HEALTH CARE FACILITIES AND ROAD TRAFFIC INJURIES IN THIRUVANANTHAPURAM CITY

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Dissertation submitted in partial fulfillment of the requirements for the award of the degree of

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I owe my sincere gratitude to my family, who had sacrificed so much to make my dreams come true and for their continued support and motivation.

DECLARATION

I hereby declare that the work embodied in this dissertation entitled "**Health care facilities and Road traffic injuries in Thiruvananthapuram city" is** the result of original research and has not been submitted for any degree in any other university or institution.

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CERTIFICATE

I hereby certify that the work embodied in this dissertation entitled **"Health care facilities and Road traffic injuries in Thiruvananthapuram city"** is a bona fide record of original research work undertaken by Dr. Annup Balan B, in partial fulfillment of the requirements for the award of the degree of 'Master of Public Health' under my guidance and supervision.

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Dedicated to My Parents and Brother

LIST OF ABBREVIATIONS

RTI	Road Traffic Injuries
GIS	Geographical Information System
SCRB	State Crime Records Bureau
LISA	Local Indicators of Spatial Association
CLARA	Clustering Large Applications
CRS	Coordinate Reference System
EPSG	European Petroleum Survey Group

ABSTRACT

Background: Road traffic injuries (RTI) are a growing public health concern in India. Despite Kerala having better health infrastructure and better-connected roads as compared to other states, Kerala ranks among the top five states with the highest incidence of RTI in India. Hence it is essential to understand the attributes responsible for this rising trend.

Methods: RTI data for the year 2016 was obtained from the State Crime Records Bureau, Thiruvananthapuram. Health care facilities capable of providing emergency trauma care services in the city were identified from secondary sources. Population data were obtained from the 2011 Census data. Spatial statistical analysis was used to look for geographical distribution and spatiotemporal clustering of road traffic injuries.

Results: A total of 2,319 people, including pedestrians, got injured in 1,926 accidents in Thiruvananthauram city during 2016. A significant spatial autocorrelation (Moran's $I = 0.23$) was found within the 100 wards. The rates of RTIS were significantly high among senior citizens, male sex, two wheeler users and during day time. Most of the deaths (48.2%) occur among the most active age group of 30- 60 years. A severity map was generated and using Local Indicators of Spatial Association (LISA), the hotspots were identified. A significant number of clusters (8) were identified among the 100 wards. The mean distance from the accident hotspots to the nearest health care facility was 1.2 km and this was similar with respect to public and private facilities.

Conclusion: There appears to be significant spatial-temporal clustering of RTI within Thiruvananthapuram city. The deaths occurring among pedestrians, two wheelers and women need special attention. The study inference should be used for better planning and management strategies in reducing RTI in Thiruvananthapuram City.

CHAPTER 1- BACKGROUND

The World Health Organization defines road traffic injury as a fatal or non-fatal injury incurred as a result of a collision on a public road involving at least one moving vehicle **(**World Health Organization, 2017; Gharde et al., 2017). Children, pedestrians, cyclists and the elderly are among the most vulnerable of road users **(**WHO, 2017; Gharde et al., 2017). The world's first road traffic accident is supposed to have occurred in 1896 (Gopalakrishnan, 2012). In developing countries more than 85 percent of all swaths and 90 percent of disability adjusted life years are lost from road traffic injuries (Nantulya and Reich, 2002)

1.1 GLOBAL SCENARIO

Over 1.2 million people die each year on the world's roads. Between twenty and fifty million suffer from non fatal injuries (South-East Asia Regional Office, 2017). Road traffic injuries (RTI) were the ninth leading cause of death globally and it's forecasted that it will be the fifth leading cause of death by the year 2030 (WHO, 2004; WHO, 2009).

Road safety has been in the limelight with global focus for decades. Road transportation is often regarded as the most dangerous means of movement, judging by the chances of an individual dying on the road. It is riskier to travel by road as compared to air and rail (Shavhani, 2007).

Around 94% of road traffic related deaths are from low- middle income countries. Ironically these countries have half of the world's registered vehicles due to rapid motorization without adequate infrastructure development or road safety measure (Sebego et al., 2014; Borowy, 2013; WHO, 2013).

In developing countries, amidst the ongoing double burden of communicable and non communicable disease burden, road traffic injuries claim a lot of lives. About 85% of annual deaths and 90% of the disability adjusted life years are lost due to road traffic injury (Choueiri et al., 2010). This often drives many families to poverty by the loss of their breadwinners. As in most road traffic injuries and deaths, it's often impossible to attach a value to each case of human sacrifice or suffering.

Designing roads, enforcing traffic regulations, amongst others are challenging that the transport sector faces to achieve sustainable road transport safety. In some countries, both developed and developing have regarded vehicles as murder weapons, making it possible to charge and prosecute drivers after car accidents and reckless driving (Choueiri et al. , 2010).

1.2 SCENARIO IN INDIA

Traffic crashes and consequent injuries represent a growing public health concern in India, particularly in light of increasing motorization (Fitzharris et al., 2009). In 2014, about 141,526 people were killed on the roads of India and 477,731 people had stumbled to injuries as a consequence of road traffic injuries (Road accidents report India, 2015). Road traffic injuries are the eighth leading cause of death in India (GBD Mortality and Causes of Death Collaborators, 2015). A majority of the deaths and injuries have been observed with two wheelers.

1.3 SCENARIO IN KERALA AND THIRUVANANTHAPURAM

As compared to other states in India, Kerala has a higher literacy rate, better health infrastructure and services, higher density of population distribution and connectivity of

roads to all villages (Prasannakumar et al., 2011). Kerala ranks among the top five states in India with high road traffic injuries (Ministry of Road Transport & Highways, 2015)

Thiruvananthapuram City Corporation is one among the fastest growing cities in South India, where drastic changes in land use and land cover have taken place in recent years. Most of the expansions have been with inadequate planning and this has lead to narrow roads and traffic congestion. Over the years the vehicle density in the city has been alarming and the road conditions have remained the same.

With the development of Information Technology hub and the numerous start ups of a number of IT based industries has increased the number of vehicles without a proportional increase in road infrastructure. The roads in the area are always under excessive pressure, the likelihood of accidents is more, the possibility of spatiotemporal prediction of accidents is very important to traffic police department as well as transportation planners and engineers

Table 1.1 Road Traffic Injuries Statistics

	Year	No. of Accidents	No. of Deaths	No. of Total Injuries
Kerala	2015	39014	4196	43735
	2016	39420	4287	44108
Thiruvananthapuram City	2015	2199	164	2650
	2016	2453	180	2994

Source- Kerala Police Records

Table 1.1 has summarized data from the Kerala police records on the number of road traffic injuries that had occurred in Kerala and Thiruvananthapuram city in the years 2015 and 2016.

Other Related Statistics

- 372,278 persons who committed various violations yielded Rs 5.06 Crore in fines (December 2015)
- 24,060 persons for parking vehicles in no-parking zones and 5,910 for driving without license
- 1,329 persons were booked for using mobile phones during driving
- Overtaking through the left, careless driving, overloading and not dimming the headlights

With the recent initiatives and commitment from the Kerala state government on road and traffic safety initiatives and movements, with focus on seat belt laws and helmet laws. The central government has also expressed keen concern on the need for vehicle structure integrity; safety features for example airbags, anti braking system (ABS) in cars and conducted active road safety campaigns throughout the country to educate and create awareness to the general public on need for good driving behaviour, avoiding alcohol during driving or riding and distracted driving.

CHAPTER 2- LITERATURE REVIEW

Relevant literature using key words road traffic injuries, road traffic accident, traffic safety, and geographic information system, geospatial analysis and accident spots were reviewed. Findings of previous studies were summarized. The concept of geographical spatial analysis and its ability to inculcate spatial variation, spatial distribution, time factor and demographic composition of road traffic accidents were given importance. The reason for a detailed description on related theories, concepts and approaches was due to the complexity of occurrence of road traffic accidents.

2.1 ROAD TRAFFIC INJURY THEORY AND CONCEPT- SYSTEMS THEORY AND SAFETY CONCEPT

Systems theory describes the different complex socio-technical systems in the society and its integrity for road safety. Hollangel stated that road injuries occur when components of a system interact with each other unpredictably (Hollangel, 2004). Salmon et al. had started a system based model in the road transport domain is keen to understand latent conditions and road error within the road transport system. This is essential in formulating strategies to promote error tolerance within the road transport domain (Salmon et al., 2006).

2.1.1 ROAD TRANSPORT PLANNING AND STRATEGY

A sustainable long term objective ensures and contributes to the safety of vehicles and that of vulnerable road users. As seen in most developing countries; Transport infrastructure, administration and planning expand at a fast pace. Hence, adequate attention needs to be emphasized on eliminating fatal injuries (Quigley et al., 2012).

Quigley et al. (Quigley et al., 2012) had identified the following:

- Motorised traffic with a flow must be segregated from non-motorised traffic
- Network of the main traffic routes must be created for pedestrians and cyclists
- Balance between motorised and non-motorised traffic for priority at crossings
- The maximum speed limit should be restricted on roads and road intersection where it mixes with non-motorised traffic

During the planning stage of a road or road system, it is necessary to carry out traffic studies to estimate the volumes of traffic that will have to be considered in design years (O'Flaherty, 2006). Road planning and implementation should be finalised keeping in mind future prediction of growth in terms of population and economy.

2.1.2 ROAD DESIGN IMPACT ON ROAD TRAFFIC ACCIDENT

Road design requires economic and environmental assessment in relation to the justification, scale and location of road scheme alternatives (O'Flaherty, 2006). Road design involves using traffic volumes which are derived from measurements of current traffic and estimates of future traffic. O'Flaherty explained current traffic, reassigned traffic, redistributed traffic, normal traffic and generated traffic should be adequately and thoroughly evaluated when designing a new/improved road (O'Flaherty, 2006). Shawky et al. found that road width had a significant effect on road injuries and fatalities. The risk of severe road traffic injuries and fatalities increase with increasing number of road lanes at the expense of the slight and medium road traffic injuries (Shawky et al., 2014). Zegger et al. recorded that there was evidence of more fatal crashes at marked crosswalks compared to unmarked crosswalks.

Road design conditions correspond with road traffic crashes in developing countries (Zegger et al., 2002). Peltzer and Mashego highlighted that causes of road traffic crashes are due to an

interaction of pre-crash factors that include road environment geometry and poor road design (Peltzer and Mashego, 2003).

Improvements on existing road design have had a significant reduction in road traffic crashes and injuries. Schneider et al. reported raising road medians on both intersecting streets had a significant reduction on road traffic crashes and lower numbers of pedestrian crashes (Schneider et al., 2010). Davies in his report on the United Kingdom Implementation, of Pedestrian Safety Facilities found an increase in extensions of pedestrian safety crossing width in Nottingham by 2.5m into the street had a significant influence on pedestrian safety records. The effect of this extension was noticed in the reduction on average pedestrian crashes from 4.7 to 1 per year (Davies, 2000).

2.2 FRAMEWORKS FOR ROAD TRAFFIC ACCIDENTS - HADDON SAFETY MEASURE MATRIX

William Haddon, a physician in 1980 developed a matrix that identified the potential risk of a crash, in relation to the person, vehicle and the environment. Haddon's work relied on public health efforts to address phases in the crash and injury process (pre-crash, crash, and post-crash). The strength of the Haddon matrix is it can be applied in multidisciplinary domains and it is comprehensive in explaining the causal factors responsible for traffic injuries. The main pitfall to Haddon matrix is that, it lacks a clear direction of the association between the main components of the traffic system. Table 2.1 has a summary of Haddon safety measure. Table 2.2 has Haddon's matrix for motor vehicle collision.

Table 2.1 Haddon safety measure matrix

	Before crash	**In crash**	**After crash**
Driver (Road User)	Training, education (e.g. avoidance of drink-driving) attitudes, conspicuous crossing (Pedestrians, cyclists)	In-vehicle restraints fitted and worn	Emergency medical services
Vehicle	Primary safety (e.g. Braking, roadworthiness, visibility) speed, exposure	Secondary safety (e.g. impact protection)	Salvage
Road	Delineation, road geometry, surface condition, visibility	Road side safety e.g. hazardous poles	Restoration of road and traffic devices

Source; Commission for Global Road Safety 2008).

Table 2.2 Haddon's Matrix for Motor Vehicle Collision

Phase	**Host**	**Factor**		
		Agent or vehicle	**Physical environment**	**Social environment**
Pre-event (Primary Prevention)	Driving skill, Time pressures	Car design & handling, Anti-lock brakes, Maintenance of car	Road design; Speed limits	Reliance on private, rather than public transportation rather than public transportation raises traffic load; Compliance with seat belt law
During the event (Secondary Prevention)	Wearing seatbelt	Air bags working Size of car & crash resistance	Weather conditions; ice on road	Quality of emergency assistance; Assistance from bystanders
Post-event (Tertiary Prevention)	Ability to call for help ; Knowledge on first aid	Tendency of car to catch on fire	Emergency vehicle access to collision site	Sustained funding for emergency services

Source; Commission for Global Road Safety 2008).

Later Jorgensen and Abane made a heuristic adjustment to human-ecological model to suit road traffic accident analysis. The model (Figure 2.1) comprised of three main components in road traffic accidents:

- Vehicle: Vehicle composition, age, safety features such as air bag, seat belt, and vehicular technical condition.
- Environment: All external surroundings of the road system, the road width and built up environment. All aspects of the physical environment were further classified as; daylight and climate referring to weather climatic conditions and road conditions. Also spatial conditions in terms of arrangements and macro-structures, settlement distribution pattern (urban or rural/ sparse or populated area), situation of areas of residence and working areas, road intersection, principle of traffic separation, topography and road constructions qualities, are also included.
- Behaviour of the population: Demographic composition of the population, attitudes and general traffic behaviour. It further extends to driving behaviour, years of driving experience, driving style and driving under the influence of hard substance.

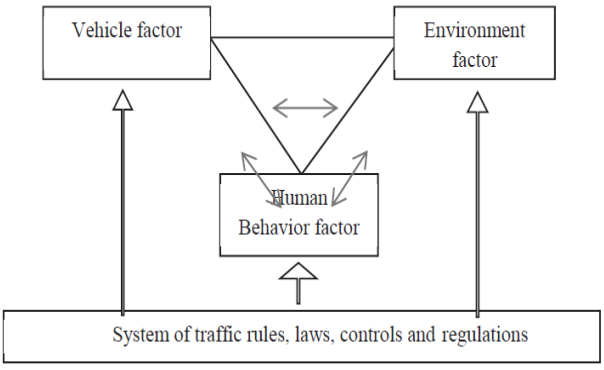

Figure 2.1 – Model for Traffic Accidents, source: Jorgensen and Abane (1999)

The model assists in controlling and maintaining a certain regulated level of law and order in road safety (Jorgensen and Abane, 1999; Komba, 2006).

2.3 GEOGRAPHIC INFORMATION SYSTEM (GIS) APPLICATION ON ROAD TRAFFIC ACCIDENT

Geographic Information System (GIS) is a powerful tool that has been used in data interpretation of road traffic injuries. It has been possible because of the availability of road accidents statistical data; accident crash location, number of crashes and road geographic data. This secondary data can be meaningfully used for road traffic accident spatial analysis using GIS software. Further on mapping of accident hotspots helps to establish correlations between road geometry and accident's location.

Some of the potential uses of GIS were presented in Lai and Chan's (Lai and Chan, 2004) study in analysing road accidents in Hong Kong. Various points-pattern techniques were used. The observations revealed phenomenal distributional patterns of hidden behaviour of accident data. Ziari and Khabiri (Ziari and Khabiri , 2005) using Iran car crashes data from the police accident reports were able to develop a tool that generates a contour map in identifying areas of high crash occurrence determined by crash density and clusters of crashes involving pedestrians and cyclists.

A spatial kernel density estimation method in GIS was used by Jang et.al (Jang et.al, 2013) to measure the concentrated density of pedestrian crashes. Prasannakumar et al. carried out a study in Thiruvananthapuram city in 2008, using GIS and mapped road accident hotspots within the city (Prasannakumar et al., 2011).

Rankavat and Tiwari in Delhi used GIS techniques to identify pedestrian accident-prone areas, pedestrian accident-prone roads (Rankavat and Tiwari, 2013). Molla et al. investigated geo-statistical approach of traffic crash data using ordinary krigging and clustering analysis to detect traffic accident hotspot clusters in North Dakota. GIS techniques were useful in discovering critical threshold zones for higher accident prone areas in the state. They were able to generate different maps showing different attributes on the road network in the state (Molla et al., 2014).

Spatial display of road traffic injuries can be directly added if the exact geographic coordinates in respect to XY points (latitude and longitude) are known, by using GPS during road accident report data collection. This yields the actual location of the accident and hence helps to understand the possible contributing factors to the crash

Various researchers have used tools in GIS such as cluster analysis to display crash locations on digital map which can easily be interpreted. Reshma and Sheikh prioritized black spots in South Bangalore by using GIS software and assigned possible weights for various accident components (Reshma and Sheikh, 2012).

Nagarajan and Cefil identified black spots on the NH -45 starting from Tambaram to Chengalpet. Locations were identified in the study using high resolution satellite map (IKONS) based on the non-spatial data collected from the police department and the field survey conducted in terms of traffic volume and vehicle spot speed, and plotting of the study stretch using GIS software (Nagarajan and Cefil, 2012). Identifying road traffic accident hotspot is vital to establishing effective measures on road safety management identification and implementation (Anderson, 2009; Molla et al., 2014). GIS further helps to understand the

correlation of crash data and traffic data (Li, 2006) and help obtain better policies to combat road traffic injuries.

2.4 ROAD TRAFFIC INJURIES AND HEALTH CARE FACILITIES

It has been recommended that the first hour after an event of road traffic injury is the most critical hour and is commonly known as the golden hour. The chance of survival drastically comes down for a trauma patient significantly after the first by almost sixty percent. As per the guidelines of the National Highway Authority of India (NHAI), it is mandatory to set up trauma centres every hundred kilometres and in 2012, the central government had addressed the growing problem by setting up four hundred trauma care centres on important national highways and had interlinked the facilities. This had been the first national initiative to have been implemented to help accident victims. A recent initiative by the government has been to not question the person who took the responsibility of bringing the accident victim from the spot of the trauma to the nearest health care facility.

As stated by Mock et al. in their case study in Ghana had pointed out that the timely arrival of Emergency medical services at the site of incidence followed by the speedy transportation of the victims to hospital by trained personnel's may reduce the consequence of road traffic injuries (Mock et al., 2003). Also they had mentioned that the many studies had revealed several critical deficiencies, a few to name are

a. Human resources (Staffing and training)
b. Physical resources (equipment, supplies and infrastructure)
c. Administration
d. Organization

Bigdeli et al. had reported that the total time intervals among emergency medical services responding to victims of road traffic injuries were longer for interurban roads as compared to the city areas in Iran (Bigdeli et al.,2010). It has been rightly mentioned that a majority of road traffic injuries were caused by road users who had violated the traffic regulations (Agnihotri,2012). Bigdeli et al. had identified after conducting thirty six semi-structured interviews with medical personnel's, police officers, members if Red Crescent, fire fighters, public health professionals, road administrators, a few road users and victims of road traffic injuries that the main variable at stake was the poor quality of post crash management. He further identified the lack of commitment of involvement of lat people, lack of coordination, inadequate pre- hospital services and lack of proper infrastructure as the core reasons for the poor quality in post crash management (Bigdeli et al., 2010).

As rightly mentioned by Agnihotri the key to dealing with road traffic injuries is to prevention. To minimize the morbidity and mortality, a national or regional multi-disciplinary trauma system needs to be developed with all facilities to care for all victims of road traffic injuries. Effective triaging is also the key to allow rapid identification of critically injured victims for a better match between the patients need and the resources available in the particular hospital (Agnihotri, 2012).

2.5 RATIONALE FOR THE STUDY

Road traffic accidents were the ninth leading cause of death globally, and will rise to become the fifth leading cause by 2030 (WHO, 2004&2009). Kerala ranks within the top five states with highroad traffic injuries despite better access to health care facilities. Thiruvananthapuram City Corporation has expanded over the years and the vehicle density

has shown an alarming increase in the past few years, but the road conditions persist to be the same and hence resulting in increased incidents of road traffic injuries (Prasannakumar, 2011). It is estimated that Road traffic injuries cost billions of rupees globally and nationally. Also road traffic injuries put significant strain on health care budgets (Gopalakrishnan, 2012). Kerala has made recent amendments to its road safety policies and has focussed its attention on road safety. Not many studies are done on geospatial analysis for road traffic injuries in Thiruvananthapuram City Corporation.

2.6 RESEARCH QUESTION

1. What is the spatial distribution of road traffic injuries in Thiruvananthapuram city?
2. Does the distribution of road traffic injuries in Thiruvananthapuram city show spatiotemporal clustering?
3. How health care facilities are distributed in comparison to the accident hot spots?

2.7 OBJECTIVES

2.7.1 MAJOR OBJECTIVES

1. To spatially map the Road Traffic Injury (RTI) cases reported in 2016 in Thiruvananthapuram City.
2. To spatially map the Health care facilities that provides emergency care services for trauma victims in Thiruvananthapuram City Corporation.
3. To explore spatial clustering, if any, of the RTIs in the city.

2.7.2 MINOR OBJECTIVES

1. To calculate the shortest distance from the accident hot spot to the nearest health care facility offering emergency care services for trauma victims.

CHAPTER 3- METHODOLOGY

3.1 STUDY AREA:

Thiruvananthapuram City Corporation is the capital of and the head quarters of Kerala. Thiruvananthapuram is also commonly known as Trivandrum. She extends from N 8 ^{0} 21' 44.485" and E 76 ^{0} 51' 20.8" to N 8 ^{0} 36' 25.542" and E 77 ^{0} 1' 27.119" and has an area of 215.86 sq km The city is bounded by the Western Ghats in the east and the Arabian Sea on the west.

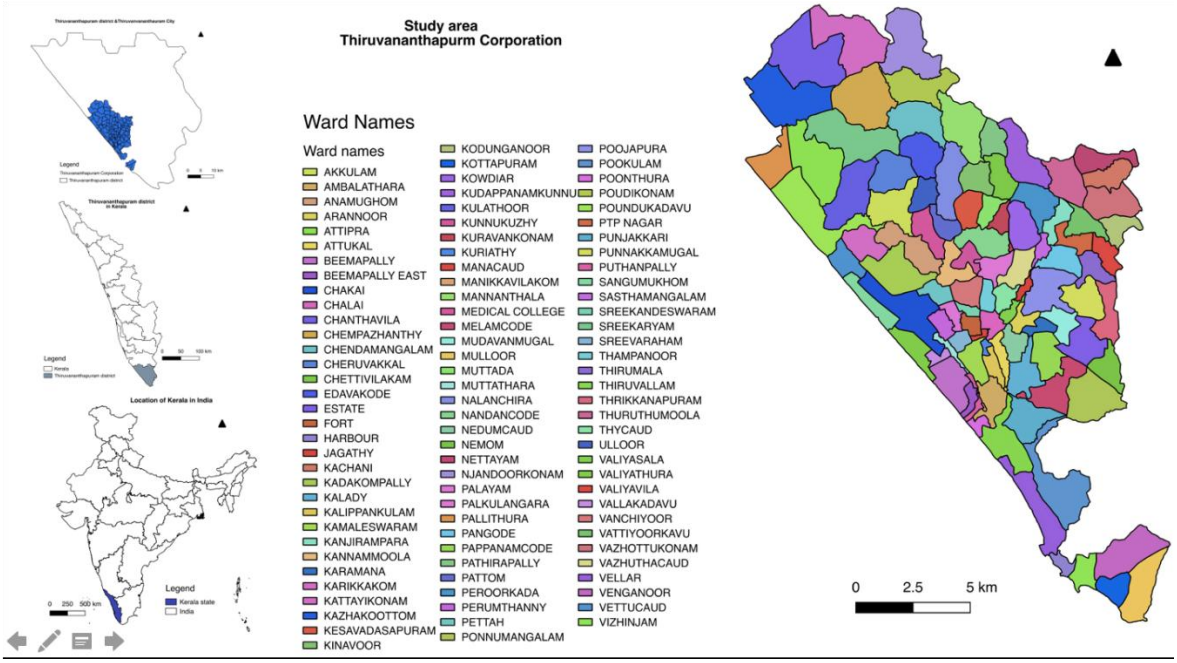

Figure 3.1 Map of the Study area with all 100 wards

3.2 STUDY DESIGN: Analytical cross sectional study

3.3 STUDY SUBJECTS/OBJECTS:

Road Traffic Injuries in Thiruvananthapuram city in 2016.

Secondary and Tertiary health care facilities within Thiruvananthapuram City

Study Time Period: January 2016 – December 2016

3.4 STEPS IN METHODOLOGY

1. A road map of Thiruvananthapuram city with all the 100 wards demarcated was created. The road networks were downloaded from openstreetmaps.org as an OSM file. Details are explained below
2. All RTIs in 2016 Thiruvananthapuram city (around 3000 in numbers) were obtained from the SCRB. A structured Data Extraction Template was used to extract the relevant details for the study from this secondary source. Geo-coordinates of the accident locations were captured with the help of Google Earth Maps. The above mentioned parameters were mapped over the base map of Thiruvananthapuram city- Using QGIS software. The Open Layer Plug in was used to overlay Google maps to cross check the layout of the data points on the road network
3. The spatial distribution of the accidents were explored using quadrant analysis of the point pattern of accidents and autocorrelation was assessed using the *Moran's I statistic* in GeoDa software. Spatial-temporal clustering of the Road traffic injuries were explored by estimating Local Indicators of Spatial Association (LISA) in GeoDa software and Clustering large applications (CLARA) using spatstat package in R

   Spatial statistical analysis was done using GeoDA and R statistical software.
4. All healthcare facilities offering emergency trauma care services in Thiruvananthapuram city were identified. The investigator visited all the centres and collected information using a pre-planned check list, including the geo-coordinates of the centre which was recorded using a hand held GPS unit

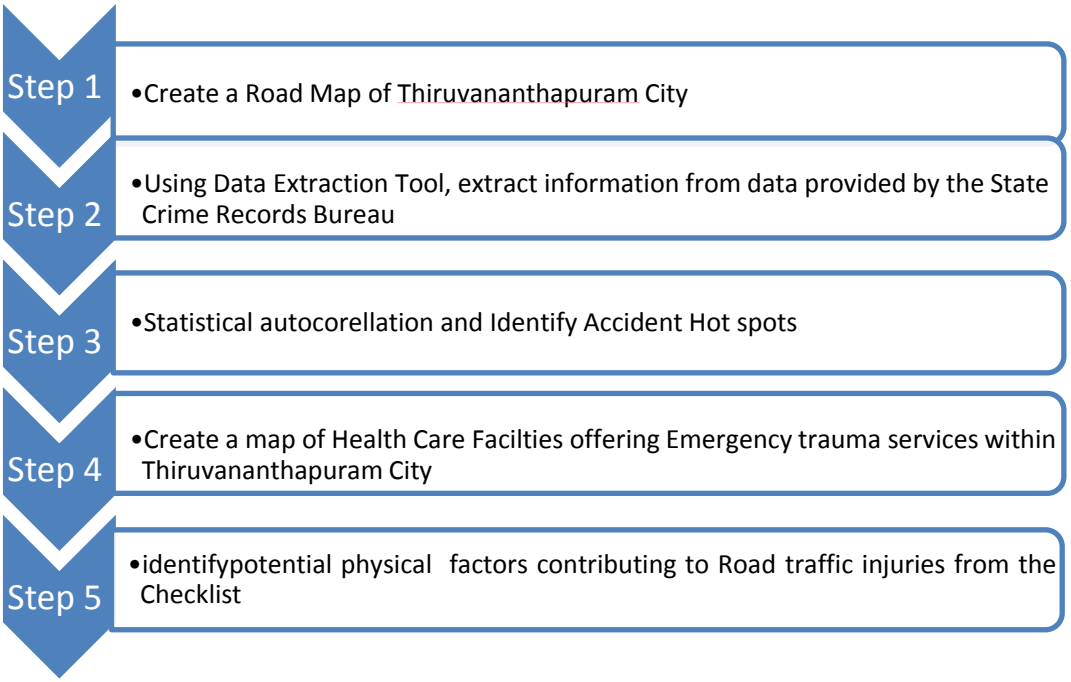

Figure 3.2 Schematic Representations of the Methods

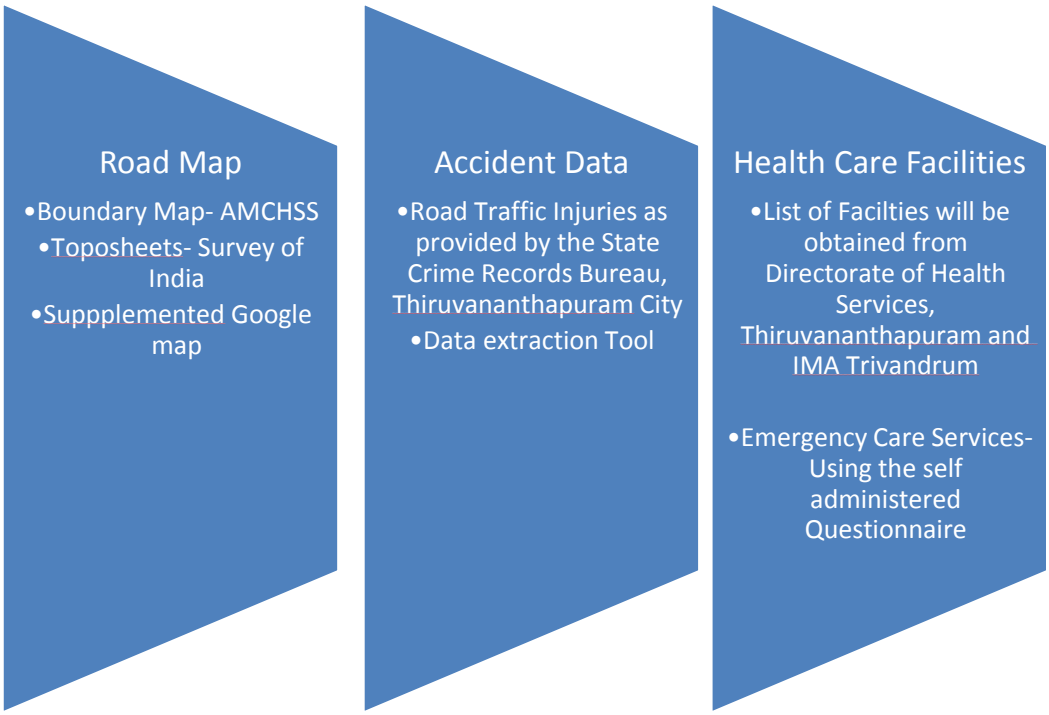

Figure 3.3 Data Collection Techniques and Tools

Software used for the Study

i. Data Analytic software

- The R project for statistical computing version 3.4.2, Geospatial analysis software and statistical software
- QGIS version 2.18, Geographic Information System Software
- GeoDa version 1.10.0.8 , Geosaptial analysis software

ii. Data management software

- Epidata Manager version 2.0.8.56 , Statistical software
- Epidata Entry client version 2.0.7.22 r547
- Microsoft Office Excel 2007 , for handling and preparation of secondary data from State Crime Records Bureau (SCRB), Thiruvananthapuram

Spatial Coordinate Reference System – The base maps were obtained in geographic Coordinate Reference System (CRS) with WGS 84 datum European Petroleum Survey Group (EPSG):4326 and for spatial analysis they were re-projected to the projected coordinate reference system with zone 43N (EPSG: 32643)

Details of the factors studied

Matrix 3.1 – Mapping of Variables

No	Tool	Variables	Comments
1	Map of Thiruvananthapuram City	Road Networks in Thiruvananthapuram City	National High Way State Highway Ordinary Roads
2	Accident Data	Serial Number , Age, Sex	
		Date & Time Accident	
		Assessment of Accident	
		Type of vehicle	
		Number of people involved	
		Location details	Name of road and approximate distance from Police Station
		Mode of Collision	Pedestrian/ Two wheeler/ Four wheeler/ Heavy vehicles
		Type of Injury	Death / Grievous/ Minor
		Sections Booked	
		Influence of Alcohol	
3	Health Care Facilities	Type of Health Care Facility	Government/ Private
		Type of Health Care	Secondary/ Tertiary

Matrix 3.1 and Matrix 3.2 gives a detailed description of the co-variables used in the study and the way in which they were collected. Attention is given to Road traffic injuries and Health facilities located within the city. Health care facilities having an Emergency Room and requisite competency (as stated by the hospital authorities) to handle trauma were only are taken in the study. These were mostly secondary and tertiary health care facilities.

Matrix 3.2- Variable mapping and additional details

No	Tools	Obtain From	Comments
1	Thiruvananthapuram Corporation with boundaries of all 100 wards	Available with the geospatial resources at AMCHSS	
2	Map of Thiruvananthapuram City Road networks	Obtained from open source maps (openstreetmap.org). Supplemented with Google street map layer	Topographic sheets were obtained from Survey of India, Trivandrum to verify all the map details
3	Softwares used	QGIS Software + Plug-in (Group stats, Road graph) Crime stat III, GeoDa, R-geospatial and statistical software	All are in group of Free Open Source Software's (FOSS)
4	Accident Data Details	State Crime Records Bureau, Thiruvananthapuram	Data was obtained from SCRB on written permission for academic purposes
5	Health care facilities Details	Directorate of Health Services (DHS), Indian Medical Association, Trivandrum and other publicly available sources	
6	Topographic sheets (C43X3, C43W15, C43W14, C43X2)	Survey of India	Purchased data from Survey of India, Thiruvananthapuram

STEP 1 - CREATE A MAP OF THIRUVANANTHAPURAM CITY

A map of Thiruvananthapuram city boundaries with 100 wards demarcated on the map was obtained from Geospatial resources, AMCHSS. It was in geographical coordinate system WGS 84 4326, it was converted to projected coordinate reference system with 43 (EPSG 32643) Due permission was taken to procure and use it for the study.

The map of Thiruvananthapuram City with the road networks was created by obtaining a layer of open source maps from openstreetmap.org. The road network in

Thiruvananathapuram city was downloaded from open street map (www.openstreetmap.org) as an OSM file with geometric coordinate system (CRS) of WGS 84 (EPSG: 4326). The OSM (OpenStreetMap) file was opened in QGIS and the road networks was saved as a line shape file with project CRS. Following which this layer was augmented with Google street map to ensure the OSM line shape file was accurate. Meticulous effort was taken to ensure accuracy. Before deciding to use this publicly available resource efforts were made to obtain a more reliable road network map from the the Town Planners Office, Thiruvananthapuram as well as Survey Bhavan Thiruvananthapuram, city corporation office and the Town planners office Thiruvananthapuram.

A map of Thiruvananthapuram city showing the population density was generated using the 2011 ward wise census data. This map was generated to see if there were any relationship between the population density and the incidence of road traffic injuries. This was saved as a shape file layer in QGIS.

STEP 2 - DATA EXTRACTION TOOL

Data obtained from the State Crime Records Bureau, Thiruvananthapuram was in Microsoft excel format. It had information on the date, time, location of accident, name of the nearest junction, distance and direction of the location from the main police station, number of people injured, gravity of accident, type of vehicle involved, assessment of cause of accident, and demographic details of the people involved in the accident. A thorough preliminary analysis was done to ensure that there was no duplication of records.

Using the feature of Google Earth, the geo-coordinates of each accident location was captured. The rich information available with the SCRB records viz location address, details

of the nearest junction; distance and direction from the nearest police station were very helpful to pinpoint the accident locations over the road network. The geo-coordinates were obtained in geographic CRS with WGS 84 datum (EPSG: 4326) and was converted to projected CRS WGS 84 (EPSG 32643).

The accident data along with the coordinates was initially converted to a comma separated value (csv) format. The csv file was later exported to QGIS software for plotting the data and later for analysis. Using the spatial clip option under the Vector sub menu in QGIS, accidents that occurred outside Thiruvananthapuram city boundaries were removed. Data belonging to only Thiruvanananthauram city were kept. This was plotted as a separate layer in QGIS and converted to a point shape file layer.

Table 3.1 Data Extraction Template

ROAD TRAFFIC INJURIES IN THIRUVANANTHAPURAM CITY

SECTION 1 - Accident Details		
1	SL NO	
2	Date of Accident	dd/mm/yyyy
3	Time of Accident	HR:MM
4	Location of accident	
5	Type of Road	1. National Highway
		2. State Highway
		3. Major City Road
6	Name of nearest Junction	
7	Name of nearest Major city road	
8	Name of nearest Highway	

SECTION 2- Health Facility		
9	Is there a Health Facility nearby?	1. Yes
		2. No
10	Type of Health Facility	1. Government
		2. Private
11	Shortest distance to nearest Health Facility	1. < 500 m
		2. 500m - 1 Km
		3. 1.1- 5 km
		4. 5.1-10 km
		5. >10 km
12	Is there an Ambulance facility?	1. Yes
		2. No
SECTION 3 - COLLISION		
16	Name of Nearest Police station	
17	Date of intimation by police personnel	dd/mm/yyyy
18	Time of intimation by Police personnel	HR:MM
19	Nature of Injury	1. Death
		2. Grievous
		3. Minor
20	Influence of Alcohol	1. Yes
		2. No
21	Mode of collision	1. Pedestrian
		2. Two wheeler
		3. Light motor vehicles
		4. Heavy motor vehicles

22	Sections Booked	1. IPC Section 279
		2. IPC Section 304A
		3. IPC Section 336
		4. IPC Section 337
		5. IPC Section 338
		6.Motor Occurrence (MO)

Few working definitions used

- Accident Hotspot- More than 7 accidents in the same location over the past one year
- Injury – Reported as death or grievous or minor injury incurred as a result of a collision during the study period
- Fatal Injury- A road Traffic Injury that has lead to death of a person involved in the collision and has been documented by the Traffic Police officials
- Road Traffic Injury (RTI) – Any reported injury that may have resulted in death or grievous or minor in nature.

Sections Booked

- IPC Section 279- Rash driving or riding on a public way
- IPC Section 304 A- Causing death by negligence
- IPC Section 336- Act endangering life or personal safety of others
- IPC Section 337- Causing hurt by act endangering life or personal safety of others
- IPC Section 338- Causing grievous hurt by act endangering life or personal safety of others
- Motor Occurrence (MO)- Causing hurt or injury by collision with a stationary object

STEP 3 - STATISTICAL AUTOCORRELATION AND ACCIDENT HOT SPOTS

Accident Density Map- using quadrant analysis

A density map was designed taking in all the attributes. A grid size of 100 x 100 m was taken and the data was plotted. The grid layer was then clipped using the clip function in QGIS to share its boundaries with the Thiruvananthapuram wards layer. The map was generated based on the number of road traffic injuries that had occurred in the particular area over the past year. Based on the severity the top eight places were identified.

After the above mentioned steps, spatial autocorrelation was calculated by finding the Moran's-I Statistics. This was calculated using GeoDa. GeoDa was also used to calculate the Local Indicators of Spatial Association (LISA). LISA helps in identifying clustering of events and in this scenario will help in identifying accident hotspots. A weight was calculated in GeoDa prior to calculating the Moran's- I and LISA statistics.

Moran's I statistics is a measure of spatial autocorrelation. It is to construct a matrix that reflects assumptions about a particular spatial phenomenon. The expected value of Moran's-I statistics is under the null hypothesis of no spatial autocorrelation.

Moran's-I statistics ranges between -1 to +1. Generally it could be interpreted that a negative value indicates a negative spatial autocorrelation. A positive value indicates a positive spatial autocorrelation, although there are more sophisticated ways of interpreting the statistics. A value closer to zero indicates a random spatial pattern.

LISA is similar to the Gi and G*i statistics of Getis and Ord. Hence this map was also generated. LISA statistics is based on Tobler's first law of Geography, "Everything depends

on everything else, but closer things more so" that is to say in the context of the road traffic injuries data, all observations have influence in all other observations" (Tobler, 1970; Miller, 2004).

There are several clustering algorithms. The need for a clustering algorithm is to divide the data into different clusters or groups such that the objects within a group are similar to each other whereas objects in other clusters share other properties. (Kumar et al., 2015) Clustering was identified in R – Statistical software. Clustering is of three different types

1. Density based
2. Model based
3. Hierarchical method
4. Fuzzy method
5. Partitioning methods

In this study we chose to go with partitioning method. Its based on the principle to classify observations within a data set into multiple groups based on similarity. Partitioning method is further sub divided into

i. K means- Here each cluster is represented by centre or means of data points belonging to a cluster. It is sensitive to anomalous data points and outliers. The cluster mean or centroids or correlation distance is based on the z scores.

ii. Partitioning around medoids (PAM) - Here each cluster is represented by one object in cluster. It is less sensitive to outliers as compared to k means. Each observation is assigned to the nearest medoid. This is continued until the observed function can no longer be decreased. The goal is to find the k representative

which minimizes sum of dissimilarities of observation to the nearest representative object. The output is Euclidean. This is usually the sum of squares of the difference.

iii. Clustering Large Applications (CLARA) - CLARA is an extension of PAM. It's used for large data sets. The principle behind is it considers small data with fixed size and applies PAM. The quality of the resulting medoids is measured by average dissimilarity between every object in the data set and medoid of the cluster. CLARA relies on sampling and the clustering process. It tries to minimize sampling bias.

As part of CLARA, the optimal number of clusters needs to be calculated. With the existing data set, the optimal number of clusters was calculated in R statistical software and it had come as eight clusters.

STEP 4 - CREATE A MAP OF HEALTH CARE FACILITIES WITHIN THIRUVANANTHAPURAM CITY

Health care facilities were mapped as a separate layer. The list of Health Facilities within Thiruvananthapuram City Corporation was obtained from Directorate of Health Services (DHS), Thiruvananthapuram and other publicly available sources. The government as well as private health care facilities were plotted based on their GPS (Global Positioning System) coordinates. The GPS coordinates were captured using Garmin Etrex Legend GPS Unit. Prior consent was obtained from the Public relations officer or other personnel in the administrative department aware of the day to day running of the hospital or Institute in the respective health care facility. After obtaining the consent, information on the health care

facilities ability to provide emergency trauma care services were collected using a structured checklist (Table 3.1). Importance was given to secondary and tertiary health care facilities. The working definitions for secondary and tertiary health care were (Arthapedia.in, 2017):

Secondary Health Care

Secondary Healthcare refers to a second tier of the health system, in which patients from primary health care are referred to specialists in higher hospitals for treatment. In India, the health centres for secondary health care include District hospitals and Community Health Centre at block level.

Tertiary Health Care

Tertiary Health care refers to a third level of the health system, in which specialized consultative care is usually provided on referral from primary and secondary medical care. Specialized Intensive Care Units, advanced diagnostic support services and specialized medical personnel on the key features of tertiary health care. In India, under the public health system, tertiary care service is provided by medical colleges and advanced medical research institutes.

After preparing the list, it was plotted as a separate layer in QGIS and saved as a shape file. Using the buffer function in QGIS, a buffer of 5 km was created around the boundaries of Thiruvananthapuram city. The health care facilities within this buffer were saved as a new layer.

Table 3.2 Checklist for Health Care Facility		
	SL NO	
1	Type of Health facility	1. Government
		2. Private
1	What is the position you hold in the Hospital	1. Public Relations Officer
		2. Administrative
2	Does your facility have an Emergency Room (ER)	1. Yes
		2. No
3	Is the ER capable of handling trauma emergencies	1. Yes
		2. No
4	Does the health care facility have an ambulance	1. Yes
		2.No

Information Sheet and Consent Form: Appendix I

Using the density map, a layer identifying the most severe areas (greater than 31-45) with road traffic injuries over the past year were identified and the distance from the particular hot spot to the nearest health care facility was calculated using the Road graph plug-in in QGIS. The distance to the nearest government as well as the private were calculated and tabulated. Rather than taking the aerial distance from the particular hotspot, the road distance was taken. For this step the OSM layer was used.

STEP 5 - IDENTIFY POTENTIAL FACTORS CONTRIBUTING TO ROAD TRAFFIC INJURIES FROM THE ACCIDENT HOT SPOT CHECKLIST

This was not a major objective in the study. The data was analyzed and interpreted such that the other potential physical factors that contribute to road traffic injuries were identified from the accident hot spots. Since these accident hot spots are places that are vulnerable to higher morbidity and mortality. A pre- structured checklist (Table 3.3) was prepared to try and capture the physical correlates that might be responsible for road traffic injuries.

Table 3.3 - Checklist for Accident Hot spots

Accident Hot Spot Analysis Checklist		
	SL NO	
1	Type of Road	1. National Highway
		2. State Highway
		3. Major City Road
		4. Ordinary roads
2	Number of Lanes	Single lane
		Two lane
		Multi lane
3	Width of the road	1. Narrow
		2. Wide
4	Median	1. Yes
		2.No
5	Condition of the road	1. Good
		2. Bad
5	Is there a Pedestrian Crossing within 1 km?	1. Yes
		2. No
6	Is there a sudden curve?	1. Yes
		2. No
7	Is there a Pavement?	1. Yes
		2. No
8	Is there a Traffic Signal?	1. Yes
		2. No
9	Speed breaker within 1 km	1. Yes
		2. No
10	Are there street lights?	1. Yes
		2. No
11	Any distractive bill boards?	1. Yes
		2. No

12	Is there a hazard warning within 1 km?	1. Yes
		2. No
13	Is it an intersection?	1. Yes
		2. No
14	Is there a police personnel stationed?	1. Yes
		2. No
15	Is there a traffic police camera within 5 km	1. Yes
		2. No

3.5 ETHICAL CONSIDERATION

The protocol of the study has been approved by the Institutional Ethics Committee (IEC) of Sree Chithra Tirunal Institute of Medical Science, Trivandrum. The Ethics committee is in compliance with the Helsinki Declaration. Also the necessary permission was obtained from the State Crime Records Bureau, Thiruvananthapuram prior to using the data for academic purposes. Written informed consent was obtained from the Public Relations Officer or other personnel in the Administrative department prior to obtaining their responses for the Checklist for Health care Facility (Table 3.1)

CHAPTER 4 -RESULTS

A total of 2998 events of road traffic injuries were reported within Thiruvananthapuram City in the year 2016. After doing a thorough quality check for missing values, duplicate values and confining to data within Thiruvananthapuram City Corporation boundaries, the total came to 1926 events. Statistical analysis for data analysis was done using the R project for statistical computing. A p value of five percent was considered statistically significant. The variables were grouped and categorized into eight different categories. Data pre-processing was done to remove irrelevant attributes, handle missing values and pre-processed the data to make it appropriate for analysis.

4.1 DESCRIPTIVE ANALYSIS OF THE ACCIDENT DATA

Table 4.1 gives a brief summary on the descriptive analysis of the accident data obtained from the State Crime Records Bureau (SCRB), Thiurvananthapuram for the year 2016. As per the SCRB reports, 2,319 people were involved in road traffic during the 1926 events that had occurred in Thiruvananathapuram city. Of this 72.3 percent were accused while 27.7 percent were victims. The age of the people involved in road traffic injuries ranged from 2-90 years. This has been represented in figure 4.1. The highest incidence of road traffic injuries were among 31- 60 years of age.

The following tables (Table 4.1 – 4.7) give the details of the people involved. It was noticed that the age group of 31- 60 years reported maximum number of deaths(48.2), grievous injuries (59.7%) and minor injures (62.1%). Males met with RTI (80%) more often than females (20%). Among the males who met with RTI, 84.7 percent died, 77.6 percent sustained grievous injuries and 80 percent sustained minor injuries. In comparison to men,

women had met with fewer deaths (4.7%) but had succumbed to lesser (22.4%) grievous injuries and minor injuries (19.4%). About eighty four (4.4%) accidents occurred by colliding with stationary objects. And two-third (66.9%) of the injuries occurred during the day time while one third (33.1%) of the injuries during the night time. It was surprising to note that as per the official reports; only one person was reported to be drunk during the event!

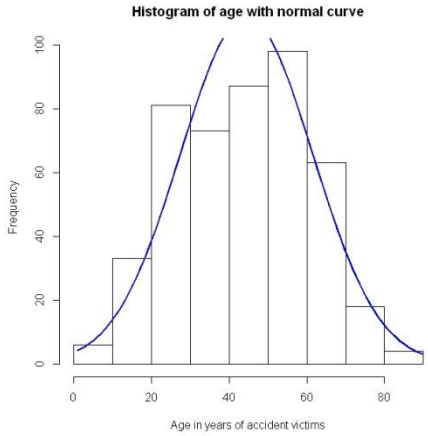

Figure 4.1 - Age distribution of people involved in RTI in Thiruvananthapuram City

Most of the reported injuries occurred in the ordinary roads (91.4%) while the rest (7.8%) occurred in the National highways and state highways (0.8%). About 1540 injuries were reported under grievous injuries while 150 were reported dead and about 629 injuries were reported as minor injuries. Among the reported accidents, majority (61.2%) were caused by two wheeler vehicles users. It was also noticed that the rate of deaths were highest among two wheeler users (44.8%) followed by heavy vehicle (19.9%). Looking at the categories of people involved, it was noted that 17 percent of pedestrians had met with death and 11.3 percent had met with grievous injuries. It was also noticed that most of the accidents involving minor injuries and grievous injuries had occurred during day time. Most of the

Most of the deaths occurred between 00:00 – 04:00 hours followed closely by 21:00 –23:00 hours. Most of the accused had suffered grievous injury (73.4%) as compared to victims.

Table4.1- Descriptive data summary

S. no	Attribute	Code	Value	Total (N)	Injury n(%)		
					Death	Grievous Injury	Minor Injury
1	Number of Injury	1	1 Person	2110 (91.0)	149 (99.3)	1438 (93.4)	523 (83.1)
		2	2 and >2 people	209 (9.0)	1 (0.7)	102 (6.6)	106 (16.9)
2	Age	1	<18 yrs	85 (3.9)	4 (2.7)	52 (1.4)	29 (5)
		2	19-30 yrs	594 (26.9)	37 (26.2)	414 (30)	143 (24.4)
		3	31-60 yrs	1317 (59.6)	68 (48.2)	885 (59.7)	364 (62.1)
		4	Above 60 yrs	214 (9.6)	32 (22.9)	132 (8.9)	50 (8.5)
3	Sex	M	Male	1829 (80)	127 (84.7)	1195 (77.6)	507 (80.6)
		F	Female	489 (20)	23 (15.3)	345 (22.4)	122 (19.4)
4	Time of Day	T1	(00:00-03:59)	63 (2.7)	7 (4.7)	34 (2.3)	22 (3.6)
		T2	(04:00-07:59)	275 (11.9)	19 (12.7)	196 (12.7)	60 (9.5)
		T3	(08:00-11:59)	546 (23.5)	32 (21.3)	384 (24.9)	130 (20.7)
		T4	(12:00-15:59)	576 (24.8)	30 (20)	388 (25.2)	158 (25.1)
		T5	(16:00-19:59)	609 (26.3)	35 (23.3)	399 (25.9)	175 (27.8)
		T6	(20:00-23:59)	250 (10.8)	27 (18.0)	139 (9.0)	84 (13.3)
5	Type of Road	NH	National Highway	180 (7.8)	19 (12.7)	115 (7.5)	46 (7.3)
		OR	Ordinary roads	2121 (91.4)	131 (87.3)	1413 (91.8)	577 (91.7)
		SH	State High way	18 (0.8)	0 (0)	12 (0.7)	6 (1)
6	Type of Accident	1	Pedestrian involved	451 (13.4)	31 (17.1)	351 (11.3)	69 (5.3)
		2	Two wheeler	2042 (67.6)	81 (44.8)	1042 (72.7)	919 (71.0)
		3	Three wheeler	235 (7)	11 (6.1)	136 (4.4)	88 (6.8)
		4	Four wheeler	433 (12.9)	22 (12.1)	265 (8.5)	146 (11.2)
		5	Heavy motor vehicles	206 (6.1)	36 (19.9)	97 (3.1)	73 (5.7)
7	Accused/ Victim	A	Accused	1676 (72.3)	121 (80.6)	1133 (73.4)	422 (67.4)
		V	Victim	643 (27.7)	29 (19.4)	410 (26.6)	204 (32.6)
8	Assessment of the Accident	1	Fault of Driver	2255 (97.2)	119 (79.3)	1517 (98.4)	619 (98.6)
		2	Other reasons	64 (2.8)	31 (20.7)	24 (1.6)	9 (1.4)

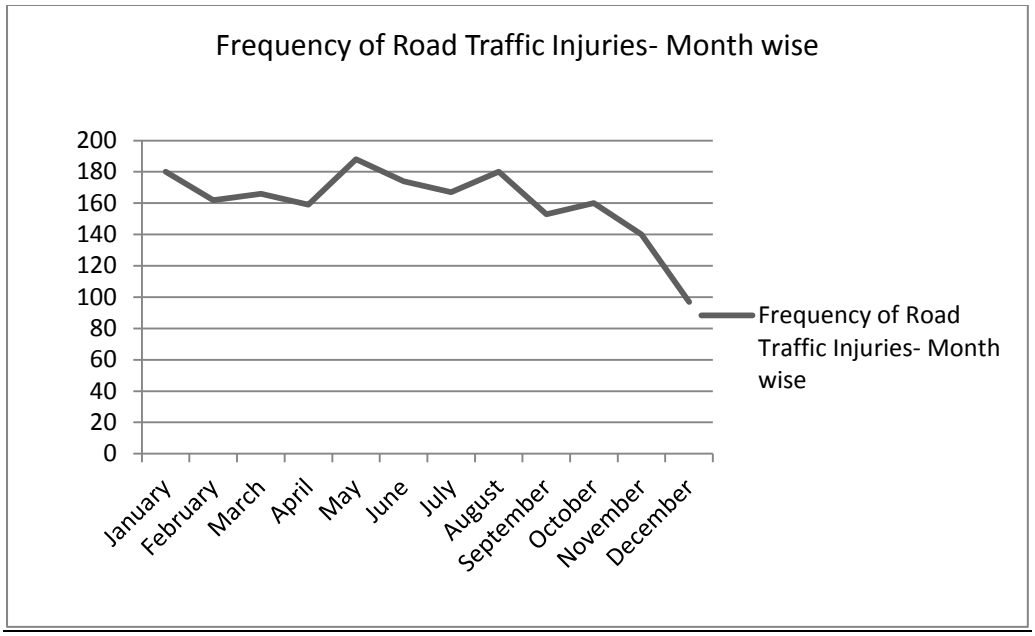

Figure 4.2 – Frequency of RTI – Month wise

Figure 4.2 shows the month wise distribution of road traffic injuries. It can be seen that it was highest during the month of May and lowest during the month of December.

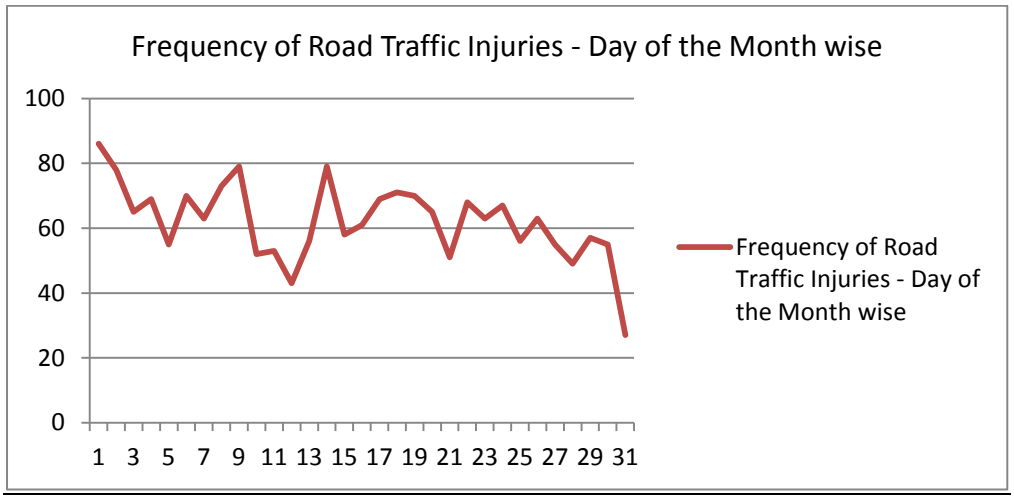

Figure 4.3 – Frequency of Road traffic injuries – Day of the month wise

Figure 4.3 shows the distribution of road traffic injuries based on the Day of the month. It is evident that its highest during the beginning of the month. The lowest incidence of injury was noticed towards the end of the month. The lowest

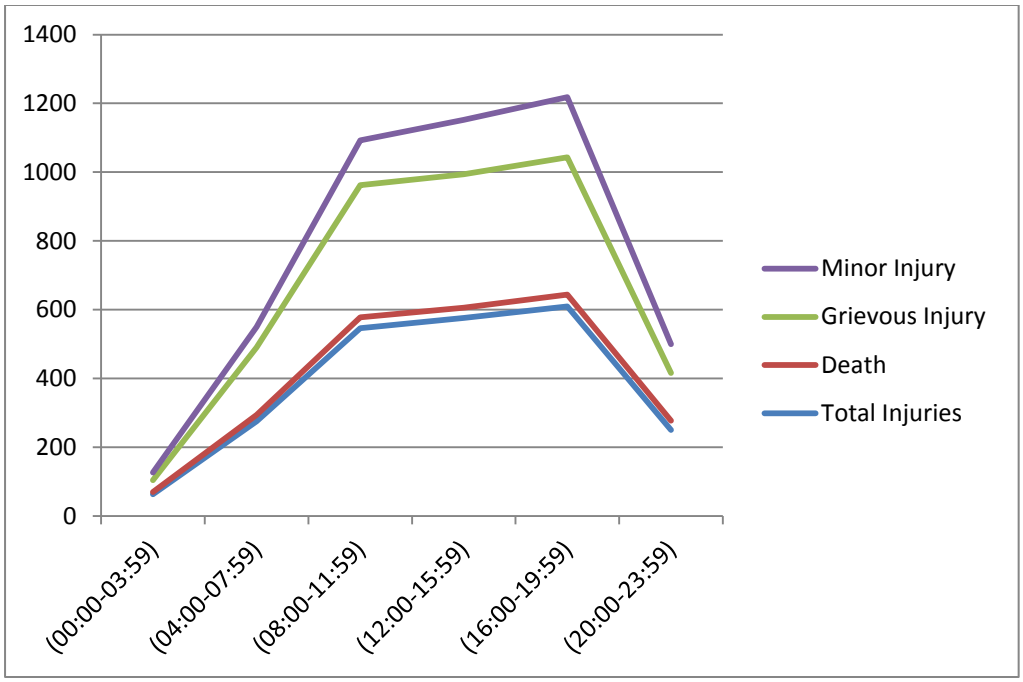

Figure 4.4 – Frequency of Time and Injury

Figure 4.4 shows the distribution of injuries across time. It was noticed to be highest during late afternoons (16:00-19:59) followed by afternoon hours (12:00 – 15:59) and it was observed least during early morning hours of 00:00-03:59. Most number of reported injuries were minor injuries followed by grievous injuries.

4.2 BIVARIATE ANALYSIS OF THE ACCIDENT DATA

All the variables were cross tabulated with deaths, grievous and minor injuries. The factors found significantly associated are detailed below. A p value of less than 0.05 was taken as significant.

4.2.1 RELATIONSHIP BETWEEN DEMOGRAPHIC VARIABLES AND TYPE OF INJURIES

i. Age profile of people who got killed

Table 4.2 – Age distribution and death

Age group (years)	Death n(%)		* p- value
	No	Yes	
<18	61(3.6)	4 (2.8)	<0.01
18-30	452 (26.5)	37 (26.2)	
31-60	1042 (61.1)	68 (48.2)	
Above 60	150 (8.8)	32 (22.7)	
Total	1705 (100)	141 (100)	

*χ^2 test for trend

Table 4.2 shows a significant association between age of the individuals involved in road traffic injuries and reported deaths. It was found that the highest proportion of death was found within the age group 31-60 (48.2%) and the lowest was noticed within age group < 18 years (2.8%) advance in age and death had a strong association except in the above 60 years age category. These observations had an association with p value <0.01.

ii. Sex and Minor injury

Table 4.3- Sex and grievous injuries

Sex	Grievous Injury		*p-value
	No injury	Injury present	
Female	64 (16.6)	345 (22.4)	< 0.01
Male	322 (83.4)	1195 (77.6)	
Total	386 (100)	1540 (100)	

*χ^2 test for trend

Table 4.3 shows the association between sex and grievous injuries reported. Sex was found to be significantly associated with grievous injury. Compared to women (22.4%), men had a (77.6%) had sustained grievous injury. This observation showed a strong association with p value <0.01

4.2.2 RELATIONSHIP BETWEEN TYPE OF VEHICLE AND INJURY

Table 4.4 and 4.5 represent the association between the type of road and the outcomes as deaths and minor injuries respectively

Table 4.4 - Type of vehicle and Death

Type of Vehicle	Death n(%)		*p- value
	No	Yes	
Two wheeler	1168 (65.7)	81 (54)	<0.01
Three wheeler	168 (9.4)	11 (7.3)	
Four wheeler	324 (18.2)	22 (14.7)	
Heavy Vehicle	116 (6.5)	36 (24.0)	
Total	1776 (100)	150 (100)	

*χ^2 test for trend

Table 4.4 shows the strong association between death and type of vehicle. Among the people who died, majority had met the RTI with two wheelers, followed by drivers of heavy vehicles and the least were noticed among three wheelers. There seems to be a strong association between the order of vehicle and death.

Table 4.5 - Type of vehicle and Minor injury

Type of Vehicle	Minor Injury n (%)		*p-value
	No injury	Injury present	
Two wheeler	907 (69.9)	322 (51.1)	<0.01
Three wheeler	103 (7.9)	88 (14.0)	
Four wheeler	188 (14.5)	146 (23.2)	
Heavy vehicle	99 (7.6)	73 (11.6)	
Total	1297 (100)	629 (100)	

*χ^2 test for trend

Table 4.5 shows that Minor injuries were reported most among three wheelers followed by four wheelers. Among the people who sustained minor injuries, majority were two wheelers (51.1%) followed by four wheelers (23.2%). Least was noticed among heavy vehicles drivers (11.6%)

4.2.2 RELATIONSHIP BETWEEN PEDESTRIAN AND MINOR INJURIES

Table 4.6 - Collision involving pedestrians and minor injuries

Pedestrian involved or not	Minor Injury n(%)		*p-value
	No injury	Injury present	
No pedestrian	7 (1.9)	8 (10.4)	<0.01
Pedestrian	347 (98.1)	69 (89.6)	
Total	354 (100)	77 (100)	

*χ^2 test for trend

Table 4.6 represents the association of involvement of pedestrians with reported minor injuries. Pedestrian's involvement was found to be significantly associated with occurrence of minor injuries. Minor injuries were higher when pedestrian were involved in the event.

4.2.4 RELATIONSHIP BETWEEN TIME OF ACCIDENT AND GRIEVOUS INJURIES

Table 4.7 and show the association between the time of day when the accident had occured with grievous injuries.

Table 4.7 - Day time and grievous injuries

Day/ Night	Grievous Injury n(%)		*p-value
	No Injury	Injury Present	
Day	214 (55.4)	1074 (69.7)	<0.01
Night	172 (44.5)	466 (30.2)	
Total	386 (100)	1540 (100)	

*χ^2 test for trend

Time of accidents was found to be significantly associated with the type of injury. Grievous injuries had a strong association with day time. Table 4.7 shows the association between grievous injury and time.

4.2.5 RELATIONSHIP BETWEEN TYPE OF ROAD AND DEATH

Table 4.8- Type of road and Death

Type of road	Death n (%)		*p- value
	No	Yes	
NH	136 (7.7)	19 (12.6)	0.05
OR	1626 (92.1)	131 (87.3)	
SH	4 (0.2)	0 (0)	
Total	1766 (100)	150 (100)	

*χ^2 test for trend

Table 4.10 shows the association between type of road and death. The type of road was found to be strongly associated with death. Death had occurred highest in the National Highways (NH) as compared to Ordinary Roads (OR). There were no deaths reported in the state highway (SH). Hence there is a significant association between the type of road and death.

4.3 GEOSPATIAL ANALYSIS

4.3.1 MAP OF THIRUVANANTHAPURAM CITY WITH WARD DEMARCATION AND ROAD NETWORKS

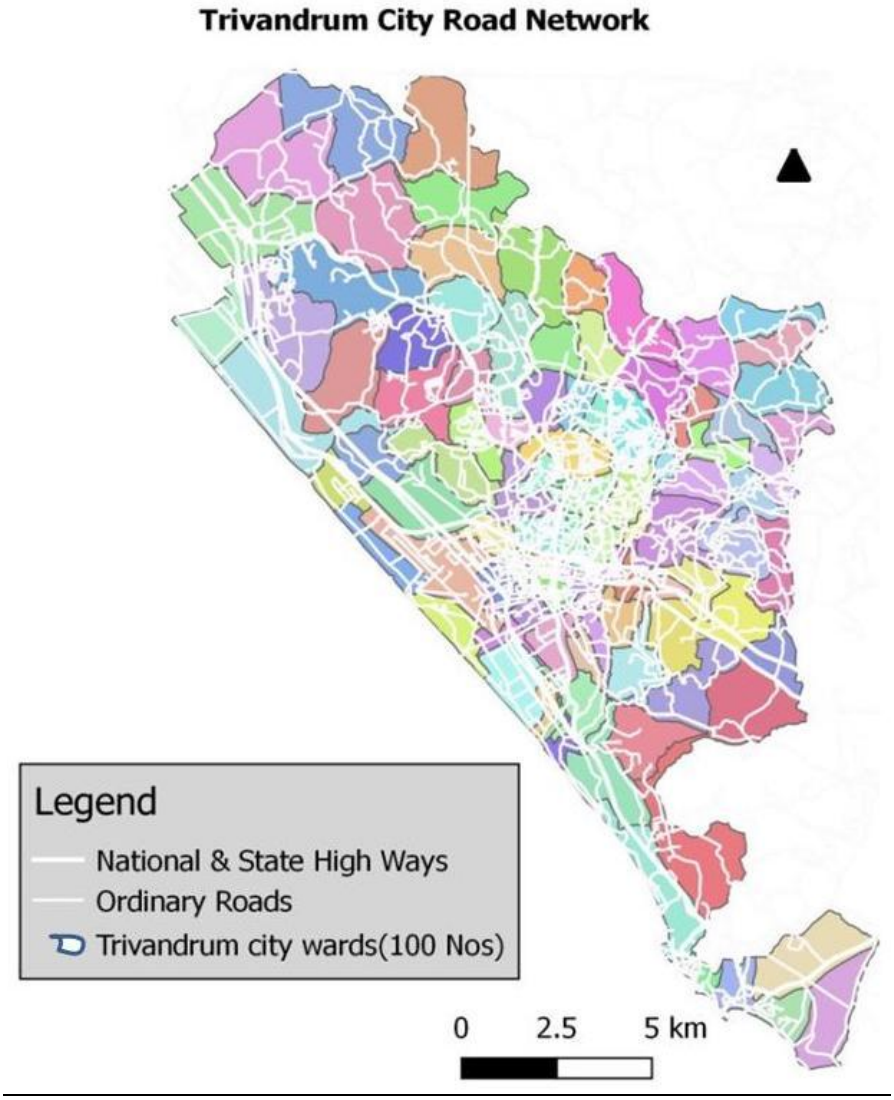

Figure 4.5 Map of Thiruvananthapuram City with ward demarcation and Road networks

Figure 4.5 shows the map of Thiruvanathapuram city with 100 wards and the vast interconnected network of roads in the City. Road network was obtained from open streetmap.org, this has been explained in- depth in Chapter 3. The roads have been classified into highways and ordinary roads.

4.3.2 DISTRIBUTION OF ROAD TRAFFIC INJURIES IN THIRUVANANTHAPURAM CITY

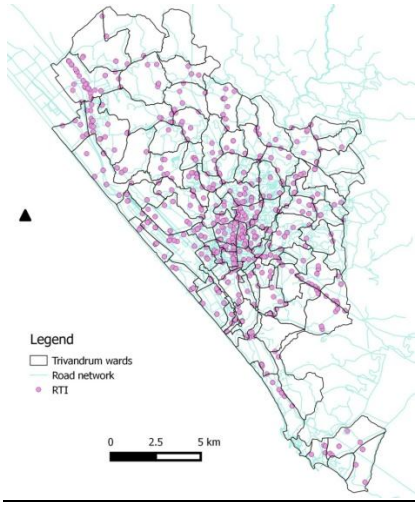

Figure 4.6 Distribution of RTI in Thiruvananthapuram City

It can be seen from figure 4.6 and figure 4.7 show the distribution of road traffic injuries is more in the city roads as compared to both the national as well as the state highways.

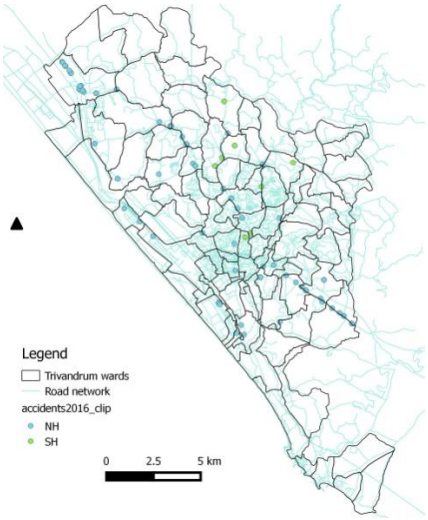

Figure 4.6a Distribution of RTI in NH and SH

4.3.3 CHLOROPLETH MAP SHOWING MEAN POPULATION DENSITY OF THIRUVANANTHAPURAM CITY

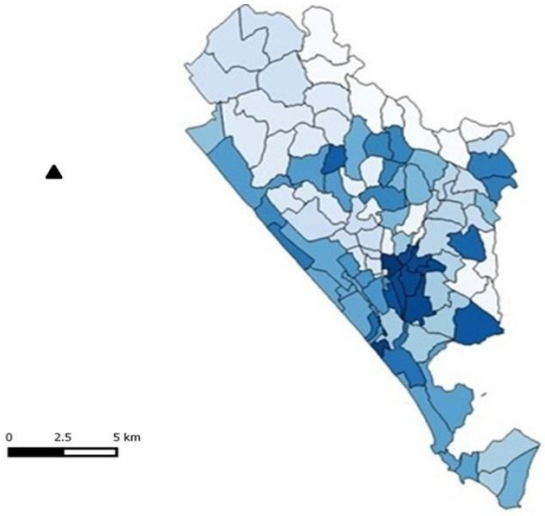

Figure 4.7 Chloropleth map showing mean population density

The most dense wards from figure 4.7 are Thycaud , Kannammoola, Thampanoor with upto 800 people per square kilometre and the least dense wards are Nemom, Kudappanamkunnu, Venganoor with a population density of 3 people per square kilometre

4.3.4 CHLOROPLETH MAP SHOWING ACCIDENT DISTRIBUTION – WARD WISE

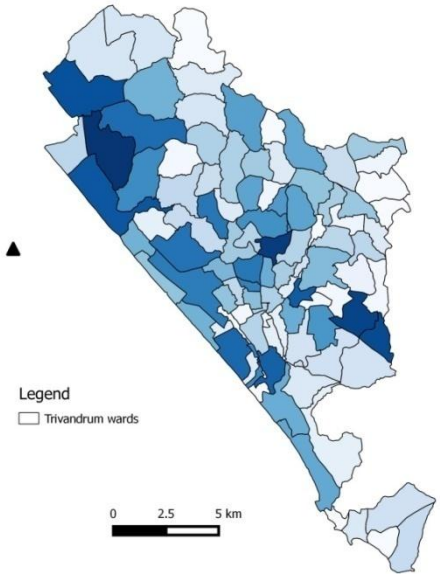

Figure 4.8 Chloropleth map showing Accident distribution – ward wise

Figure 4.8 shows a Chloropleth map on the ward wise distribution of accidents. Though it cant conclude much on the relationship between road traffic injuries and population density, the wards with a low density of people per square kilometre, had less number of events of road traffic injuries

4.3.5 QUADRANT ANALYSIS OF RTI IN THIRUVANANTHAPURAM CITY

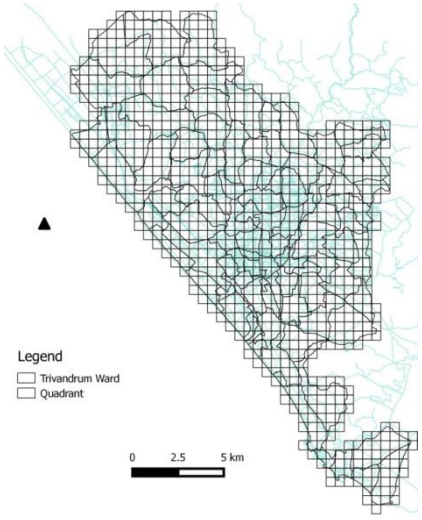

Figure 4.9 Grid with road network

Figure 4.9 and 4.10 show the quadrant analysis done to create a density map to portray severity of road traffic injuries. Figure 4.6 shows the hotspots with location of places with more than 7 events of road traffic injuries in the year 2016 in the particular location.

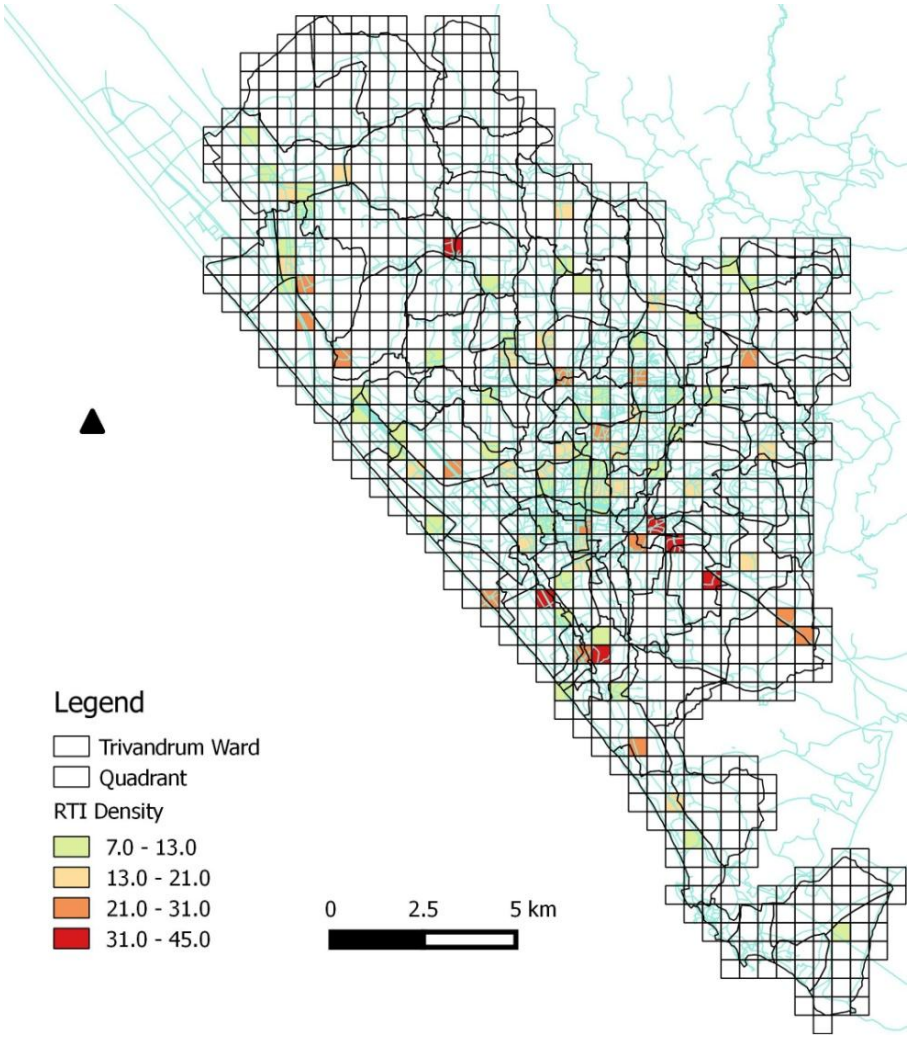

Figure 4.10 Accident Density Map

4.3.6 DISTRIBUTION OF ROAD TRAFFIC INJURIES BASED ON TIME

Figure 4.8 shows the distribution of road traffic injuries in Thiruvananthapuram city based on time. It can be seen that more number of road traffic injuries were reported during the day as compared to night.

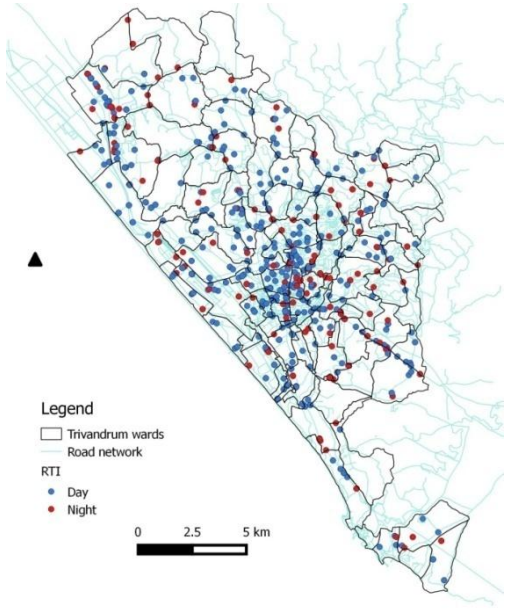

Figure 4.8 RTI Day/ Night distribution

4.3.7 SPATIAL AUTOCORRELATION (MORAN'S – I)

Moran's- I is a statistical test to find spatial autocorrelation. In the given set of features and an associated attribute/s, it evaluates whether the pattern is clustered, dispersed or random. This is based on feature locations and feature values simultaneously. The value ranges from -1 to 1. A value towards 1 indicates perfect clustering and a value towards -1 indicates the data set is dispersed. Morans- I was calculated using GeoDa software and after calculating

the weights for the particular data set the Morans I came to be 0.22849. This indicates positive spatial auto correlation.

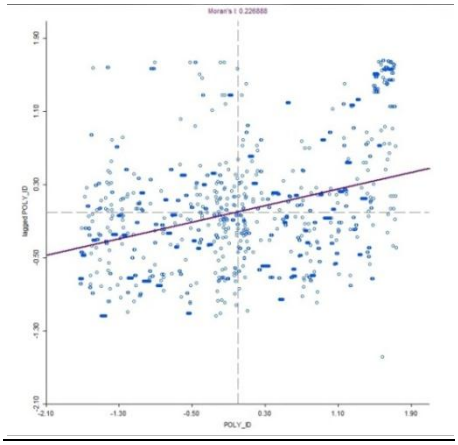

Figure 4.12 Moran's I plot

4.3.8 LOCAL INDICATORS OF SPATIAL ASSOCIATION (LISA)

LISA statistics serves two purposes. They may be indicators of local pocket of non-stationary, or hot spots, similar to Gi and G*i statistics of Getis and Ord statistics. They are also used to assess influence of individual locations to identify outliers as in Anselin- moran scatter plot. With the help of GeoDa , LISA statistics was obtained. As seen below they show the high- high which denote the hot spots and the low – low which denote the cold spots. This was calculated after creating a weight for the calculation.

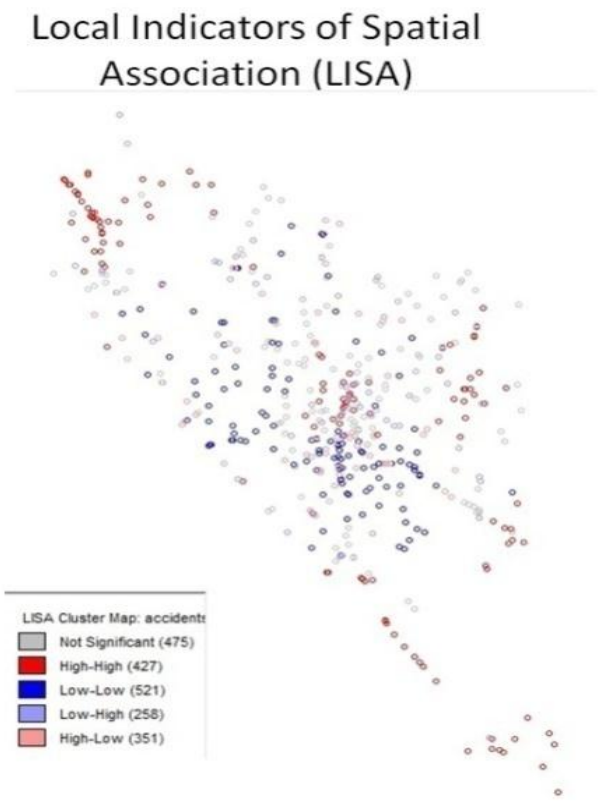

Figure 4.13 Local Indicators of Association (LISA) plot

4.3.9 CLUSTERING LARGE APPLICATIONS (CLARA)

After getting the optimal number of clusters as eight, the covariates taken to create the cluster plot were: - Age, Sex, Location, Day, Time and the Type of injury. The scatter plot is as shown in Figure 4.11. It was generated in R- statistical software. It illustrates the optimum number of clusters in the data set. After the generation of the optimum number of clusters , a cluster plot was generated as seen in Figure 4.14

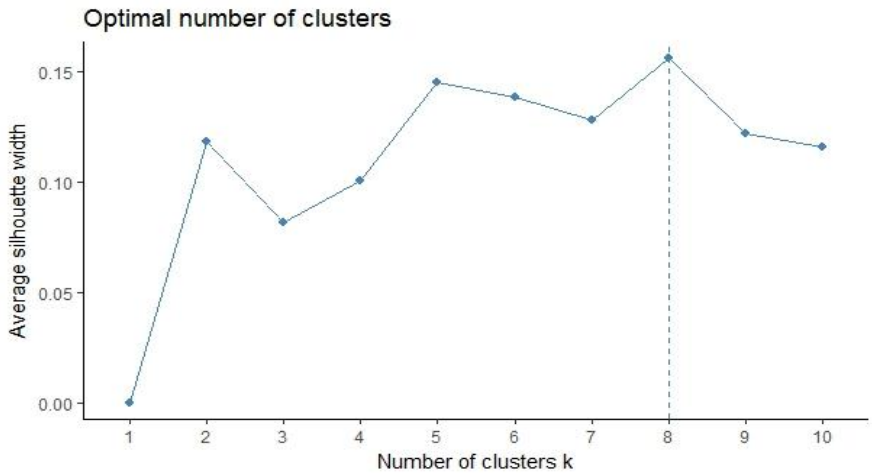

Figure 4.14- Optimal number of clusters

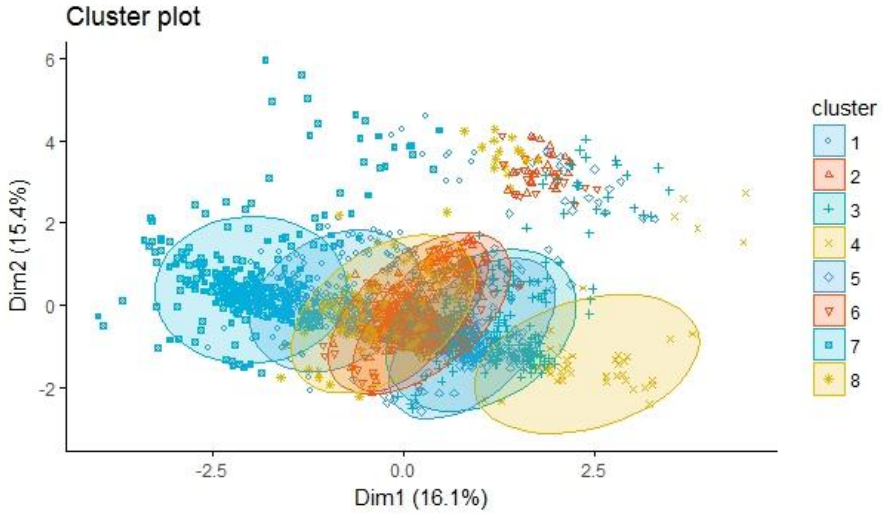

Figure 4.15 – Cluster plot

4.3.10 ACCIDENT HOTSPOTS

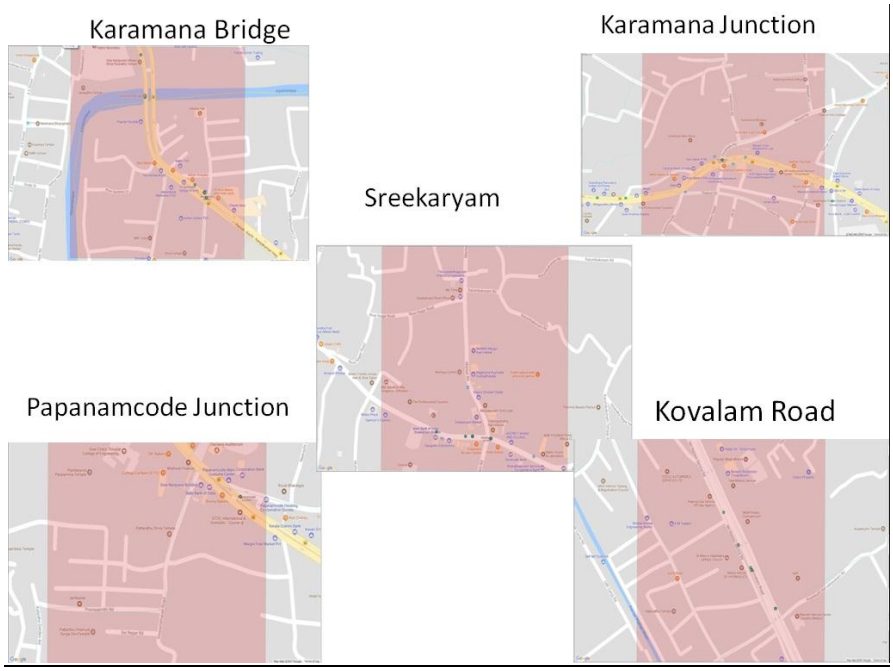

Figure 4.16 Hotspots identified

The accident hotspots were identified after augmenting the results from LISAand the cluster plot to Google street maps layer. The identified hot spots with the maximum clustering were Karamana bridge, Karamana junction, Sreekaryam, Papanamcode junction, Kovalam road. These hot spots are seen in Figure 4.16.

4.4 HEALTH CARE FACILITIES

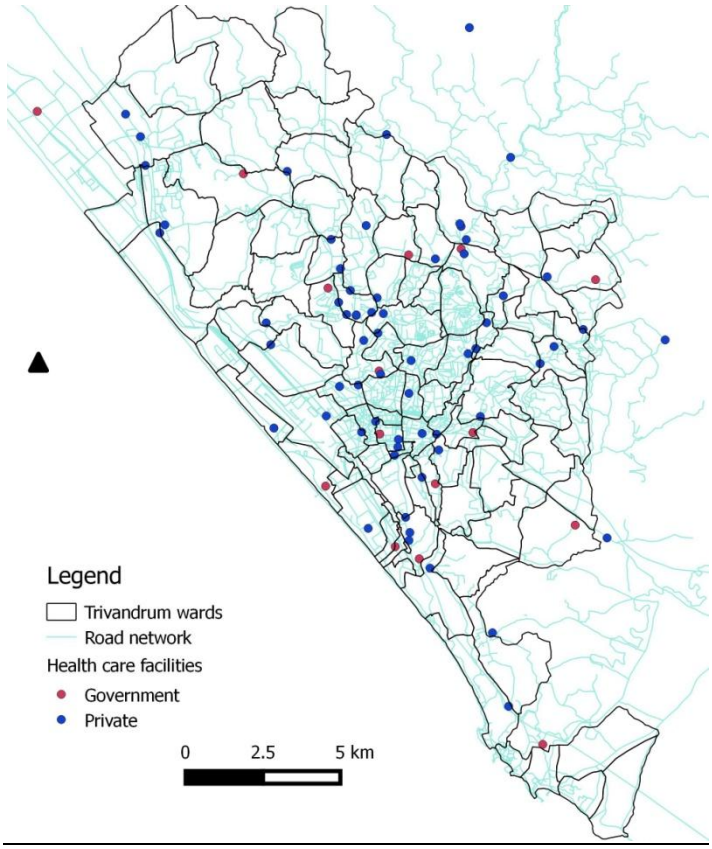

Figure 4.17 Health Care Facilities

Figure 4.17 shows the distribution of health care facilities in Thiruvananthapuram City Corporation. The health care facilities are more densely distributed close to the city than the peripheries. About 180 health care facilities were identified from various sources. After identifying the centres that provided emergency trauma care services and creating a buffer of 5 km from the boundary of Thiruvananthapuram city, a total of eighty three health care facilities were identified. Of this 20 were government facilities and the rest sixty three were private facilities.

Table 4.9 Distance to the Nearest Health care facility from the Hotspot

		Type of Health Faciltiy	Shortest Distance to nearest Health Facility (metres)
Accident spot identified	1	Government	420
		Private	783
	2	Government	870
		Private	979
	3	Government	575
		Private	1306
	4	Government	1856
		Private	3035
	5	Government	1950
		Private	1043
	6	Government	1148
		Private	400
	7	Government	2085
		Private	1891
	8	Government	1184
		Private	438
Mean distance to nearest health facility		Govt	1260.6
		Privt	1234.4

Eight accident hot spot with highest density of road traffic injuries were selected. The mean distance from each of these were calculated and it was found to be 1.26 km and 1.23 km to the nearest government facility and private facility respectively. The distance measured was not the aerial distance but the road distance.

CHAPTER 5- DISCUSSION

The current study looks at geospatial distribution of road traffic injuries and health care facilities in Thiruvananthapuram city. It also explores spatiotemporal clustering in road traffic injuries. As mentioned in previous chapters, data on road traffic injuries was for the time period January to December 2016. It has been noticed that there is a difference in the road traffic fatalities and mortality rates between high income countries versus low and middle income countries (WHO, 2004). The pattern that is observed is a decrease in rates of fatalities in high income countries. This could be attributed to the implementations of a wide range of road safety measures, including seat-belt use, vehicle crash protection, traffic-calming interventions and traffic law enforcements. While the same cannot be said about the middle and low income countries where there has been a rise in fatality rates since 1960's (WHO, 2004)

In the accidents in Thiruvananthapuram, more males were involved in accidents compared to women; the sex ratio (Female: Male) being 1:3.7. This observation is in concordance with what was observed by Singh and Dhatarwal in Haryana as well as other researchers. (Singh and Dhatarwal, 2004; Farooqui et al., 2013). The difference in sex could be related to both increased exposure and risk taking behaviour among men (WHO, 2004). The current study was restricted to city boundaries. Within city limits, usually the vehicle speeds are much less and so should fatalities as compared to high velocity crashes in highways.

The highest incidence of deaths had occurred in the age group 31- 60 years. In most other studies this has been noticed in thesimilar age groups 20- 40 years followed by the age 40- 60 years (Kochar et al., 2002; Singh and Dhatarwal, 2004).

In most of the hospital based studies it has been noticed that it's the pedestrians that were commonly involved followed by two wheelers vehicles (Eke et al., 2000; Singh and Dhatarwal, 2004) but in the present study, we noticed that two wheelers were more commonly involved followed by the pedestrians. Though this can be context specific, pedestrian injuries might have been under reported. In general two wheelers and pedestrians are termed as vulnerable groups.

Age was found to be significant association with deaths. In the current study, the proportion of deaths among people aged 60 years and above was high (22.9%). Be it actual road users or pedestrians. This was also observed by Mitchell and requires a lot of attention (Mitchell, 2001; World Health Organization, 2004). There is a misconception that older drivers are a threat to traffic safety. They are associated with high rates of road traffic injury and death. Older drivers usually have low crash rate but experience more crashes at complex traffic situations for example intersections. . This is due to physical frailty of the elderly. This is usually worsened due to pre- existing co-morbid conditions (Peden M et al., 2004: Mitchell, 2001).

Among motorized users in this age group; probably a more thorough study might bring out the reasons on why they have such issues. It might even be the traffic density that might pose a challenge for this particular age group. We face a huge challenge in coming years to try and make our homes as well as the roads friendlier for the elderly. However, this finding are in contrast to observations where they had noticed most commonly affected age group was 20-39 years (Farooqui et al., 2013; Singh and Dharrarwal, 2004).

The rising number of injuries in particular grievous injuries among age group of 18- 30 years requires a more detailed outline for this pattern. This may be due to insufficient licensing regulations or high risk seeking behaviour.

In India, pedestrians, cyclists, and motorcyclists are the most vulnerable road users constituting to over 70 percent of all road traffic deaths, and car occupants only about 5 percent which is in concordance with the current study findings (Mohan, 2004). Current study shows a significant association with involvement of pedestrians, though there might be an underreporting of pedestrian injuries in the current study context. Singh and Dhattarwal had noted that a majority of the cases registered were due to the fault of the driver, this is also in concordance with the findings of the current study (Singh and Dhattarwal, 2004)

Majority of the RTI reported were due to the fault of the driver, as was also observed in a case study in Mashhad, Iran (Shafabakhsh, Famili and Bahadori, 2017).Another concerning attribute that was identified in the current study was time. The time between a road crash and road death is a major attribute. Most injuries happened during day time. A study in the European high income countries found that about fifty percent of the deaths from road traffic injuries occurred within minutes, either at the scene or while in transit to hospital. For those patients taken to hospital, around fifteen percent of deaths occur within four hours after the crash, but around thirty five percent occurred after four hours (Buylaert et al., 1999).

The golden hour as defined in emergency medicine “refers to the time period lasting for one hour or less following traumatic injury being sustained by a casualty or medical emergency during which there is the highest likelihood that prompt medical treatment will prevent death” This concept was first described by Dr. R Adams Cowley.

As per the National highway authority of India (NHAI, 2012) it had proposed to set up a designated trauma centres every hundred kilometres. Though predefined for the highways, this has not been defined for city limits.

A preliminary survey of the main accident hot spots with the pre- structured check list concluded that the hotspots lacked police personnel, hazard warnings and speed breakers within one kilometre of the accident hotspot. They also lacked pedestrian crossings. Most of the hotspots had a traffic signal and the roads were wide with medians separating the traffic. A few of the hotspots had recent expansions and it would be interesting to identify the trend of road traffic injuries in these particular hotspots in the coming years or taking two different points in time. Another interesting observation was all the hotspots had a high overall vehicle density. It would have been interesting if a real time vehicle density was available for the study. Most of the hotspots are now equipped with street lights. A few of the spots had recently got streetlights in accordance with the road expansion process hence it is difficult to document since the study period and the physical survey were conducted at different times.

A few of the other contributing factors to road traffic injuries in India identified by Gopalakrishnan were; reckless and high speeds, no proper legislation, the attitudes of the 'right of the mighty' bigger vehicles towards smaller vehicles, overburdened or over capacity hauling of public and transport vehicles, poor maintenance of vehicles, drunk and driving, driver fatigue and encroachment by unauthorized persons and properties (Gopalakrishnan, 2012). These factors weren't identified in the present study because they were beyond the scope of the study.

Geographic Information System (GIS) helps to identify the factors that cannot be found through usual statistical method and results in reliable decisions and make use of available resources. GIS also increases the collaboration of all involved in the event and provides an integrated language to describe the data (Sambrani, 2012). Sambrani also had shown the recent advancements in GIS especially executive research techniques and GIS. Finding the shortest distance requires knowledge on Spatial Decision Support Support System (Sambrani, 2012). This integration is needed for analysis of the best and shortest route. This can also be used for choosing and analyzing alternative routes. A similar algorithm had been used in finding the nearest health care facility to the hot spot in QGIS. GIS is the tool to manage traffic accident data and augments decision making in road traffic injuries (Baraklianos et al., 2012)

It was noticed that most of the hotspots identified in the current study were in intersections. This was in congruent with Housainloe et al., they had also identified the effective factors and estimated their importance in intersection crashes in Tehran (Housainlou et al., 2009). Soleimani et al. had identified the best solution in collecting, saving and presenting geographic information related to traffic accidents (Soleimani, 2009)

GIS can be used to find the best places for establishing emergency centres, hospitals, black spots and assessing the effectiveness of services according to the location (Araghi et al., 2011). They can be also used to find the local dispersion pattern for hospital services. GIS can also help make evidence based decisions (Ahmadi et al., 2017). Though the current study wasn't in these lines, the capabilities of GIS are phenomenal. We were able to identify the mean distance from the accident hotspot to the nearest health care facility as 1.27 km to the nearest health care facility from the hot spots. But we weren't able to capture the victim's

choice of health care facility. This is quite challenging since following an event of road traffic injury, despite a particular health care facility being in proximity to the location of the event, the victim might choose to approach a distant health care facility. This often delays and brings challenges on the concept of golden hour.

The road traffic injuries showed spatial autocorrelation meaning that accidents tend to occur in a clustered pattern over certain locations. We have used spatial analysis techniques to delineate the spatial clusters over time (spatiotemporal clusters) and their locations. A similar study was done in 2008 (Prasannakumar et al., 2011) revealed that there were hot spots as well as cold spots in Thiruvananthapuram city. The factors for temporality taken by Prasannakuar et al. were season and proximity of religious and educational institutions to the accident hotspots. The current study took the distance to the nearest health facility that provided emergency trauma care services.

The data collection took place during an ongoing epidemic of dengue in Thiruvananthapuram and many hospitals were faced with a crisis on beds and most of the emergency casualties were flooded with people. An important observation by the principle investigator how important effective triaging is and its advantages to the patient in meeting the needs for the patient was understood. Giving preference to patients with fever, many health care facilities had difficulties in accommodating individuals who were in dire need for more medical attention. Hence effective triaging does play an important role as stated by Agnihotri (2012).

5.1 STRENGTHS AND LIMITATIONS OF THE STUDY

The study spatially mapped all health care facilities providing emergency trauma care service in Thiruvananthapuram city and all RTIs reported during 2016. This helped to identify the

hot spots as well as the cold spots of RTI, adjusting for the underlying population density. Hotspots shall help us to prioritize establishment of emergency trauma care services in a more pragmatic way. The study was able to identify the mean distance to the nearest health care facility providing emergency trauma care services.

The major limitation that was felt in the study was the lack of follow up data on people who had suffered grievous or minor injuries. The poor topology of the road network, that was obtained from the OSM sources were a limiting factor, preventing us from undertaking more detailed network analysis.

Valuable information could have been obtained by correlating locations of RTI with availability of ambulance services, but was not planned in this study.

5.2 CONCLUSION AND RECOMMENDATIONS

The study helped in value addition of the routinely captured RTI data using the capabilities of open source GIS software. Information about 1926 accidents that occurred in Thiruvananthapuram city in 2016 was obtained from SCRB and were geocoded. The investigator visited and collected information (including the geolocations) of all health care facilities that offer emergency trauma care services within the city and within 5 km buffer zone around the city limits. On analysis, it became evident that there is geospatial and spatiotemporal clustering of RTI within Thiruvananthapuram city. A preliminary analysis of the hotspots around the city limits revealed many correctable factors like lack of traffic wardens or other traffic calming measures during peak traffic hours that could be adding to RTI proneness. The fatalities especially in the 18-30 and above 60 years are alarming and require better and probably more stringent license procedure.

During the study, we found that many redundant and outdated methods are followed in the routine data collection. Using modern techniques, we can simplify data collection sheets and still improve the quality of data. It is recommended that the traffic police officials should record geolocations of the accident spot, rather than continuing with the laborious exercise of mentioning the distance and direction from the nearest junction and distance from the main police station. By recording the latitude and longitude can replace a lot of descriptive information to pinpoint the location. Likewise rather than recording the name, address and other details, just recording the the Aadhaar information will help us to get a more accurate and complete information on the socio-demographic features. Similarly, it is recommended to record the Vehicle Information Number (VIN) along with the registration number, rather than continuing with the current practice of vehicle type and other related details. It is also recommended that the town planning office should pro-actively publish the road networks within their jurisdiction at periodic intervals.

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ANNEXURE 1
INFORMATION SHEET

TITLE OF THE STUDY:
Health Care Facilities and Road Traffic Injuries in Thiruvananthapuram City during the Year 2016

Dear Sir/ Madam,

I am Dr. Annup Balan B, currently pursuing my Master of Public Health at Achutha Menon Centre for Health Science Studies, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum, Kerala. As part of my Master's thesis, I am conducting a study titled ' Health Care Facilities and Road Traffic Injuries in Thiruvananthapuram City during the Year 2016'. The objectives of my study are:-

1. To spatially map the Road Traffic Injury (RTI) cases reported in 2016 in Thiruvananthapuram City.
2. To spatially map the Health care facilities that provides emergency care services for trauma victims in Thiruvananthapuram City Corporation.
3. To explore spatio-temporal clustering, if any, of the RTIs in the city.
4. To calculate the shortest distance from the accident hot spot to the nearest health care facility offering emergency care services for trauma victims.

Road Traffic Injuries in Thiruvananthapuram City

Traffic crashes and consequent injuries represent a growing public health concern in India, particularly in light of increasing motorization. Road traffic injury is the eighth leading cause of death in India. Compared to other states in India, Kerala has a high literacy rate, better health infrastructure and services, higher density of population distribution and connectivity of roads to all villages. Ironically Kerala ranks among the top five states with high road traffic injuries. Hence this survey is conducted to identify the different correlates that influence road traffic injuries.

How is the study done?

I will be doing a geospatial analysis of road traffic injuries that have occurred in 2016. Clustering of accidents will be looked for; these clusters are known as Accident Hot spots. A map of health care facilities in Thiruvananthapuram city will be created. Health care facilities equipped with an Emergency Room and competent to cater for trauma care services will only be given importance. Following which I will be able to calculate the shortest distances from accident hot spots to the nearest health care facility.

I need your utmost contribution by letting me on information on whether your Institute / Hospital is capable to handle Trauma Emergencies and if it has a means of transport to commute patients during emergencies. This information will be asked using a Questionnaire. The average time required to fill the Questionnaire is about 5 minutes. Please feel free to ask the Principal Investigator on any Questions that need further clarification

What are the benefits and harms of participating in the study?

Even though there are no direct benefits for you from this study, the information obtained will be valuable to learn various correlates that influence road traffic injuries and the high mortality associated with road traffic injuries.

There is no direct harm associated with participation in the study but in case you do perceive any sort of harm, please do bring it to the attention of the principal investigator and it will be taken care of immediately.

Will your personal details be kept confidential?

The information given by you will be kept strictly confidential and will be used only for research purposes. Personal information will not be disclosed to anyone else. Participation in the study is purely voluntary and you can withdraw from the study at any point of time.

If you are willing to take part kindly express your willingness for the same, by signing the consent form given below

For any clarification regarding the study, you can contact me and for any queries on the authentication of this study you can contact the Member Secretary, Institutional Ethics Committee (IEC) of Sree Chitra Tirunal Institute Medical Science and Technology

1. Dr. Annup Balan B
   MPH Scholar
   AMCHSS, SCTIMST, Trivandrum
   Phone: 8281687567
   e-mail id: dr.annupbalan@gmail.com

2. Dr.Mala Ramanathan
   Member Secretary, AMCHSS,
   SCTIMST, Trivandrum
   Phone: 0471 2524234
   email id: mala@sctimst.ac.in

CONSENT FORM

I _____

Declare that I have read the above information provided to me regarding the study

Please tick your response

1. Yes, I am willing to participate in this study
2. No, I am not willing to participate in this study

Signature of Respondent _____

Date _____

Relationship with the Institute/ Hospital _____

श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान, त्रिवेन्द्रम
तिरुवनन्तपुरम - ६९५०११, केरल, इंडिया
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM
Thiruvananthapuram - 695 011, Kerala, India
(An Institute of National Importance under Govt. of India)
Grams : Chitramet, Phone : +91-471-2443152, Fax : +91-471-2550728 / 2446433, E-mail : sct@sctimst.ac.in, Website : www.sctimst.ac.in

Institutional Ethics Committee
(IEC Regn No. ECR/189/Inst/KL/2013)

SCT/IEC/1043/MAY-2017 13.06.2017

Dr. Annup Balan B
MPH Student
AMCHSS
SCTIMST, Thiruvananthapuram

Dear Dr. Annup Balan,

The Institutional Ethics Committee reviewed and discussed your application to conduct the study entitled "HEALTH CARE FACILITIES AND ROAD TRAFFIC INJURIES IN THIRUVANANTHAPURAM CITY" (IEC/1043) on 20th May, 2017.

The following documents were reviewed:

Original submission

1. *Covering Letter addressed to the Chairperson, IEC, SCTIMST dated 12.05.2017 with checklist*
2. *IEC Application Form*
3. *Approval letter from TAC*
4. *Short Curriculum Vitae of Principal investigators and Guide*
5. *Full proposal*
6. *Information Sheet and Consent Form - English*
7. *Questionnaire for Health Care Facility*
8. *Data Extraction Sheet*
9. *Check list for Accident Hot spots –English*
10. *Permission from State Crime Records Bureau, Thiruvananthapuram*

Revised submission

1. *Covering Letter addressed to the Chairperson, IEC, SCTIMST with checklist*
2. *IEC Application Form*
3. *Approval letter from TAC*
4. *Full proposal*
5. *Information Sheet and Consent Form - English*
6. *Questionnaire for Health Care Facility*
7. *Check list for Accident Hot spots –English*
8. *Letter from Mr. Santhosh Kumar.J, Inspector of Police, Road Accident Information System, State Crime Records Bureau, Thiruvananthapuram dated 06.06.2017, No: 29/RAIS/SCRB/ TVPM.*

The following members of the Ethics Committee were present at the meeting held on 20th May, 2017 at G. Parthasarathi Board Room, AMCHSS, SCTIMST

SL. No.	Member Name	Highest Degree	Gender	Scientific /Non Scientific	Affiliation with Institution(s)
1.	Smt. Sathi Nair	MA (English Literature	Female	Lay Person	No
2.	Dr. Kala Kesavan. P	MBBS, MD	Female	Basic Medical Scientist	No
3.	Dr. Mala Ramanathan	PhD	Female	Social Scientist (Member Secretary)	Yes

IEC Decision

The IEC approved the conduct of the study in the present form.

Remarks:
The Institutional Ethics Committee expects to be informed about the progress of the study, any SAE occurring in the course of the study, any changes in the protocol and patient information/informed consent and asks to be provided a copy of the final report.

There was no member of the study team / Guide who participated in voting / decision making process. The ethics committee is organized and operated according to the requirements of Good Clinical Practice and the requirements of the Indian Council of Medical Research (ICMR).

Sincerely,

Mala Ramanathan
Member Secretary, IEC