied widely in traffic safety studies in many countries for a long time (Mohaymany *at el.*, 2013; Dereli and Erdogan 2017).

As a developing country, associated with growing technology and an increasing population, like Sri Lanka, the number of vehicles in traffic is increasing day by day. In developing countries, most traffic accidents are due to human error, lack of road facilities etc. Situated in the western province of Sri Lanka, the Colombo Municipal Council area is the largest urbanized city and financial center. As a result, the vehicle density in the Colombo MC area has shown an alarming increase in the past few years. Therefore, more RTAs have occurred in this area more than other areas in Sri Lanka. Consequently, it is usually possible to reduce the accident probability and intensity through different scenarios and methods. Hence, it is necessary to examine spatial and temporal RTAs. There are so many researches have road accidents using GIS in the world. However, currently, in Sri Lanka, GIS has been applied in some researches to analyze the RTAs. But it is very limited. In this study, examine the spatial and temporal trend of RTA in the Colombo MC area.

Reducing road accidents requires commitment, informing, awareness and decision-making by government, industry, non-governmental organizations and international agencies.

Accordingly, these results can be effectively used by various organizations for adopting better planning and management strategies for the reduction of road accidents.

2. OBJECTIVES OF THE PROJECT

The primary aim of this study is GIS-based space and time analysis of road accidents in an urban environment.

SPECIFIC OBJECTIVE

To examine the spatial and temporal trend of urban traffic accidents in the Colombo MC area.

3. STUDY AREA

This study area is situated in the western province of Sri Lanka; Colombo MC area is the island's capital. Diverse and vibrant, the city is the administrative and economic center of the country. It is situated between 6^0 52' to 6^0 59' north latitude and 79^0 49' to 79^0 54' east longitude. It is bordered by the Indian Ocean. The total area of the study area is around 37 sq km. Totally 55 GND and 23 police divisions have in this area. This area has a tropical climate. Colombo MC area annual rainfall is up to 1600mm and the annual temperature is 20 – 30C^o (Metrology Department, 2019). Colombo MC Area is a multi-religious, multi-ethnic, multi-cultural city. The population of Colombo is a mix of numerous ethnic groups, mainly Sinhalese, Sri Lankan Tamils and Sri Lankan Moor. There are also small communities of people with Chinese, Portuguese Burgher, Dutch Burgher, Malay and Indian origins living in the city, as well as numerous European expatriates. Colombo MC area is the most populous city in Sri Lanka, with 642,163 people living within the city limits. Figure 3.1 shows the study area of this study.

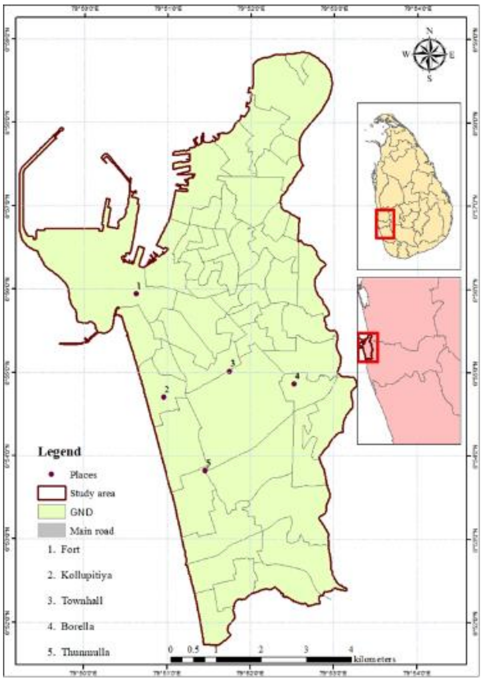

Figure 3.1: map showing the study area

4. MATERIALS AND METHODOLOGY

The study mainly used the GPS data, attributes data such as date, time and, analyses carried out using ARC GIS 10.5. It is utilized to identify the spatial and temporal patterns of RTA in this area.

4.1 Data Collection

Road accident data.

Road Traffic accident dataset collected from the police headquarters in Colombo. More than 76,000 road traffic accidents were analyzed during 2004-2018. Besides, the maximum number of road traffic accidents have been recorded in 2004. The Road Traffic accident dataset included vital accident information like the date and time of accidents, accident places, accident and vehicle types, age and gender of drivers, the number of the injured, accident injury levels, etc.

Boundary data

A boundary digital map was provided by the Urban Development Authority.

4.2 Methodology

4.2.1 Spatial analysis

Point pattern analysis

Average nearest neighbor: Calculates the nearest neighbor index based on the average distance from each feature to its nearest neighboring feature (Environmental Systems Research Institute, 2020).

Spatial autocorrelation (Morans I): This method was proposed by Moran (1948) which is a measure of global spatial autocorrelation technique, based on comparison of attribute values of neighboring points (Lakshmi *et al*., 2019). This tool is used to calculate the degree of dispersion or concentration of the features or spatial data (Aghajani *et al*., 2017).

High/Low clustering (Getis-Ord General G): The High/Low Clustering (Getis-Ord General G) tool is an inferential statistic, which means that the results of the analysis are interpreted within the context of the null hypothesis.

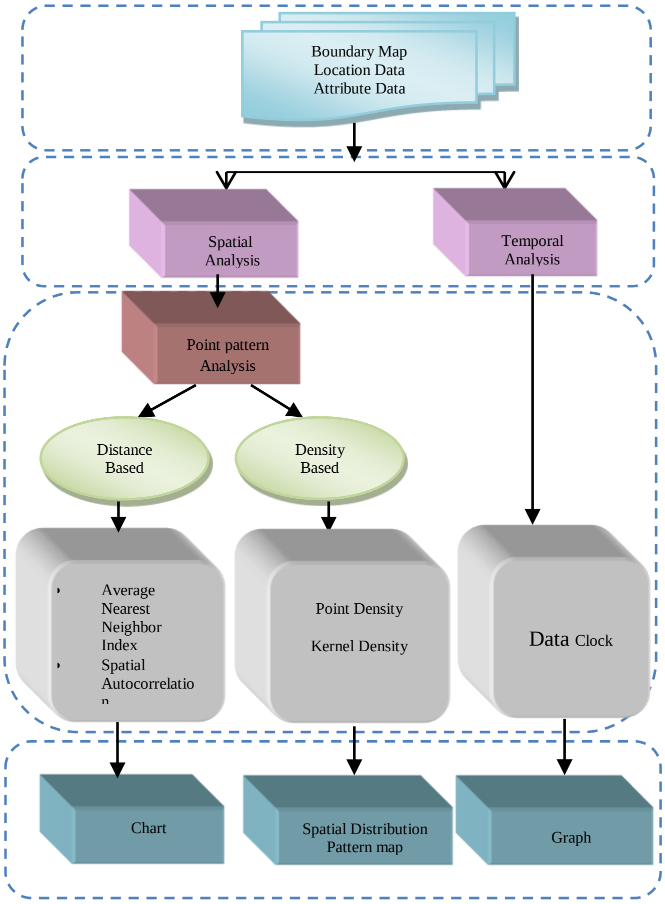

Figure 4.1 Summarized Methodology Chart for this Study

Point density: Calculates a magnitude per unit area from point features that fall within a neighborhood around each cell.

Kernel density estimate: This method shows a kernel density surface map of the RTA intensity. This process involves estimating the density of RTAs across an entire two-dimensional study area, based on the known locations of discrete events.

4.2.2 Temporal Analysis

Tracking analysis: Tracking analysis help to spot and analyze time-related trends and patterns. Its capabilities are sophisticated visualization, exploration and analysis of time-related data.

4.3 Data visualization

The analysis was mainly represented results using spatial distribution maps and charts and tables.

5. RESULTS AND DISCUSSION

Spatial and Temporal Trend of RTA

The number of road accidents also varies with time and location. Therefore, road accident incidence and road accident risk change continually with time and space. It is of vital important to analyze road traffic accidents in both spatial and temporal scales to improve traffic security management.

5.1 Spatial Distribution of Road Traffic Accidents

5.1.1. Distance based point pattern in road traffic accidents

In this study, various point pattern analysis methods used to identify the spatial distribution pattern of RTAs and identify their trends. According to this method firstly identified the nature of the RTA. It is based on the Average Nearest Neighbor, Spatial Autocorrelation (Morans I) and High/Low Clustering (Getis-Ord General G). These three types of methods are distance-based PPA. That method can be identified under the spatial statistic tool in ARC GIS. In this study, RTA data were analyzed together all fifteen years, not only in which, all data were analyzed into three groups of year periods such as 2004-2008, 2009-2013, 2014-2018 and each of the groups include five years.

Figure 5.1 shows Average Nearest Neighbor (ANN) analysis result of in fifteen years and its null hypothesis states is a RTAs are randomly distributed. But its null hypothesis state was rejected and the RTA pattern reveals clustered. Figures 5.2, 5.3, 5.4 shown in cluster distribution of the RTA. In this study, the null hypothesis state is RTAs are randomly distributed. But its null hypothesis state was rejected and the RTA pattern reveals clustered. It can be said with 99% confidence level.

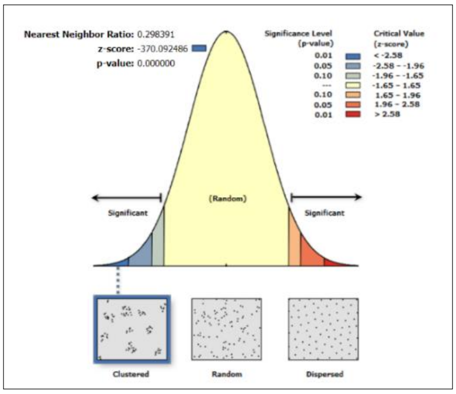

Figure 5.1 ANN analysis results in fifteen years

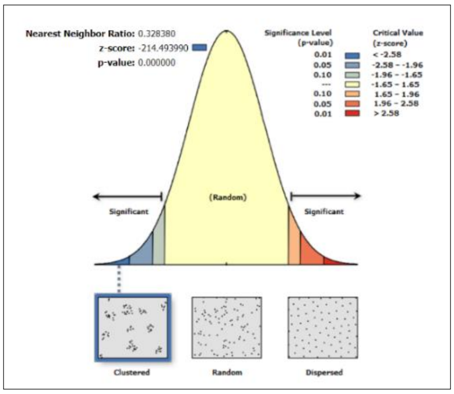

Figure 5.2 ANN result of in period of 2004-2008

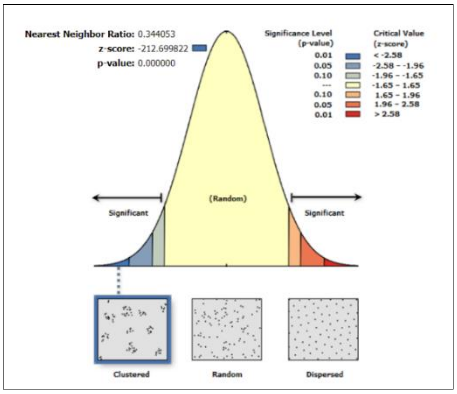

Figure 5.3 ANN result of in period of 2009-2013

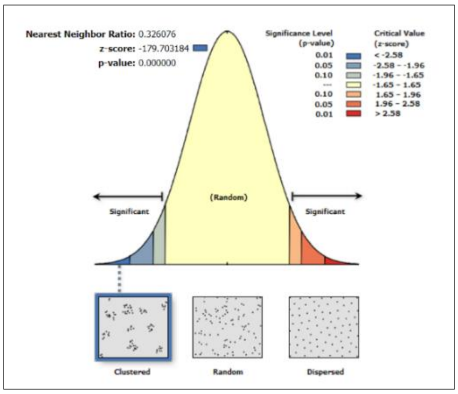

Figure 5.4 ANN result in period of 2014-2018

Figures 5.5 shows spatial autocorrelation results. Its 99% probability (confidence level) that the distribution of RTA is clustered.

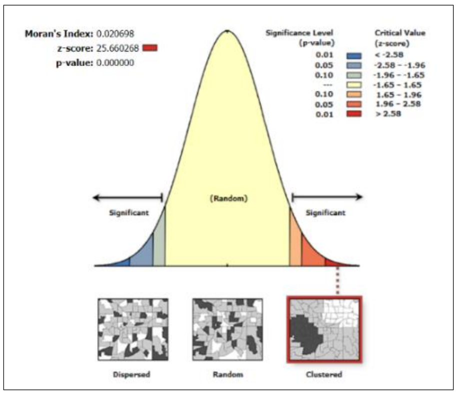

Figure 5.5 Spatial autocorrelation (Morans I) result in fifteen years

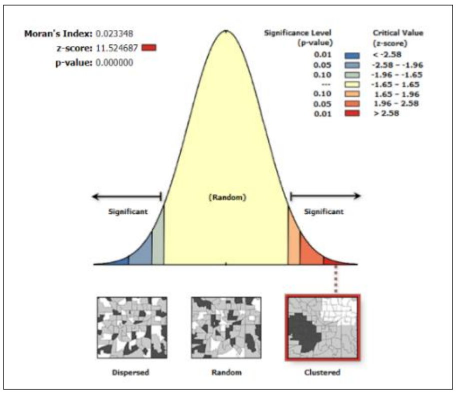

Figure 5.6 Spatial autocorrelation (Morans I) result in period of 2004-2008

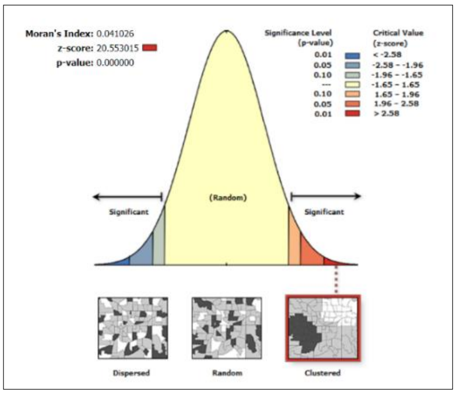

Figure 5.7 Spatial autocorrelation (Morans I) result in period of 2009-2013

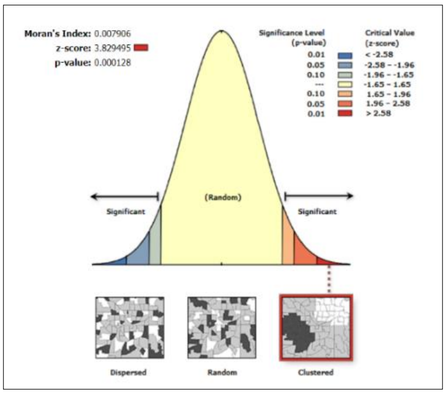

Figure 5.8 Spatial autocorrelation (Morans I) result in period of 2014-2018

As shown in Figures 5.6, 5.7, 5.8 an accident distribution pattern was clustered. In this analyze the null hypothesis state is the RTAs are randomly distributed. But its 99% probability (confidence level) that the distribution of RTA is clustered.

According to the High/Low Clustering (Getis-Ord, General G) analyze the null hypothesis state was RTAs are randomly distributed. But High/Low Clustering (Getis-Ord, General G) analysis result was a high cluster pattern Therefore, reject the null hypothesis and its result shows as in Figure 5.9. As shown in Figures 5.10, 5.11 the result showed cluster distribution of the RTA. In other words, 99% probability (confidence level) that the distribution of RTA a clustered pattern of high values.

Figure 5.12 shows the random distribution of the RTA. Therefore, can’t reject the null hypothesis. In other words, 90 probability (confidence level) that the distribution of RTA a pattern is random.

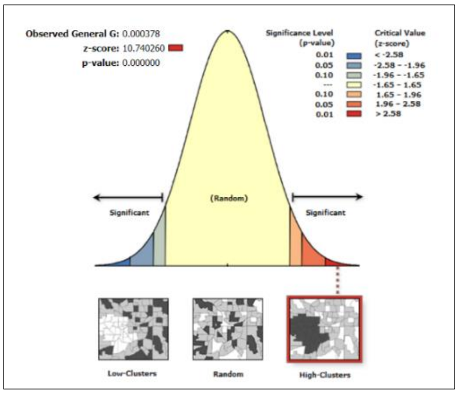

Figure 5.9: High/Low clustering result in fifteen years

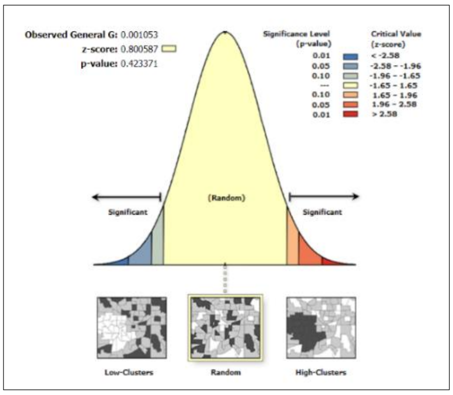

Figure 5.10: High/Low clustering result of in period of 2004 - 2008

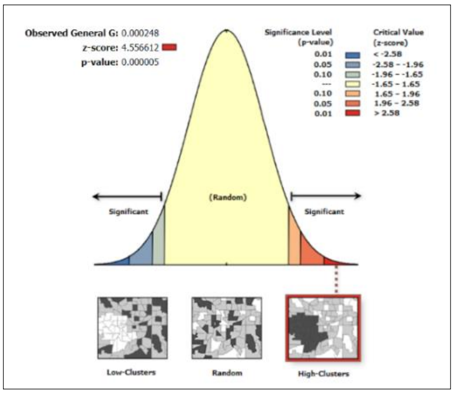

Figure 5.11: High/Low clustering result in period of of 2009 - 2013

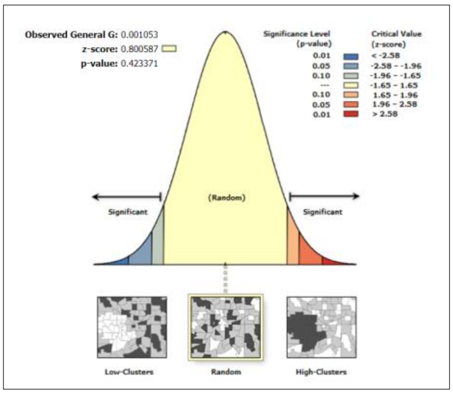

Figure 5.12: High/Low clustering result in period of of 2014 - 2018

4.1.1.2 Density based point pattern in road traffic accidents

Point density analysis of road traffic accidents

Figure 5.13 shows the distribution of the point density in RTA locations concerning fifteen years in 2004-2018. The point pattern results show density per square kilometer. In this study, high RTA density areas were scattered throughout the study area. Most of the high RTA density areas were reported middle part of the study area. It had recorded from 6000.001 to 11000.000 km^2. Accordingly, the highest point density areas were Thunmmulla junction, Kollupitiya junction, Bambalapitiya Junction, Townhall, Kosgas junction, Borella junction, Technical junction and Milagiriya junction. All of these places are connected with three, four, or five roads together. On the other hand, low accident density areas were situated in the new port city area and the north part of the study area. It had from 0 to 900.000km^2.

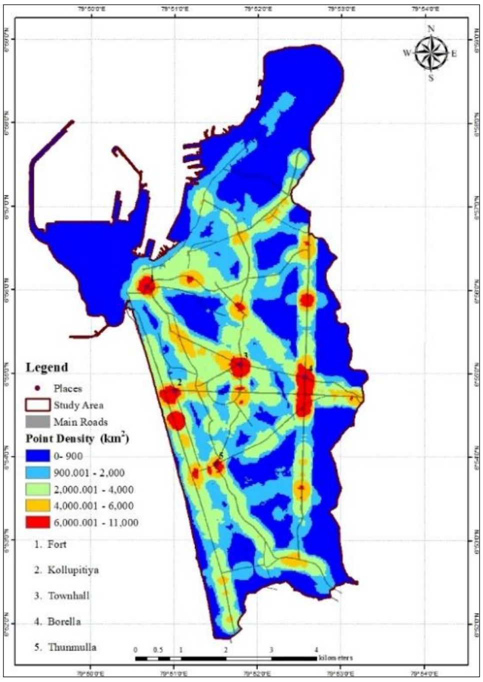

Figure 5.13: Point density of road traffic accidents since 2004 to 2018

Kernel density estimation of road traffic accidents

Figure 5.14. illustrates the distribution of KDE in RTA locations concerning fifteen years in 2004-2018. The KDE results show by the percentage of per square kilometer. In this study, high RTA density areas were scattered throughout the study area. Most of the high RTA density areas were reported middle part of the study area. It had recorded from 7556.629 to 15415.521 KDE percentage of per square kilometer (KDE % km^2) value. Accordingly, the places with the highest kernel density area are Thunmmulla junction, Kollupitiya junction, Bambalapitiya junction, Townhall, kosgas junction, Borella junction, Technical junction and Milagiriya junction. All of these places are connected with three, four, or five roads together. On the other hand, low road traffic accident density areas were situated in the new port city area and north part of the study area. It had from 0 to 967.248 KDE percentages per square kilometer (KDE % km^2) value.

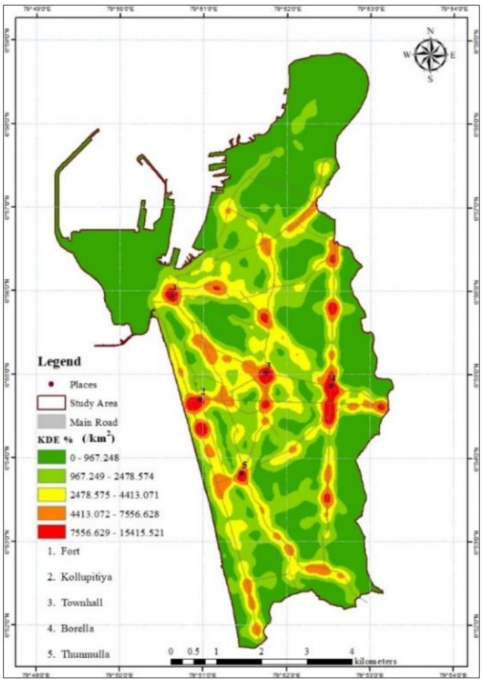

Figure 5.14: Kernel density estimation of road traffic accidents in fifteen years.

4.1.2 Temporal Distribution of Road Traffic Accidents

In this study, tracking analysis used to analyze the temporal distribution of the RTA in this area. The temporal distribution of RTAs over the fifteen years was measured yearly, monthly, daily and timely. In this area, RTAs in temporal distribution showed in two ways. These are,

- Year by month
- Day of the week by hour of day

Figure 4.15 shows temporal distributions of road traffic accidents in the year by month with over fifteen years. In 2004 was the maximum number of road traffic accidents reported year. The maximum number of road traffic accidents were reported months of January, February, May, June, July, August and September of this year over fifteen years. In 2004 more than 600 number of road traffic accidents occurred in these months. The lowest number of road traffic accidents was reported in 2018, with a total of 168 to 334 a month. The development of transport infrastructure is contributing to the reduction of road traffic accidents from 2004 to 2018 in the Colombo MC area not only in Sri Lanka. Among them introduce new traffic rules, introduce new technology such as traffic light systems, are important.

Figure 4.16 shows temporal distributions of RTAs on the day of the week by the hour of the day with over fifteen years. In this period, the highest number of RTAs reported between 8.00 a.m. and 10.00 a.m, between 11.00 a.m and 1.00 p.m, between 2.00 p.m and 4.00 p.m and between 5.00 p.m and 7.00 p.m on weekdays. As well as more than 725 in the number of RTAs have been reported during this period.

There some reasons that lead to an increase in the number of accidents these times and weekdays. Such as in Sri Lanka, the main government and non-government institute, universities, schools and trade centers are located in this area. Therefore, a large number of peoples migrate to this area daily such as students, work employers, etc.

Government and non-government institutes in Sri Lanka began their day work after 8 a.m. In this situation, there are a large number of peoples migrate in this area between 8 a.m and 10 a.m. Also due to the closure of schools and preschools after 11 a.m there can be identified traffic congestion between 11 a.m to 1.p.m and 2.p.m to 4.p.m, in this area. As well as the closure of government and non-government institutes after 4. p.m there can be identified traffic congestion between 5.00 p.m and 7.00 p.m in this area. Therefore, RTAs increased during this time. The minimum number of RTA was reported between 12 midnight and 6.00 a.m on all days of the week. The minimum numbers of RTAs were recorded in those times between 1 and 181. Because there are no more vehicles to travel to the road in this period

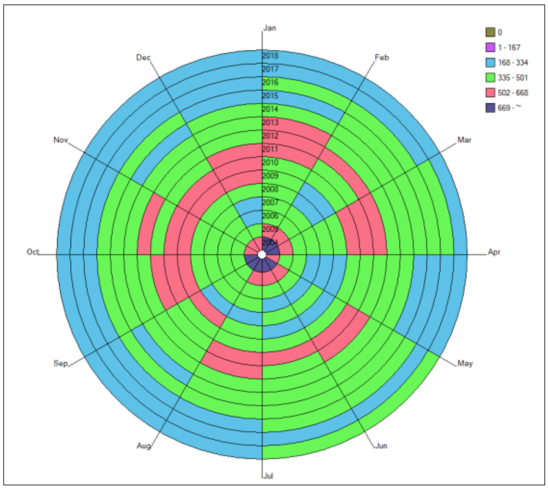

Figure 5.15: Road traffic accident on year by month

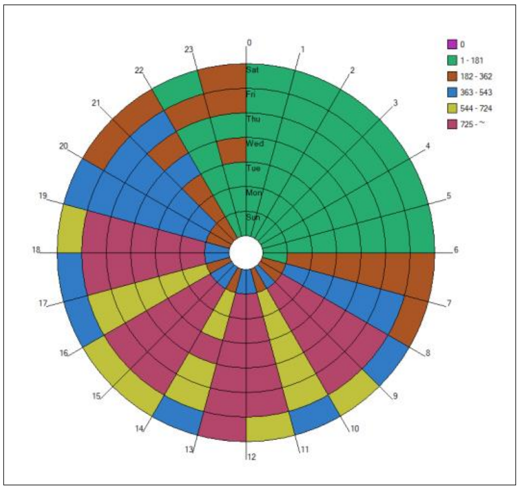

Figure 5.16: Road traffic accident on day of the week by hour of day

CONCLUSIONS AND RECOMMENDATIONS

Road traffic accident data were analyzed together all fifteen years, not only in which, all data were analyzed into three groups of year periods.

According to the average nearest neighbor analysis, spatial autocorrelation (Morans I) and high/low clustering (Getis-Ord General G) in fifteen years, a null hypothesis state was rejected and the RTA pattern reveals clustered with 99% confidence level. As well as their three groups of year periods such as 2004-2008, 2009-2013 and 2014-2018 null hypothesis state was rejected and RTA pattern reveals clustered with 99% confidence level. But high/low clustering (Getis-Ord General G) from 2014 to 2018, a null hypothesis state was not rejected. Its RTA pattern reveals random.

According to the point density and KDE results, the high road traffic accident located middle part of the study area. Because there are more roads connect in this area. So, there are a lot of three-ways, four-ways and five-ways junctions in this area and can be identified as the most number of accidents that occurred in those places. There some reasons that lead to occur the road accidents in this study area. In this area were abundantly concentrated main private and government schools, the main branch of private and government institutes, main transport centers, playgrounds, trade centers, etc. As a result of this Colombo MC area has highly inhabitants than other areas and expanded by nearly 500,000 daily floating populations. According to that reason, more traffic users use this area's roads daily. Hence, road traffic accident density was higher than other areas.

There is a low-density area recorded in the new port city area. Because the new port city area was new construction in Sri Lanka. This is because its transport facilities have not been provided during this year. Therefore, the map showed that the area has low road traffic density.

According to temporal analysis, in 2004 was the maximum number of road traffic accidents reported year. The maximum number of RTAs were reported months of January, February, May, June, July, August and September of this year over fifteen years. In the Fifteen years, the minimum number of road traffic accidents was reported on the 29th of February and 13th, 14th and 15th of April. In this period, the highest number of road traffic accident reported times were 8.00 a.m. to 10.00 a.m, from 11.00 a.m to 1.00 p.m, 2.00 p.m to 4.00 p.m and 5.00 p.m to 7.00 p.m on weekdays. The minimum number of road traffic accident was reported between 12 midnight to 6.00 a.m on all weekdays.

There some factors that can be identified for the temporal distribution of road accidents in this area. Colombo MC area has highly inhabitants than other areas and expanded by nearly 500,000 daily floating populations. In Sri Lanka, the main government and non-government institute, universities, schools and trade centers are located in this area. This is the main reason people move to daily in this area.

Many peoples in Colombo MC area travel to their hometowns and spend the time with the relations in for festival days. Colombo MC Area was very clammed those days and no congestion. This means reducing the number of RTA on those days. As well as those who are staying temporally in this area they leave for their village on weekends. Therefore, no more maximum number of an accident reported weekends. The fact in arrears, these reasons can be contributed to urban dynamic and human mobility as well as traffic volume and pattern, in this area.

To recapitulate, Colombo MC area is an urbanized area with centers of administrative, business and service sectors. Hence this has led to a relatively high road traffic accident in the area. Finally, this analytical and theoretical result will undoubtedly lead to enhanced road traffic accident prevention strategies of the Colombo MC area in the future.

REFERENCE

Le, K. G., Liu, P., and Lin, L. T. (2019). Determining the road traffic accident hotspots using GIS-based temporal-spatial statistical analytic techniques in Hanoi, Vietnam, *Geo Spatial Information Science*, *00*(00), 1–12 Retrieved March 30 2020 from https://doi.org/10.1080/10095020.2019.1683437

Mohaymany, A. S., Shahri, M. and Mirbagheri, B. (2013). GIS-based Method for Detecting High-Crash-Risk Road Segments Using Network Kernel Density Estimation. *Geo-spatial Information Science*, **16** (2), 113 −119 Retrieved March 30 2020 from https://doi:10.1080/10095020.2013.766396.

Sivakumar, T. and Amarathung, D. (2015). Development of Traffic Accident Prediction Models Using Traffic and Road Characteristics: A Case Study from Sri Lanka. *EASTS 2015 Conference, i*.

Wang, X., Abdel-Aty, M., Brady, P., (2006) Crash estimation at signalized intersections: significant factors and temporal effect, Transportation Research Record. *Journal of the Transportation Research Board*, **1953**, 10–20.

World Health Organization (2020). https://www.who.int/news-room/fact-sheets/detail/road-traffic injuries#:~:text=Every%20year%20the%20lives%20of,a%20result%20of%20their%20injury.andtext=for%20the%20injured.-,.,Road%20traffic%20crashes%20cost%20most%20countries,of%20their%20gross%20domestic%20product.