# Exploring influencing factors to optimize the public transport sector with the aspects of mode choice behavior and road safety measures: A field study on Colombo Metropolitan Area in Sri Lanka

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Engineering

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# DEDICATION

*I would like to dedicate this thesis to my beloved parents and teachers who have supported me all the way since the beginning of my studies.*

# ACKNOWLEDGEMENTS

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R.A.M.Madhuwanthi

# DECLARATION

I, R.A.M.Madhuwanthi, declare that this thesis titled, '*Exploring influencing factors to optimize the public transport sector with the aspects of mode choice behavior and road safety measures: A field study on Colombo Metropolitan region in Sri Lanka'* and the work presented in it, are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other publication at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.

…… ……..
Student's Signature Date
(R.A.M.Madhuwanthi)

I certify that I have read and this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Engineering.

……. ……
Supervisor's Signature: Date
(Prof. Shusaku Nomura)

# ABSTRACT

Increasing private vehicle usage is directly affected to increase the traffic congestion on road. Traffic congestion is a serious issue in a country and it is a burden to the economic development of a country. Increasing share of public transport system is a massive solution to reduce the congestion as the public transport mode can carry more passengers in one car and it can carry a significant amount of trip during the congestion hours [90]. The traffic growth rate was 5.4% per annum in Sri Lanka and public bus and train transport growth rate were 4% and 2.8% respectively. But private transport growth rate was 11.8% [8]. It has been estimated that the growth rate of trips by car accounts six times while public transport growth rate accounts only 1.5 times during the period of 2013-2035 [11]. The majority of respondents in Colombo area are unhappy about the public transport as the lack of time reliability and then delay their journey with wasting time and cost [10]. Hence Colombo Metropolitan Area (CMA) was selected as the study area with the intention of encouraging people for the public transport. Hence the objectives are starting from the identification of feasible field for the data collection and then to identify the factors influencing to mode choice behavior for private and public modes and to assess the relationship between access mode choice and public mode choice.

11 Divisional Secretariat Divisions (DSD) in CMA were identified for the data collection by using pre-formatted questionnaire. Statistically significant number of data was collected and analyzed to assess the influencing factor for mode choice behavior modeling. By conducting descriptive analysis and Factor Analysis, the results show that the peoples who have low income level, likely to use the public transport. Majority of peoples use public transport for long distance trips and young peoples greatly use public transport. It may for the purpose of education as they do not have any vehicle ownership. Most private vehicles are used for a short distance trip at the peak hour by the residence in the study area and then the roads fill with vehicle and it may cause to high traffic congestion. As the next objective, logistic regression was contended to find a probabilistic model to identify the likeliness for the public transport. The model accuracy was 78.4%. In addition to that, the relationship of the access mode with public mode was modeled up with Structural Equation

Modeling (SEM) approach to find the relationship of the access mode and public mode. That model depicts that, there is a relationship between access mode and public modes. The traveler first selects the public mode and then selects the access mode for a journey.

The last objective is to evaluate the road accident and measure the severity impacts to the public transport. The calibrated model with accident severity explores that the pedestrian location is a significant point for the accident severity. Accordingly, pedestrian accident was mapped with GIS software and run the hot spots analysis to find the pedestrian accidents prone locations. There were nine critical locations have been identified. Beyond the objective of this study, the pedestrian safety issues have been identified and suggested some solutions by designing the road as a specific model to improve the road network with the aspects pedestrian facilities. These findings will be aided for the decision makers and policy makers in the transportation sector to afford a moral service to travelers.

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# CHAPTER 1

# Introduction

## 1.1 Background

Mobility and transport activities are prominent parts in human's day to day life. For instance, peoples are moving to access for working, education, business and other recreational activities for their daily life. On the other hand, in the aspects of a country's economic development, the mobility is vital for moving goods and individual for manufacturing industry, trading within the county and overseas and for agricultural industry and etc. With increasing population growth, the need and wants of the people are getting more complex and then the transportation system also should have to develop together [1]. A well -developed transport system aids to increase the quality of the human life by saving community time, providing easy access for education, health service and safer travel facilities.

World transportation system includes land, air and maritime transport for passengers and freight [2]. From these three types, land transportation for passengers is a main integral part of the transportation system. According to the International Energy Agency (iea), light-duty vehicle (LDV) for passenger usage rate is growing rapidly in developing countries. Figure 1.1 depicts that the land transportation modes (Rail, Road freight, Buses, 2/3 wheelers, Passenger LDV) are taken the large mode share of the global transportation system. International Energy Agency has predicted that the land travel usage rate will double by 2050 [3]. This study only concerns about the modes of land transportation system.

The people's travel decisions are derived from the daily activities of their life [4]. The lifestyles of the household members are also depending on the travel decisions of each other. Thus the transportation sector with better travelling facilities can developed after understanding lifestyle and the activity scheduling of the individuals. Hence the

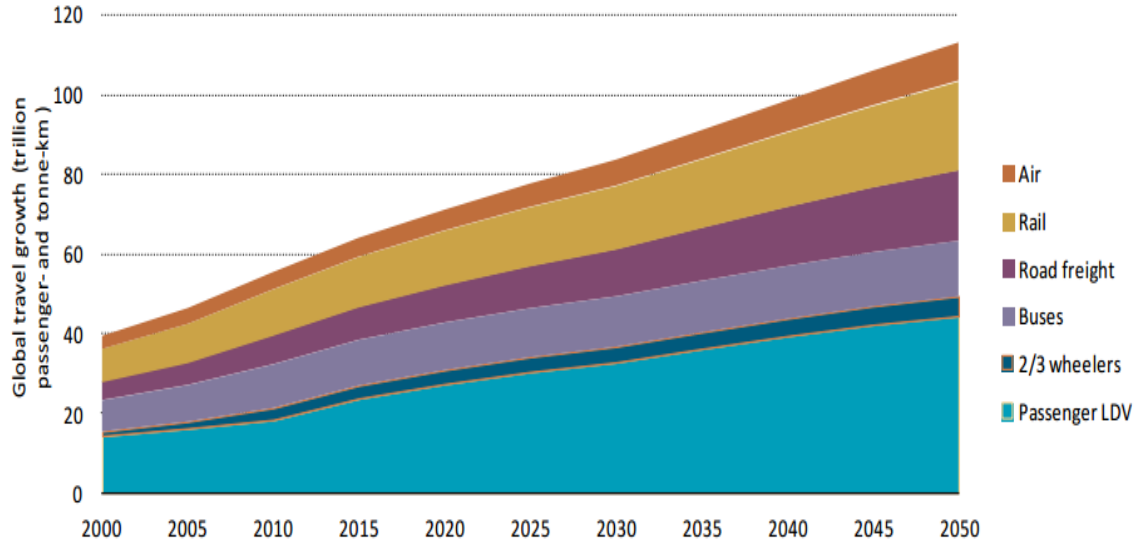


**Figure 1.1**: Passenger and Freight Travel by Mode in the World

*Source: International Energy Agency OECD/IEA 2012*

transportation modeling can be able to develop based on the travel behavior and the variables related to the personal preferences. Hence this transportation modeling is a vital tool to develop the sector with forecasting future travel demand, identifying better investment places, safer areas with reducing traffic accidents and so on. Currently, the transportation sector is in developing urban cities becoming more complex due to the growth of population and with their needs and wants. Transportation system should have been developed together with economic growth, social improvements and concerning with human health, environmental impacts since currently transportation sector faces some challengers due to the high demand of private vehicle ownership, low demand for public transport and traffic congestions etc. [5].

"Over 1.2 million people die each year on the world's roads, and between 20 and 50 million suffer non-fatal injuries" [6] and continues increase the rate of road accidents. Low-income and middle-income countries have high number of road fatality accidents (over 90%) rather than high-income countries. Road traffic accident rates for the low-income and middle-income countries are 21.5 and 19.5 per 100,000 populations respectively. But that rate for the high-income countries is 10.3 per 100,000 populations. World Health Organization (WHO) predicts that the road traffic accidents will be the 5$^{th}$ leading reason to death by

2030. But according to the data in 2004, the reason of road accident was in the 9$^{th}$ place implies that the road traffic accidents are increasing rapidly [6].

Most road fatalities in the high-income countries occur for car owners while majority of road fatalities from pedestrian, cyclist and motor cycle riders in low-income and middle-income countries [7].

Lack of attention for the road safety and traffic injuries at the level of international and local, is an undesirable problem to increase the rate of road accident in the world. On the other hand, no one or no any agency is responsible for the road accidents and fatalities as a whole at any country. If there is a particular department or agency that responsible for the road safety and traffic crashes, they can get the decision with the aspects of the design of the road network, rural/urban transport planning and even the design of the vehicles with concerning to reduce the road traffic crashes and safety facilities only [7].

## 1.2 Motivation

The growth rate of the traffic flow over the urban city was 5.4% per annum in Sri Lanka from the past two decades. The bus transport growth rate was 5%, railways 0% and private vehicle growth rate was 60% in 2011. Hence it can be seen that the public transport service growth rate was very slow when compare to private vehicle growth rate [91].

Colombo Metropolitan Area (CMA) is the only one metropolitan region in Sri Lanka which is in the Western Province of Sri Lanka. CMA is the most economically active and high populated region in Sri Lanka and the capital city of the county is also situated in this region. There is a significant amount of (37.3%) of outside community come to the western province for their work while over the half of community (51.2%) is from their own community. Hence, due to this high mobility situation, traffic flow is increasing rapidly in the western province [8].

Casual labors and salaried employees in Sri Lanka, are mostly working outside urban area from their own community places. But most of agricultural farmers and family based business peoples are in their own places and they are not coming to the urban area. High

percentage of middle class household use public transport for their traveling. Peoples for all type of income level have a bicycle or motorcycle and majority of people's mode choice is motorcycle. When the travel time is increased from 31 minutes to 52 minutes, people tend to choose taxi of three wheelers instead of public transport [8].

The demand for the sector of public transport in Sri Lanka is getting down as it is running with ineffective policy and lack of traveler facilities [9]. According to Sevanatha Urban Resource Center in Sri Lanka in 2002, a majority of the residence in the city of Colombo area wait for the public transport at the bus stop or railway stations in their day to day life and get late to reach the destination with losing time and money. Over 50% of the residents are not satisfied about the condition and the operating system of the public transport in their city [10]. On the other hand, the trip demand and private vehicle usage of the CMA in the western province of Sri Lanka are increasing rapidly [11]. Figure 1.2 illustrates that the total trips by a person on weekdays are gradually increasing and it will be forecasted by 1.75 times from 2013 to 2035.

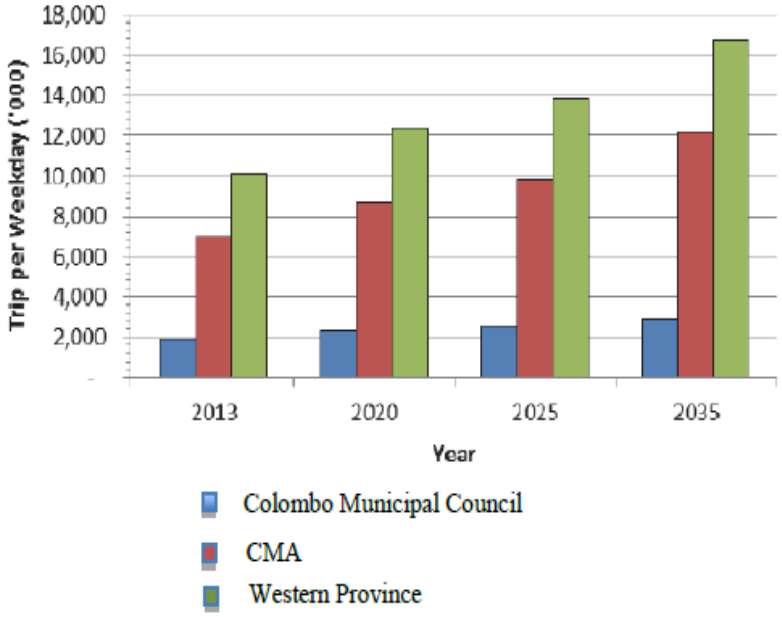


**Figure 1.2**: Increase of Person Trip Demand of the Region

*Source: JAICA, 2014*

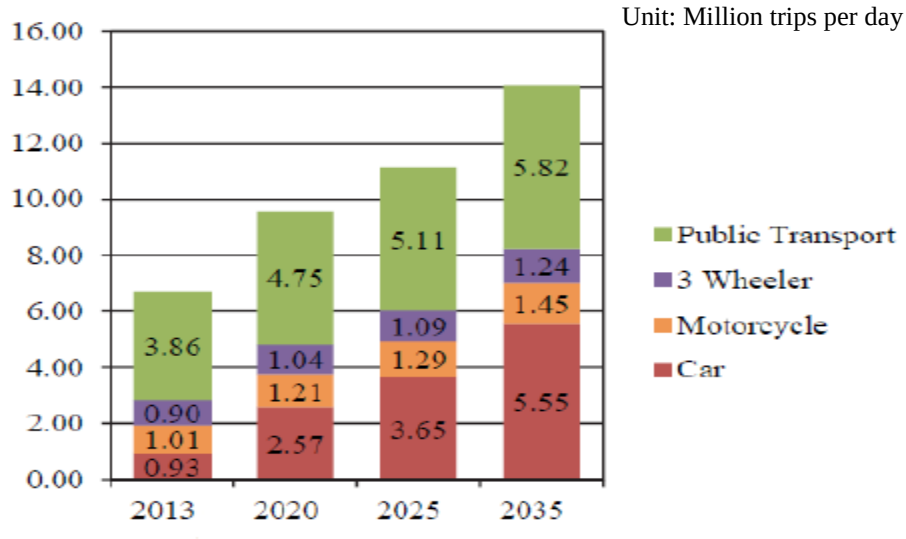


**Figure 1.3**: Increase of Person Trip by Mode of Transport

*Source: JAICA, 2014*

Figure 1.3 shows that the trip made by private car will be increased from 0.93 million trips to 5.55 million trips by 2013 to 2035 while 3.86 million trips by public transport will be increased only 5.82 million trips in the same period. It shows that the growth of trips by cars accounts 6 times while public transport growth rate accounts only 1.5 times during the same period. As well as, the 1.5% of country GDP was losing due to the traffic congestion on roads [11]. Because of these negative impact of the traveler and the sector, it is essential to develop the public transport of the CMA in Sri Lanka. As well as, around 50% of the country's economic activities are coming from this region and the largest international seaports and the airport of the country are located in the area too [12]. Hence the development of public transport of this area is vital and it will be directly affected to the economic development of the country. As an initial pace, exploring the most affective impacts to develop the public transport is required and it is the ultimate goal of this study.

Experts in the transportation sector in Sri Lank show that the public transport facilities and the policies are still in the primary level and the image of the public transport is gradually decreasing [13]. Thus the evaluation of resident's behavior of choosing mode for their regular travel purposes and analysis of influencing factors to choose that mode are necessary [14]. Further, experts have identified the important of introducing a new

modernized railway system with covering parking facilities and easy access way for buses and for railway stations. Additionally, they show the entire operating system can be improved through connecting all taxi, buses and stations together [13]. To create such a modernized system, it is vital to analyze the resident's access mode choice behavior for public transport. Hence, identification of a model for access mode choice behavior is also necessary for the improvement for the public transport [15].

Safety is a key significant factor that should be considered to improve the public transport since that public modes carry more passengers in one vehicle [16]. The traffic accidents are gradually increased from 2008 to 2012 in the western province of Sri Lanka. It was estimated that the traffic accident growth rate was 43 % in this region. Pedestrian accidents rate goes to the highest rate from all kind of road accidents in the western province and lack of pedestrian facilities in the region are some main issues to develop the public transportation sector [12]. If pedestrian safety and facilities are increased, the demand for the public transport may customarily increase. Hence analyzing road accidents in the study area, recognizing most specific reasons for the accidents and identifying most risk area for the accident are vital to improve the safety on road and it will be caused to improve the public transport.

## 1.3 Objectives

Different social groups with various demographic (economic, education, occupation, etc.) characteristic in the population behave in a different way to the transportation systems and it is very essential to examine the mode choice behavior of the population to serve a better transportation service [17]. As a multi-cultural nation and the gap between the lifestyle of poor peoples and rich people in Sri Lanka is very high, the recognition of community choice is needed for providing upgraded transportation facilities and service. Moreover, even the majority of Sri Lankan peoples are using the public transport and at present, usage rate of private transport is rapidly increasing too, it is essential to develop the public transportation sector by exploring the most influencing impact factors for the sector. Hence the following objectives are needed to fulfill through this study.

- To identify the factors influencing to mode choice behavior for private and public modes.
- To develop a model of probability tendency with identifying a mostly associated factors for choosing public transport.
- To evaluate the relationship between access mode choice and public mode choice behavior.
- To evaluate the road accidents and measure the severity impacts to the public transport.

## 1.4 Structure of the Thesis

The thesis structured with 6 chapters as the following way;

Chapter 1 starts with explaining the background of the research, along with the motivation factors to do this research. Further, the objectives of the research are explained.

Chapter 2 discusses about the research framework with explaining the entire research work and conceptual framework with the flow of this study. Further, explains about the focusing area for the study. Focusing area is the CMA in the western province of Sri Lanka. From CMA, the feasible region for the data collection was found from a special mechanism with the intension of getting a powerful data sample. The mechanism to select the feasible study area also for the data collection is discussed in this chapter

Chapter 3 explains about the analysis of mode choice behavior. The first part discusses about the literature review and the theoretical background of the mode choice modeling methods. The next section discusses about the factors influencing to mode choice behavior of the residence in the selected area with the descriptive analysis and factor analysis. The third section explains the procedure of the model development of public mode choice behavior with logistic regression methods. The last section explains about the relationship between access mode choice and public mode choice and finally with the chapter summary.

Chapter 4 conveys the assessment method of road accident distribution of the western province of Sri Lanka. At the beginning of this chapter discusses about the situation of the

world safety on road and comparison between Sri Lankan road safety and other countries. Then the next section discusses about the descriptive statistics and impact factors for the severity of the accidents with approach of SEM for the selected area. Finally, high rate of pedestrian accident locations were found using Arc GIS package.

Chapter 5 conveys the discussion of the result that the overall study was founded and the significant of the research and limitation of the entire research. Further, a proposal with specific solutions to improve the pedestrian facilities, was included to this chapter.

Chapter 6 describes about the conclusions, recommendations for the originated results and about the future works of this study.

# CHAPTER 2

# Research Framework and Study Area

## 2.1 Entire Research Framework

As the decreasing demand for the sector of public transport in Sri Lanka, it would be vital to discover the opportunities for sector development. Hence the overall goal of this research is to find the most affected elements with the aspects of mode choice behavior and road safety conditions. Traveler needs and wants related to the mode choice and their expectations, satisfaction morals from the travel mode can be recognized through the analysis of mode choice behavior. On the other hand, even rapidly decreasing the usage rate of public transport, still travelers in the developing counties specially, Asian and African countries are using public transport. TRL (Transport Research Laboratory) has identified that traveling in public transport appears a high risk as the modes of public transport of those countries are overloaded and poorly maintained. According the travelers in these countries, their perception is, to improve and ensure the safety on public transport is vital as many passengers travel in one vehicle [16]. Screen Line Survey in Sri Lank shows that the bus is the main public transport in Colombo and in the peak hours' buses are over- crowded; the factor loading is in between 108% to 171% in this area [12]. Hence measuring unsafe area and providing safety improvements for the public transport sector is important. Hence, with considering about mode choice behavior and safety on public transport, the research objectives are defined by initiating to find the most suitable study area as to recommend for the development. Finding factors influencing mode choice behavior for private and public vehicle, evaluating relationship between access mode and public mode choice behavior and evaluating the impact safety facilities for the improvement of public transport with examining pedestrian crashes and critical location in the selected area, are the other objectives in this research and the entire framework of the research in Figure 2.1.

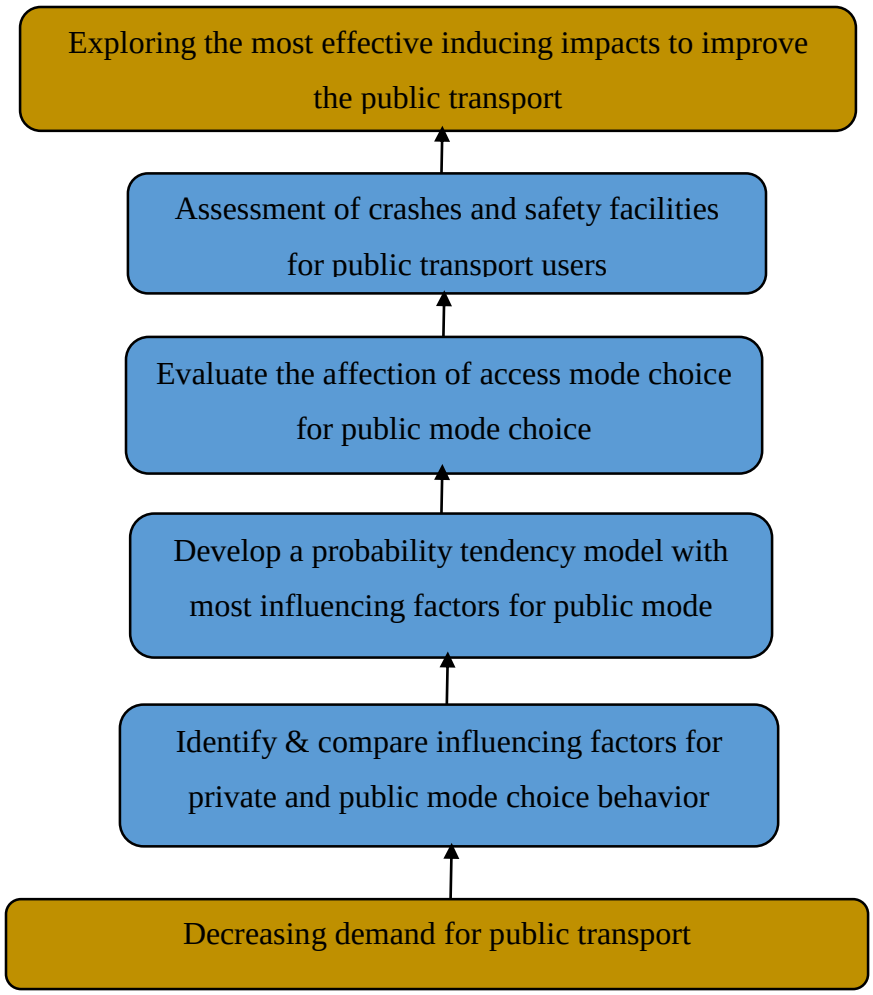


**Figure 2.1**: Entire Framework of the Research

## 2.2 Conceptual Framework of the Research

How organize the event behind the research objective and how each event interrelated with each are shown in the conceptual framework, which is depicted in Figure 2.2. In addition to that, the conceptual framework shows why motivate to the next work in the research study [18]. Through this conceptual framework, this research is summarized the aspects involved to understand the complex range of features that associated with the mode choice behavior and road safety situation behind this study. This conceptual framework is covered about what evaluated and how evaluated with technical methodology etc.

The leading policy of this conceptual framework is, to explore the most affective impacts to improve the public transport. The subjects of the evaluation, are the transport users in the study area and as the evaluation process of the mode choice is concentrated on the demographic characteristics, travel trip characteristics, access mode choice and traveler perception related to the mode choice. The data instruments based on these categories were collected through a state preference survey (SP) with a pre- designed questionnaire to the study area.

For the evaluation process of the road safety, the categories of crashed mode characteristics, casualty details and crash attendance circumstances such as weather condition, lighting condition, road surface, day and time of the crash, traffic condition etc., were considered. The data set was collected from the Traffic Police Division in the Western Province of Sri Lanka. As the evaluation technology, the primary data that was collected from the standard questionnaire which was sent to the respondents in the selected area, was used to analyze with suitable statistical tools occasionally such as logit modeling, factor analysis, Structural equation modeling with SPSS computer software and moreover hotspots analysis and density analysis with GIS computer software etc.

The agents involved with this research can be divided into several categories. For instance, mostly the residence of the study area who are the traveler and were the respondents to the questionnaire and casualty who faced for the accidents in the study area. On the other hand, there were considerable stakeholders that involved to this research such as Sri Lanka Ministry of Transport, Japan International Cooperation Agency (JAICA), Traffic Police Division in Western Province of Sri Lanka and responsible decision makers in the transportation field and even academic advisors who are related to the research institute.

## 2.3 Study Area and the Focusing Area

Study area covers the entire Western Province of Sri Lanka. There are three Districts in the western province; Colombo, Gampaha and Kalutara as well as the 40 Divisional

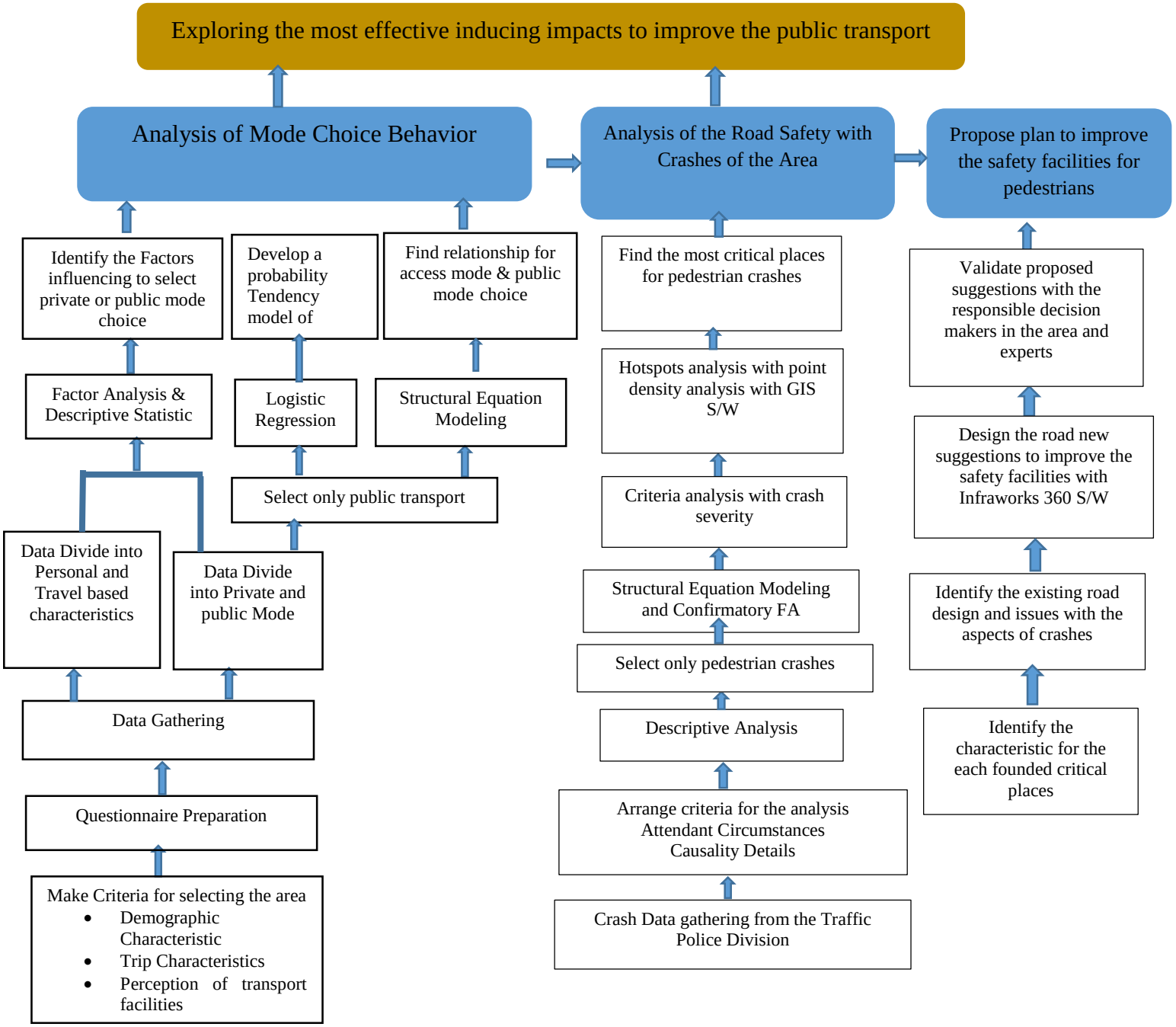


**Figure 2.2**: Conceptual Framework of the Research Work

Secretariat Divisions (DSD) are in this province. For the analysis part of road safety was used the dataset of traffic accident in the entire western province while the analysis part of mode choice behavior was used only the Colombo Metropolitan Area (CMA) which is in the western province and it is the metropolitan region in Sri Lanka. The area of CMA is 995.5 sq.km (27% of Western Province) and out of 40 DSDs, CMA is included 20 DSDs [12] from the main three districts as in

Table 2.1. The population was 3,682,536 in the CMA in 2012, which is 63% of the western province.

Colombo is the largest city and capital in Sri Lanka and it is situated in the CMA, western province of Sri Lanka. Around 1 million commuters by 160,000 vehicles daily come to the city. Public transport share is decreasing rapidly, 67% in 2004 to 58% in 2013. The average vehicle speed in the peak hours is below 10 km/hr due to traffic congestion on road. Moreover, the largest international airport and seaport are also in this CMA area [12]. Therefore, the development of this area is a big achievement in the development of economic point of view.

### 2.3.1 Focusing Area for Mode Choice Modeling



Figure 2-4: Western Province of Sri Lankan
*Source: Wikipedia image*

**Figure 2.3**: Western Province & Colombo Metropolitan Area in Sri Lanka
*Source: JAICA 2014*

**Table 2.1:** Colombo Metropolitan Area

| District | No. of DSDs in CMA | Land area Sq.km |
|---|---|---|
| Colombo | 11 | 429.1 |
| Gampaha | 6 | 386.3 |
| Kaluthara | 3 | 180.1 |
| **Total** | **20** | **995.5** |

The 20 DSDs in the region of CMA are included to three districts within the boundary of western province of Sri Lanka. Urban structure, transport network, traffic congestions, population distribution and even strategic transportation programs are highly varied since these 20 DSDs are in three different districts and specially most economically powerful district of Colombo is also included to that threes. Hence these DSDs and their main cities are experiencing different traffic congestions levels, urban structure and environmental issues and so on. Thus it is important to focus a suitable feasible area for the data collection and for a best modeling transportation pattern.

#### 2.3.1.1 *Methodology to find the feasible area in the CMA*

One of the objectives of this research is to find a feasible research area for the study and then a tool has been created to provide a recommendation as to whether a DSD of the CMA should convert to analysis of modeling with activity based mode choice behavior. It is an evaluation to find the opportunities for researchers and for travel decision makers to emphasis the importance of analyzing modeling approaches to the region. There are top twenty DSDs in the largest metropolitan area of the Western Province of Sri Lanka that are targeted for this effort. A list of criteria that were targeted to gain information about each division's population characteristics, automobile availability, current and future conditions of the transportation network and transport system development strategies for this analysis. After analyzing the results of the criteria, each division was given a point as one or zero. If each region that met the majority of the criteria with ones (1s), was recommended as a suitable division for the behavior analysis.

The data mainly obtained from a large home visit survey (HVS) that was conducted by the Ministry of Transport and Japan International Cooperation Agency (JICA) in 2013. That survey was conducted for the project of "Urban Transport System Development for Colombo Metropolitan

Region and Suburbs" (CoMTrans) within Western Province of Sri Lanka in April 2014. This survey is provided about the household information, individual's attributes and trip information sampling 3.0% (about 44,000 households) from the Western Province. In addition to that survey details, the data from the Screen Line survey, Trip Generation survey and Travel Speed survey that are conducted by CoMTrans team and census information from the Department of Census and Statistics were also used for this study. The following criteria are the significant and importance measurements for the recommendation of modeling approaches.

*a. Population Measurements*

Household trips based on the relationship with the individuals' activities in the households [19]. Thus identification of household characteristic is important for travel modeling. Hence, the percentage of population, percentage of student population, percentage of employee population, percentage of registered automobile, the growth rate of each region are collected. Households with students have more constraining activities than without students. And also households with automobiles and without automobiles have different trip based activities since they have different mode choices. These factors are greatly affected to the mode choice behavior. The population growth rate of a metropolitan region plays a major role in what decisions will be made for the future of the transportation system. After determining the percentage for all of the division, the third quartile of all of the participating division is used to decide whether to meet the criterion.

As in Table 2.2**,** the third quartile is used as a turning point for the percentage of population, percentage of student population, percentage of employee population, percentage of registered automobile and the growth rate of each division. The data was collected from the survey, which was done by CoMTrans team in 2013, from the census of Population and Housing in 2012 and from the Department of Census and Statistics. The recommended divisions are highlighted in the table if it greater than to the value of third quartile. The average and third quartile results are also shown in the table.

**Table 2.2:** Details for the Population Characteristics & Motor Vehicle Availability

| District | DSD | Population Measurement | | | | Registered motor vehicle | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Population % | Growth rate | Employed population % | Student population % | Motor Cars % | Motor cycles % | Dual Purpose vehicle % | Motor Tricycle % | Bus % |
| Colombo | Colombo | 9.15 | 0.01 | 4.51 | 1.32 | 29 | 34 | 9 | 19 | 2 |
| | Dehiwala- | 1.57 | 0.125 | 0.52 | 0.42 | | | | | |
| | Homagama | 3.31 | 3.15 | 1.36 | 0.49 | | | | | |
| | Kaduwela | 3.66 | 3.23 | 2.23 | 0.69 | | | | | |
| | Kesbewa | 3.29 | 3.11 | 1.04 | 0.60 | | | | | |
| | Kolonnawa | 2.47 | 1.2 | 0.82 | 0.36 | | | | | |
| | Maharagama | 3.14 | 3.3 | 1.66 | 0.76 | | | | | |
| | Moratuwa | 2.79 | 0.02 | 1.15 | 0.62 | | | | | |
| | Rathmalana | 1.79 | 0.03 | 1.04 | 0.36 | | | | | |
| | Kotte | 2.56 | -0.14 | 1.23 | 0.76 | | | | | |
| | Thibirigasya | 8.85 | 0.04 | 3.45 | 3.34 | | | | | |
| Gampaha | Biyagama | 2.90 | 1.73 | 1.17 | 0.46 | 16 | 49 | 7 | 23 | 1 |
| | Gampaha | 3.44 | 1.65 | 1.09 | 1.04 | | | | | |
| | Ja-Ea | 3.18 | 2.01 | 1.14 | 0.60 | | | | | |
| | Kelaniya | 2.73 | 0.78 | 1.24 | 0.87 | | | | | |
| | Mahara | 2.68 | 2.53 | 0.6 | 0.50 | | | | | |
| | Wattala | 2.84 | 3.15 | 1.11 | 0.64 | | | | | |
| Kalutara | Bandaragam | 1.41 | 3.9 | 0.36 | 0.25 | 9 | 51 | 6 | 30 | 1 |
| | Kalutara | 2.50 | 3.57 | 0.88 | 0.59 | | | | | |
| | Panadura | 2.89 | 2.5 | 0.89 | 0.78 | | | | | |
| | **Average** | **3.36** | **1.79** | **1.38** | **0.77** | **18.00** | **44.67** | **7.33** | **24.00** | **1.33** |
| | **Third** | **3.29** | **3.15** | **1.27** | **0.77** | **22.50** | **50.00** | **8.00** | **26.50** | **1.50** |

Note: Highlighted values result in a point towards recommendation.

*b. Road Network*

The situation of the transportation network and its issues in the region would affect whether a travel model would be beneficial to the area. Road network condition can be measure using vehicle speed performance and traffic congestion indices [20]. The average speed on the road in peak hours, the morning and evening commute time refers to as the number of peak hours and the bus loading factor as a percentage are found in the selected region to measure the current transportation

**Table 2.3:** Details for the Road Network

| District | DSD | Road Network | | |
|---|---|---|---|---|
| | | Average speed (km/h) Morning | Peak hours | Bus loading factor % |
| Colombo | Colombo | 8 | 5 | 106 |
| | Dehiwala | 12 | 5 | 101 |
| | Homagama | 18 | 4 | 106 |
| | Kaduwela | 11 | 4 | 130 |
| | Kesbewa | 14 | 4 | 166 |
| | Kolonnawa | 11.5 | 5 | 127 |
| | Maharagama | 30 | 5 | 106 |
| | Moratuwa | 28 | 5 | 101 |
| | Rathmalana | 28 | 5 | 101 |
| | Kotte | 34 | 4 | 130 |
| | Thibirigasyaya | 25 | 5 | 130 |
| Gampaha | Biyagama | 17 | 4 | 130 |
| | Gampaha | 30 | 5 | 138 |
| | Ja-Ea | 16 | 4 | 142 |
| | Kelaniya | 10 | 4 | 116 |
| | Mahara | 11 | 4 | 116 |
| | Wattala | 16 | 5 | 145 |
| Kalutara | Bandaragama | 35 | 4 | 106 |
| | Kalutara | 33 | 4 | 110 |
| | Panadura | 40 | 3 | 120 |
| | **Average** | **21.4** | **4.4** | **121** |
| | **Third quartile** | **30** | **5** | **130** |

Note: Highlighted values result in a point towards recommendation

service. The average peak hours less than 30 km/h (third quartile of the speed) referred to as high congestion divisions are given a positive score for this measure. The divisions with a daily peak hour greater than five hours are given a point towards the recommendation of a model development.

Buses are the major public mode of transport in the selected region. In the morning period, buses are over-crowded on the inbound direction on almost all major corridors according to the Screen Line survey, which was conducted by CoMTrans team. The load factors on the all corridors indicate more than 100%. The divisions with a loading factor greater than the third quarter value (130%) are given a point towards the recommendation division.

Table 2.3 shows the value for the average speed on the road in peak hours, the morning and evening commute time refers to as the number of peak hours and the bus loading factor as a percentage. The divisions that were awarded a point towards recommendation are shown highlighted.

**Table 2.4:** Details for the Trip Generation Density

| District | DSD | Trip Density (Trip/ha) | | | |
|---|---|---|---|---|---|
| | | Car | Motor Cycle | Bus | Railway |
| Colombo | Colombo | <100 | <100 | <200 | <100 |
| | Dehiwala-Mt.Lavinia | <50 | <50 | <200 | <5 |
| | Homagama | <20 | <20 | <200 | <5 |
| | Kaduwela | <20 | <50 | <50 | <5 |
| | Kesbewa | <20 | <50 | <100 | <5 |
| | Kolonnawa | <50 | <50 | <50 | <10 |
| | Maharagama | <50 | <50 | <50 | <10 |
| | Moratuwa | <50 | <100 | <50 | <50 |
| | Rathmalana | <50 | <100 | <50 | <50 |
| | Kotte | <100 | <50 | <200 | <20 |
| | Thibirigasyaya | <200 | <100 | <200 | <100 |
| Gampaha | Biyagama | <50 | <20 | <50 | <5 |
| | Gampaha | <5 | <10 | <50 | <20 |
| | Ja-Ea | <10 | <10 | <50 | <5 |
| | Kelaniya | <50 | <20 | <50 | <20 |
| | Mahara | <20 | <10 | <50 | <20 |
| | Wattala | <10 | <20 | <50 | <50 |
| Kalutara | Bandaragama | <10 | <5 | <20 | <5 |
| | Kalutara | <5 | <10 | <20 | <5 |
| | Panadura | <50 | <50 | <50 | <50 |
| | **Average** | **46** | **43** | **89** | **26** |
| | **Third quartile** | **50** | **50** | **125** | **50** |

Note: Highlighted values result in a point towards recommendation.

*c. Trip Generation Density*

Trip generations are high in CMA where the majority of workplaces, educational institutions as well as facilities for social and economic activities are located. For regions that have a high percentage of trips, the travel model would provide more precise estimates of travel to work. The work trip is especially important because these trips are long-term decisions that are taken regularly during the week and at the same general time each day. It is therefore critical to provide an accurate estimate of work trips to create a practical representation of congestion during peak travel periods. Table 2.4 depicts that the number of trip generations per hectare (trip/ha) by motorcycle, by car, by bus and by railways are obtained and the third quartile values are used as the breaking point for a recommendation.

*d. Transport System Development Strategies*

The future transportation plans of the region are necessary to include in this analysis because travel demand modeling is the practice of forecasting future transportation needs. The travel models are more appropriate at predicting travel patterns that are associated with the implementation of policies. Therefore, the travel models are able to provide how the strategic factors are affected to the future transportation developments. Transport Demand Management (Electronic Road Pricing-ERP system), Parking Information System, Pedestrian Path & Cycle Road Network Development Plan and Expressway Network System are the considerable strategies that proposed by CoMTrans Urban Transport Master Plan, 2013 to implement in the future in CMA [12].

- Transport Demand Management (ERP system) is proposed, which includes the development of a system for the installation of toll gates, and installation of fee payment machines. The boundaries of the ERP system are proposed to be on the boundaries of CMA.
- Parking Information System is proposed, which includes the development of a system for collection of parking full/empty information and the development of a system for providing information.
- Pedestrian Path & Cycle Road Network Development Plan is proposed to facilitate the promotion of walking and bicycle riding. This contributes to energy saving in

transportation as well as for a good health condition of the traveler as they can walk. The network proposed includes a pedestrian way and pedestrian and cycle way.

- Under the Expressway Network System, it is proposed to develop two expressways mainly. Urban expressway-1 is broadly covered area of CMA when the two expressways are compared [12].

**Table 2.5:** Details for the Strategies of Transport System Development

| District | DSD | Transport System Development Program | | | |
|---|---|---|---|---|---|
| | | Transport Demand Mgt. (ERP system) | Pedestrian Path & cycle road network development plan | Parking Information system | Expressway network system |
| Colombo | Colombo | Yes | Yes | Yes | Yes |
| | Dehiwala | No | Yes | Yes | Yes |
| | Homagama | No | Yes | Yes | Yes |
| | Kaduwela | Yes | Yes | Yes | Yes |
| | Kesbewa | Yes | Yes | Yes | Yes |
| | Kolonnawa | Yes | Yes | Yes | Yes |
| | Maharagam | Yes | Yes | Yes | Yes |
| | Moratuwa | No | Yes | Yes | Yes |
| | Rathmalana | No | Yes | Yes | Yes |
| | Kotte | Yes | Yes | Yes | Yes |
| | Thibirigasya | Yes | Yes | Yes | Yes |
| Gampaha | Biyagama | No | Yes | Yes | Yes |
| | Gampaha | No | No | Yes | Yes |
| | Ja-Ea | No | No | Yes | Yes |
| | Kelaniya | No | Yes | Yes | Yes |
| | Mahara | No | Yes | Yes | Yes |
| | Wattala | No | Yes | Yes | Yes |
| Kalutara | Bandaragam | No | No | Yes | No |
| | Kalutara | No | No | Yes | No |
| | Panadura | No | No | Yes | Yes |

Note: Yes is mentioned as a point towards recommendation.

Table 2.5 shows the significant future strategies that the decision makers are introduced for the transportation industry in the selected region. These strategies are given simple Yes or No for each division if they are planning to implement. If a strategy is apparent, that division was given a point toward approval for modeling approaches.

**Table 2.6:** Final Recommended Area in CMA

| District | DSD | Population Measurement | | | | Registered Motor Vehicle | | | | | | Road Network | | | Trip Density | | | | Transport System Development strategies | | | | Recommendation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Population | Student | Employee | Growth | Motor Cars | Motor cycles | Dual Purpose vehicle | Motor Tricycles | Buses | Heavy Vehicles | Average Speed | Peak hours | Bus loading factor | Car | Motor cycle | Bus | Railway | Transport Demand Mgt.(ERP) | Pedestrian Path & cycle road network plan | Parking Information system | Expressway network system | Total no. of 1s | YES (Y) /NO (N) |
| Colombo | Colombo | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 17 | Y |
| | Dehiwala | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 12 | Y |
| | Homagama | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 12 | Y |
| | Kaduwela | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 14 | Y |
| | Kesbewa | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 14 | Y |
| | Kolonnawa | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 12 | Y |
| | Maharagama | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 14 | Y |
| | Moratuwa | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 13 | Y |
| | Rathmalana | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 13 | Y |
| | Kotte | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 13 | Y |
| | Thibirigasya | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 18 | Y |
| Gampaha | Biyagama | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 7 | N |
| | Gampaha | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 7 | N |
| | Ja-Eala | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 6 | N |
| | Kelaniya | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 7 | N |
| | Mahara | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 4 | N |
| | Wattala | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 9 | N |
| Kalutara | Bandaragam | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 4 | N |
| | Kalutara | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 4 | N |
| | Panadura | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 7 | N |

Note: Highlighted values result in a point towards recommendation

#### 2.3.1.2 *Finding the Focusing Area*

By considering Table 2.6, for all of the conditions, the measure was given a value of one if the criterion was met and zero if it was not. This is the final results of this study and if the tally was found to be 10 points (average value) or greater, an affirmative recommendation was given to the decision makers in the region. The all Divisional Secretariat Divisions in the Colombo district are recommended as feasible region for the data collection but even one of a division is not recommended from Gampaha and Kalutara districts.
Eleven divisions; Colombo, Dehiwale-Mt.Lavinia, Homagama, Kaduwela, Kesbewa, Kolonnawa, Maharagama, Moratuwa, Rathmalana, Kotte, and Thibirigasyaya are recommended from this system.

According to above recommendation tool, it is found that the these DSDs are feasible for data collection and appropriates of applying mode choice modeling for the 11 DSDs in the CMA are beneficial than the other DSDs in the CMA.

## 2.4 Chapter Summary

This chapter indicates about the overall research framework with the objectives, conceptual framework with connecting every task to the main research objectives and about the study area.

The overall framework briefs about the way of connecting the current issues and the motivation factors through the main objectives of the research. The main issue is reducing the current demand for public transport and the main goal is to find the inducing impacts to optimeze the public transport with focusing the mode choice and access mode choice approaches and road safety situation. The conceptual framework shows, how these main objectives were organized with the events, entities that were engaged through this research.

The study area covers the western Province of Sri Lank. For the part of road safety analysis, the entire western province crash dataset of road accidents was used which obtained from the Division of Traffic Police in the western province. For the part of mode choice modeling, a survey data was used which collected from the recommended area in the Colombo Metropolitan Area (CMA) of the western province as the behavioral model highly depend on the regional development

situations. The recommended area was found out using a special tool that considering several criteria such as division's population characteristics, automobile availability, current and future conditions of the transportation network and transport system development strategies etc. Accordingly, there are 11 DSDs out of 20 DSDs were selected for the further evaluation for mode choice behavior.

# CHAPTER 3

# Analysis of the Transport Mode Choice Behavior

## 3.1 Chapter Introduction

The aim of this chapter is to conduct an analysis of transport mode choice behavior of the traveler in a specific field. According to the 2nd Chapter, the selected area is Colombo Metropolitan Area (CMA), Sri Lanka that an ideal field for the study. Background of the mode choice behavior, theoretical background of the mode choice modeling, data collection procedure and criteria, factors influencing to mode choice behavior in the selected area, probability tendency model development for public transport mode choice behavior and model development for the access mode choice behavior for the public mode choice, are the main area that cover in this chapter.

After the end of this chapter the reader can realize that the influencing factor for selecting private and public transport modes for the traveler in the selected area, how the access mode choice behavior is influenced to select the public mode for their daily travelling purposes and as well as the overall travelling behavior with the demographic characteristics of the traveler in the study area.

## 3.2 Background of the Mode Choice Behavior

### 3.2.1 Urban Transport Mode Choice Behavior and Modeling

Transport sector development is vital for the economic development of a country. Decision makers in the transportation sector must have to change the policy and planning system with changing of demand for travelling. The demand can be forecasted by examining travel behavior of the residents and availability of existing infrastructure facilities of the sector. Forecasting future demand by using various mathematical approaches known as transport modelling [21]. Figure 3.1 depicts the general conceptual model for mode choice analysis. The rectangle of this framework indicates observed variables and ellipse indicates the unobserved variables.

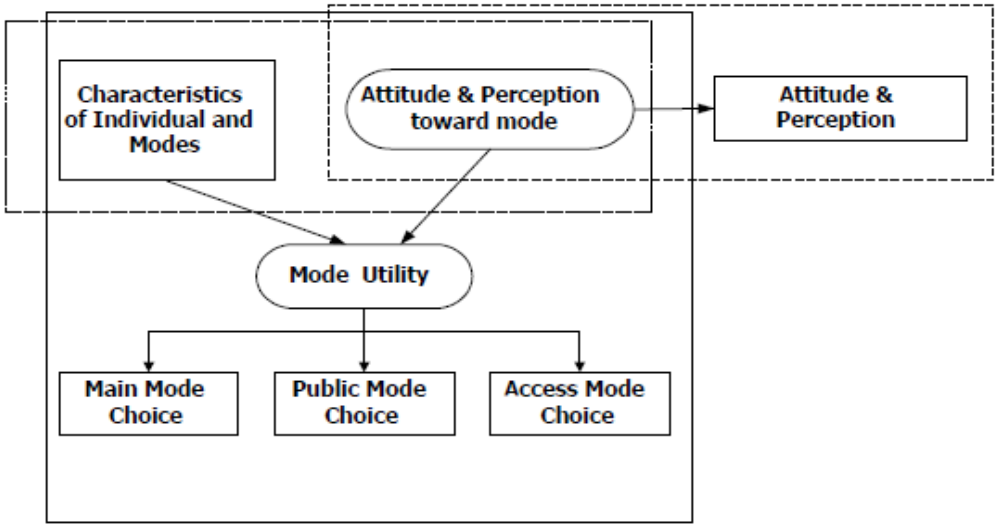


**Figure 3.1** General Conceptual Framework for Mode Choice of Traveler

*Source: Loomboonruang, Sano, 2003*

Generally, transport mode choice models are focused for a particular area as the transportation systems and policies are different with their level of economic development in region to region of a country. There are wide variety of studies that available related to mode choice behavior particularly focused in a specified residence group or specified tip purposes to a selected study area. For instance, Hongzhi G. have analyzed the traffic access mode choice of urban railway system in Beijing using Nested logit model [22]. Fengming Su. have found the mode choice of older people before and after shopping [23]. Ali A.M. focus to the factors influencing to select the transportation modes by university students [24]. Asa B. focused for modeling access mode choice for inter-suburban commuter rail by using discrete choice Multinomial Logit and Nested Logit modelling methods [25].

Discrete choice models are the common method to analyze and predict the decision maker's choice. For instance, a traveler is predicted by using available travel modes under several service conditions [26]. Each alternative has set of attributes. Some alternatives are generic for all alternative and some of them are specific [27]. "An individual is visualized as selecting a mode which maximizes his or her utility [28]".

### 3.2.2 Theoretical Background of the mode choice modeling

Individual utility can be defined using a function U, with including attributes and its alternatives and the characteristics of the individual [26]. The function can be defined as:

If $U(X_i, S_t) \geq U\left(X_j, S_t\right) \forall j \rightarrow i > j, \forall j \in C$ 3.1

Where;

*U ( )* *is the utility function*

$X_i, X_j$ *are vector of attributes i and alternative j*

(eg. Travel time, travel cost and other attributes of the available modes)

$S_t$ is a vector of socio- demographic characteristics which is describing $t^{th}$ individual (eg. It is influenced to individual preference from alternatives like their income, occupation, no. of households etc.)

*i > j means alternative i is preferred than the alternative j*

$\forall j$ *mean all the cases j in the choice set*

*If i > j i will be chosen from the set of alternatives C*

If there are J number of total travelling modes available, the probability of choosing mode j (where j $\epsilon$ *J*), then the utility function is;

$U_j \geq U_i$ 3.2

where;

$U_j$ *is utility of choosing alternative j*

$U_i$ *is utility of choosing alternative i*

In some case, people select alternative mode i over j even $U_j \geq U_i$. It happens under an error situation. In such a cases are happened while the choice is making under probabilistic choice models. In this model has two components. One is observed by the analyst and it is known as deterministic and the other one is difference between the unknown utility used by the traveler and utility by the analyst, [29] represented by $\varepsilon$;

$$U_{it} = V_{it} + \varepsilon_{it} \quad 3.3$$

Where;

$U_{it}$ *is the true utility of alternative i to the decision maker t*

$V_{it}$ *is the observable utility estimated by the analysist*

$\varepsilon_{it}$ *is error term of the utility unknown to the analysist*

### 3.2.3 Model Specification

Effective mode choice model can be gained through concerning about the factors of utility and distribution of the random variables. Logit model and Probit model are the main two types of modeling methods that can be used to find a concrete model [28].

*a. Logit model*

Logit models are widely used for modeling the travel demand mode choices. There are several number of logit models; binary and multinomial logit models. Binary logit models are analyzed about the traveler choice behavior from two discrete modes only while multiple logit models are measured more than two available alternative modes.

According to the theoretical background of the logit model, it is based on the theory of utility maximization as shown in above equation 3.1. The probability of selecting the mode of n from the M number of available modes by individual i, can be shown by the following equation; [21], [28]

$$P_{in} = \frac{\exp(V_{in})}{\sum_{m \epsilon M} \exp(V_{im})} \quad 3.4$$

$V_{in}$ *is the utility function of mode n for individual i*

$V_{im}$ *is the utility function of mode m in the choice set for individual i*

$P_{in}$ *is the probability of individual i selecting mode n*

$M$ *is the total number of available mode*

There are three main assumptions are considered with the aspect of error term of $\varepsilon_{it}$ in the equation 3.3. It is assumed that the $\varepsilon_{it}$ is Gumbel distributed, independent distributed and identically distributed.

For the binary logit model, the available traveling modes are only two modes m and n. Then the above equation, 3.4 is changed to following way;

$$P_{im} = \frac{\exp(V_{im})}{\exp(V_{in})+\exp(V_{im})} \qquad 3.5$$

$V_{in}$ *is the utility function of mode n for individual i*

$V_{im}$ *is the utility function of mode m in the choice set for individual i*

$P_{in}$ *is the probability of individual i selecting mode n*

$P_{im}$ *is the probability of individual i selecting mode m*

*b. Probit Models*

Probit models are also based on the function of utility interpretation. Probit model has less assumptions and its ability to catch all correlation among alternatives. The equation can be written as; [21], [28]

$$U_i = V(\mathcal{X}_i + S) \quad + \varepsilon_i \qquad 3.6$$

$U_i$ *is the utility function of mode n for individual i*

$V$ *is the observed component of the utility function*

$X_i$ *is the vector of observed attributes of alternative i*

$S$ *is the vector of observed characteristics of the individuals*

The errors are followed the normal distribution. There are some other models that developed to fill the gap of the logit and probit models known as General Extreme value model and Hybrid Logit models [28]. However, logit and probit models are still frequently used for mode choice modeling. Comparison of the logit, probit and General Extreme value model models are shown in Table 3.1 [21].

**Table 3.1:** Comparison of Mode Choice Models

| | **Logit Models** | **Probit Models** | **General Extreme Value Model** |
|---|---|---|---|
| Basic Hypothesis | Extreme Value Distribution | Normal Distribution | Multivariate Extreme Value distribution |
| Major Constraints | Error terms should necessarily be independently distributed | Error terms should necessarily be independently distributed | Error terms should necessarily be independently distributed |
| Model Formulation | Simple | Complex | Complex |
| Introduction of Access Modes | Model formulation and calibration becomes complex to a small degree | Model formulation and calibration becomes highly complex | Model formulation and calibration becomes highly complex |
| Application | High | Limited | Limited |
| Accuracy | High | Low | Low |

*Source: Omer Khan, Modelling Passenger Mode Choice Behavior using Computer Aided Stated Preference Data, Urban Development, Queensland university of Technology*

### 3.2.4 Model Estimation Methods

There are mainly two types of estimation methods, Maximum likelihood method and Least Square method. Formulating numerical value of model parameter and formation of various attributes in each utility function through this model estimation method.

#### 3.2.4.1 *Maximum likelihood methods*

Maximum likelihood method is a common method to determine the values of the parameters when the observed sample is most likely to have occurred. The information of the particular travels' decision of mode choice and attributes of the available mode are needed for the function [21]. The equation for the model estimation is;

$$L = \prod_{m=1}^{M} P(t_m, m) \quad 3.7$$

Where;

*L* *is likelihood the mode assigns to the vector of available alternatives*

*M* *is the total number of alternatives*

*m* *is any alternative mode in the set of available*

$t_m$ *is the observed to be chosen in alternative m;*

*P($t_m$, m) is probability of choosing m mode*

#### 3.2.4.2 *Least square Method*

This estimator has the values that minimize the difference between observed and explained models. The equation is

$$F = min \sum E^2; \quad 3.8$$

$$= min \sum (\beta o + \beta 1x1 + \beta 2x2 + \cdots + \beta kxk - Y)^2$$

The estimators are unbiased and least squired. This least square method is more effective work only for linear models. Thus, normally maximum likelihood method is the most popular and effective method for model estimation.

## 3.3 Literature about the Mode Choice Modeling

The peoples are concerning the choice of travel modes according to their trip purpose that required to be fulfilled [30]. The availability of the travel modes is different and peoples can choose the mode with their desire to complete their trip. The traveling modes are now becoming with different aspects from the conventional models. Now peoples tend to choose the mode with concerning the comfort, security, vehicle in time, trip distance, time reliability, cost of the travel mode etc. with different availability of travel modes since the people have various opportunities to choose the mode. For example, car is fast, comfortable, convenient and provides carrying capacity, privacy and expensive travel mode than the public bus. Thus the car is instrumental in that it increases

freedom to perform activities in different places, such as work, shopping, and leisure activities [31].

In order to be successful in the transportation sector, the decision makers must ensure their service is suitable for the consumers. Analyzing behavior of the consumer with the aspects of choosing their transport mode is vital to add affective attributes to the transportation service sector. On the other hand, for the modern manufactures can be ensured that their products are recognizable by the customers by evaluating their customer influencing factors related to the selection of mode for their trip purpose. Then the manufactures can change the mode with modern design with novel technical solutions and orient the product towards up to date lifestyle. Then such kind of mode/ vehicle can hit the market on the right time can be tremendously successful. The choice of a transport mode is probably one of the most important classic models in transportation planning [32]. Peoples' nature and their behavior closely are affected to the mode choice modeling process. Thus factors affecting to mode choice modeling can be monitored with concerning broadly about the characteristic of the mode, characteristics of the trip maker, as well as several other factors like, comfort, safety and convenience [33]. Since the travelers' satisfaction is also an important performance measure for the transport service providers and a determinant factor affecting the mode choice [34], analyzing travelers' behavior in the aspects of mode choice is vital. Researchers evaluate the mode choice behavior in different aspects. Some studies have examined the relationship between consumer behavior and mode choice at supermarkets [35]. When installing bike lane to the town, the retail activities are increased, for instance, on Valencia Street in San Francisco, a study of 27 businesses was conducted four years after a bike lane was installed [36]. Similarly, a recent report by New York City DOT found increased retail sales after a protected bike lane was installed in Manhattan [37]. On the other hand, the policy makers in the field of tourism are also analyzing about the attributes of the travel modes influence to the tourists' modal choice. Thus mode choice analysis is vital to organize transportation and adjust operation plan effectively [38].

## 3.4 Mode Choice in Sri Lanka

CoMTrans Home Visit Survey for the Western Province of Sri Lanka which was conducted by the Ministry of Transport and Japan International Cooperation Agency (JAICA) in 2013 shows that

around 38% of trips are made by private modes of transport, including cars, taxis, three wheelers and motorcycles while approximately 40% are made by buses and railway. The remaining 21.6 percent of the trips are made by non-motorized modes of transport including walk, bicycle, and others [12]. Normally, model share changes with the purpose of trips. According to the above survey, Figure 3.2 shows that while 74% of bus trips do not require any transfer between transport modes, only 26% of railway trips have this pattern [12].

Furthermore, Figure 3.2 depicts that most of the peoples tend to the mode of bus than the other modes for their home-based trip purposes. Especially more than half of the home-based school and home-based work trips are made by bus. Three wheelers and motor cycles are used for trips of home-based other. The private modes such as cars and the motor cycles are the widely used modes for the non-home-based trips.

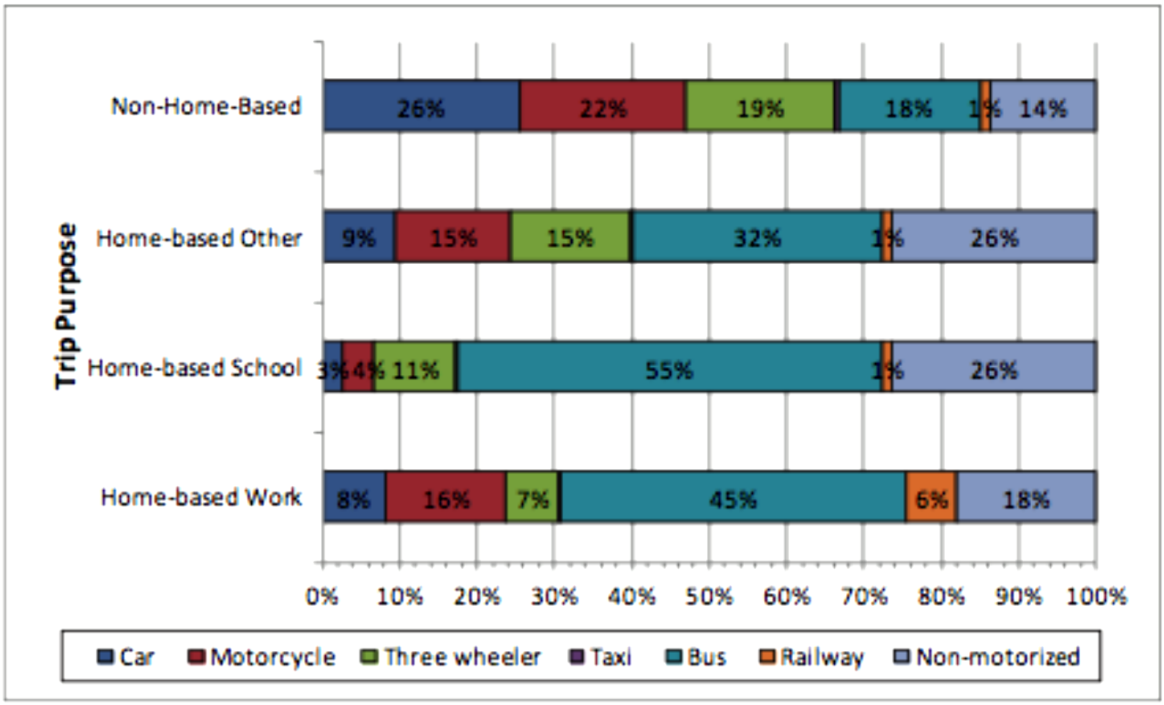


**Figure 3.2**: Modal Share by Trip Purpose in the Western Province of Sri Lanka

*Source: CoMTrans Home Visit Survey, 2013*

According to the Table 3.2, the Western Province has the highest rate of vehicle ownership. The private car, motor cycle and three wheelers have the high rates of vehicle ownership relatively. It implies that the private vehicle usage by the passenger is getting increase [39]. Kumarage (2012)

said that a proper town plan, friendly public transport facilities and a sufficient operational traffic system is needed to resolve the current congestion in the Colombo city by creating friendlier public space with increasing facilities for public transport [39].

**Table 3.2:** Vehicle Ownership Rate by Category & Province (2010)

| **Vehicle Type** | **VOR per 1000 persons** | **Province** | **VOR per 1000** |
|---|---|---|---|
| Buses | 2 | Western | 182 |
| Dual Purpose vehicle | 9 | Southern | 128 |
| Private Cars | 14 | Sabaragamuwa | 83 |
| Land vehicles | 10 | North Western | 150 |
| Goods Transport vehicles | 4 | Central | 84 |
| Motor Cycles | 66 | Uva | 73 |
| Three wheelers | 23 | North Central | 140 |
| Others | 0 | Eastern | 123 |
| | | Northern | 53 |
| **Total** | **129** | **Sri Lanka** | **129** |

*source: Sri Lanka Transport Sector Policy Note by Amal Kumarage*

## 3.5 Literature about the Affection of Access Mode Choice for the Decision Making of Public Mode Choice

People's mobility needs can be fulfilled by providing efficient public transport system to the city [40]. According to Dimitrios (2015), people tend to use public transport, if they have good accessibility for the mode of public transport and secondary they get decision about the connectivity elements such as transfer time [41].

There are many researchers have studied for more than 30 years about the airport ground access mode choice modeling for employees and passengers [42]. These analyses are aided to improve the airport land side planning and airport reginal transport system. Most of that analysis use the Multinomial Logistic (MNL) modeling and Nested Logit (NL) modeling methods for the analysis. For example, Rong (2011) has focused for airport ground access mode choice behavior by using Mixed Logit method [43], Lothar (1996) has analyzed about airport access mode choice model

with MNL and NL modeling methods [44] and Mahdi (2016) has studied about the public transport access mode choice behavior for airport access in Khomeini International Airport (KIA) in Iran [45]. Vladmir has analyzed airport and access mode choice behavior with MNL in Kyushu region, Japan and found that access time, airfare, and flight frequency were the most significant factors for choosing access mode to the airport [46].

Another way of exploring about the access mode choice behavior is to analysis the access mode choice for the railway stations. Asa (2011) has studied that how rail riders choose their access mode to the railway station with concerning car parking facilities, population density and connecting bus routes [47]. Umberto (1997) has focused the access and egress mode choice to the railway station particularly for the medium to long distance trip purposes [48].

However, it is difficult to find literature for the analysis of access mode choice behavior analysis with concerning whole public transport system for the households with their regular trip purposes and other demographic characteristics.

## 3.6 Data Collection for Mode Choice Modeling

As mentioned in Chapter 2, the feasibility area for the data collection consists 11 DSDs, which belong to Colombo districts in the region of CMA. The population in this area is 2,131,147 in 2012 and the population density is 4966 per sq.km. The land area is 429.1 sq.km in this area [12]. This mode choice analysis is a descriptive quantitative study using survey method to collect the information from the respondents by using questionnaires.

The sample of this study was selected from the population of the selected region by considering the citizens who are age of more than 15 years old. To decide the sample size logically, the Solvin's formula [49] is used.

$n = N/ (1+ N*E^2)$ 3.8

Where;

n= sample size

N= population size

E= error tolerance

The selected confidential interval is 95% implies that the margin of error will be 5%. The population size of the study area is 2,131,147.

$n = 2,131,147/ \{1+ (2,131,147) (0.05)^2\}$

$= 399.92 \sim 400$

Hence the minimum sample size should be 400 respondents for the analysis to obtain a high accurate solution with a low error probability. Before delivering the questionnaire to the community, a pilot test was arranged by randomly selecting a few residents in the study area as the questionnaire has to be clear and able to respond all required attributes which will be employed to required analysis. After the pilot test, more than 600 pre-formatted questionnaires were randomly sent to the residence in the study area and finally 422 respondents were selected for the analysis. Those who respondents were more than 15 years old and living inside the 11 DSDs in Colombo districts of CMA. Accordingly, primary data from the 422 respondents and the secondary data for this study was obtained through the published journals and reports.

The preformatted questionnaire for collecting primary data was included four parts. The first part is integrated about the social demographic characteristics of the subjects to gain the general view of their profiles with including the family income, number of earning members in the family, gender, age, educational back ground, occupation, number of family members, vehicle ownership and driving license ownership.

The second session of the questionnaire was considered about the travel behavior of the subjects with receiving the details of their travel purpose, travel distance, travel cost and the time for their daily regular traveling purposes.

The third and the fourth part of the questionnaire were considered about the factors affecting to choose the mode for traveling with concerning as they use the mode of public transport or private transport respectively. Since there are few of some factors differ to tend for the public or private transport, the questionnaire was divided into two parts for public transport users and for private vehicle users. For example, the respondents who use their private vehicle, should think about the

parking facility, which was not wanted to consider by the public transport users. The format of the questionnaire is in Appendix II.

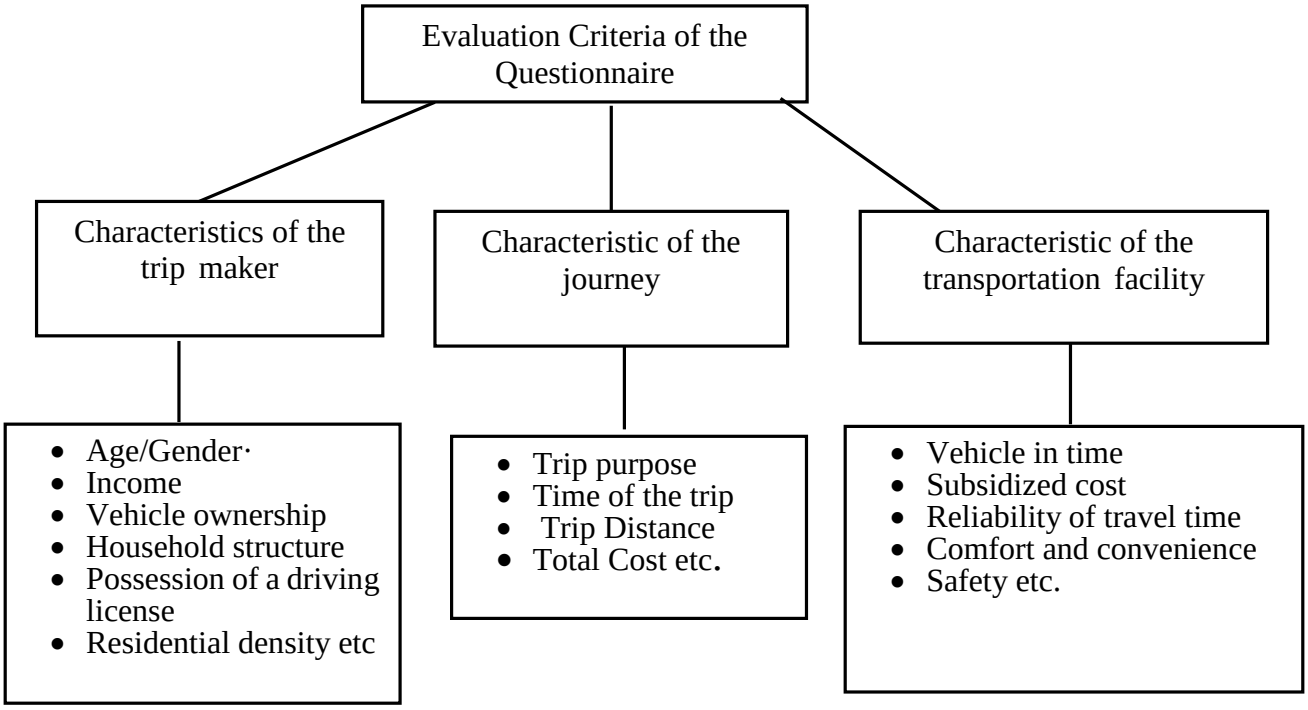


**Figure 3.3**: Evaluation Criteria of the Questionnaire

## 3.7 Factors Influencing to Travel Behavior on Transport Mode Choice

Increasing congestion on roads in metropolitan region and increasing usage of private vehicles are the serious issues that affected to the development of the transportation sector. Sri Lanka incurs a huge economic loss of around 40 billion Rupees annually due to road traffic congestion and air pollution with too many vehicles on a limited road network. On the other hand, Private vehicle usage is gradually increase while public mode share is gradually decreasing [9], [11]. To provide a productive solution for these massive issues, it is important to identify the factors influencing to choose the mode for traveling by the people. All of the factors are related with the socio economic and service attributes. The aim of this analysis is trying to identify the factors affecting to select

the transportation mode for their regular activities in the aspects of the personal characteristic and the travel- based characteristic.

### 3.7.1 Methodology for identifying factors affecting of Mode Choice

After the answered survey forms were returned, the responses were edited to ensure completeness, consistency and readability. Thus, 422 sample respondent were selected. Once the data had been checked, they were arranged in a form that enabled it to be analyzed. Then quantifiable data from the questionnaires was coded into the Statistical Package of SPSS for the analysis. Factor Analysis was then employed to analyze the data collected from the survey. Separately, factors influence for the public mode and private mode were consider with concerning respondent's personal characteristics (PC) and travel-based characteristics (TB).

Factor Analysis is a collection of methods used to examine how underlying constructs influence the responses on a number of measured variables. By using this Factor Analysis, the common influencing factors for the classified industry can be identified and it was done to reduce the number of variables to a small number of variables and grouped variables with similar characteristics together [50].

Before going to factor analysis, there are few number of assumptions should be completed

- Correlation among variables should be strong.
- The comparison index between correlation coefficient and partial correlation coefficient should be small generally.
- Every variable, which will be analyzed by using factor analysis, should spread normally.

### 3.7.2 Results for Factor analysis

#### 3.7.2.1 *Accuracy Checking for Factor Analysis*

The first output from the analysis is the matrix correlation of variables. Typically, the KMO score and the Bartlett's significant score are given in Table 3.3 to find out the accuracy of factor analysis for each mode. The KMO (Kaiser-Meyer-Olkin) score is more than 0.5 for each mode and that score implies that the analysis can be continued further for all the given modes in the table.

**Table 3.3:** KMO and Bartlett's Test

| Travel Mode | KMO and Bartlett's Test | Value for Personal Variables | Values for Travel-Based Variables |
|---|---|---|---|
| Public Bus | Kaiser-Meyer-Olkin Measure | .594 | .625 |
| | Approx. Chi-Square | 385.85 | 525.05 |
| | Bartlett's Test of Sphericity df | 45 | 55 |
| | Sig. | .000 | .000 |
| Train | Kaiser-Meyer-Olkin Measure of Sampling | .524 | .540 |
| | Approx. Chi-Square | 85.49 | 226.75 |
| | Bartlett's Test of Sphericity df | 36 | 55 |
| | Sig. | .000 | .000 |
| Car/Van | Kaiser-Meyer-Olkin Measure of Sampling | .553 | .510 |
| | Approx. Chi-Square | 121.43 | 196.82 |
| | Bartlett's Test of Sphericity df | 45 | 55 |
| | Sig. | .000 | .000 |
| Motor Cycle | Kaiser-Meyer-Olkin Measure of Sampling | .627 | .700 |
| | Approx. Chi-Square | 251.77 | 243.76 |
| | Bartlett's Test of Sphericity df | 45 | 55 |
| | Sig. | .000 | .000 |
| Three Wheeler | Kaiser-Meyer-Olkin Measure of Sampling | .551 | .521 |
| | Approx. Chi-Square | 72.63 | 162.97 |
| | Bartlett's Test of Sphericity df | 28 | 55 |
| | Sig. | .000 | .000 |
| Walk | Kaiser-Meyer-Olkin Measure of Sampling | .511 | .506 |
| | Approx. Chi-Square | 99.56 | 177.20 |
| | Bartlett's Test of Sphericity df | 36 | 55 |
| | Sig. | .000 | .000 |
| Other | Kaiser-Meyer-Olkin Measure of Sampling | .507 | .588 |
| | Approx. Chi-Square | 185.97 | 313.34 |
| | Bartlett's Test of Sphericity df | 45 | 45 |
| | Sig. | .000 | .000 |

The Bartlett's significant score is 0.000 for each mode and then it continues to further analysis. The strong correlation can be indicated by the matrix correlation of determinant score approaching zero (0) score. It can be seen through Bartlett's Test of Sphericity. The Sphericity test is based on the Chi Square transformation from the correlation matrix determinant.

### 3.7.2.2 *Factors Influencing to Choose the Public Transport*

**Table 3.4:** Varimax Rotated Component and the Total Variance of Public Transport for Personal Characteristics

| Personal | Public Bus | | | | Train | | |
|---|---|---|---|---|---|---|---|
| | Component | | | | Component | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| Family Income | .80 | | | | | -.72 | |
| Residence Type | | | -.74 | | | .72 | |
| Household Size | | | .82 | | .80 | | |
| Earning Member | .64 | | | | | | |
| Vehicle Ownership | | -.85 | | | -.84 | | |
| Gender | | .64 | | | | | .76 |
| Age | | | | .80 | | .65 | |
| Education | .81 | | | | | | .48 |
| Occupation | | | | .86 | | | -.66 |
| License Holder | | .65 | | | .76 | | |
| **Total Variance** | **71.30** | | | | **62.27** | | |

In the sector of the public transport, public bus and train are the main public mode and are considered to find the people's factors influencing to select the mode of public transport. The main two segments; personal characteristics (PC) and the travel- based (TB) are measured to find the influencing factors. Table 3.4 and Table 3.5 depict the rotated component loadings in the method of factor analysis.

The total variation before the extraction is 100% and then after extraction, 10 manifest variables for the personal characteristics (PC) and the 11 variables for the travel-based (TB) characteristics are reduced into 4 latent components for public bus. There are 9 variables are analyzed for PC segment of the mode of train. According to the tables, only 3 factors contribute a significant value (more than 60 %) for the total variance and their eigen values are greater than one.

**Table 3.5:** Varimax Rotated Component and the Total Variance of Public Transport for Travel-Based Characteristics

| Travel- Based | Public Bus | | | | Train | | |
|---|---|---|---|---|---|---|---|
| | Component | | | | Component | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| Waiting time | | | . | -.62 | .77 | | |
| Vehicle Travel Time | | | -.73 | | | | .75 |
| Subsidized Cost | .84 | | | | .90 | | |
| Access Time | .87 | | | | .93 | | |
| Comfort | | | .43 | | .60 | | |
| Safety | .60 | | | | | | .87 |
| Time Reliability | | | | .82 | | | .67 |
| Trip Purpose | | | -.70 | | | .62 | |
| Trip Distance | | .70 | | | | .55 | |
| Trip Time | | .76 | | | | .87 | |
| Total Cost | | .86 | | | | .81 | |
| **Total Variance** | **67.85** | | | | **69.69** | | |

In addition to that, the tables show the final score after Varimax rotation. This matrix determines the highest correlation score for each component, which contains several variables.

Figure 3.4 depicts the influencing factors for the mode of public Transportation. The earning capacity and education level is a one factor. The person who has low income level normally tends to use the public bus. And as well, the young people most probably use the public bus in this area than the older people and their occupation is mentioned as education in the questionnaire. The female may use the public bus than male, as most of them are not the vehicle owners in Sri Lanka. Large number of family members in a family and if they do not have vehicle, they specially use public train. Low income and young people, especially male students and male workers choose the public train rather than females.

In addition to that, based on Figure 3.4 and the factor variations, traveler much think about the cost and the access time of the bus but not much about the safety. Some travelers think about the trip

characteristics like distance, cost and time of the journey, especially if they want to go for a long distance journey, they select public modes.

According to the comfort level, people do not much think about comfort when choosing the bus for their journey. Traveler much think about the safety and time reliability when selecting train but not much about for buses.

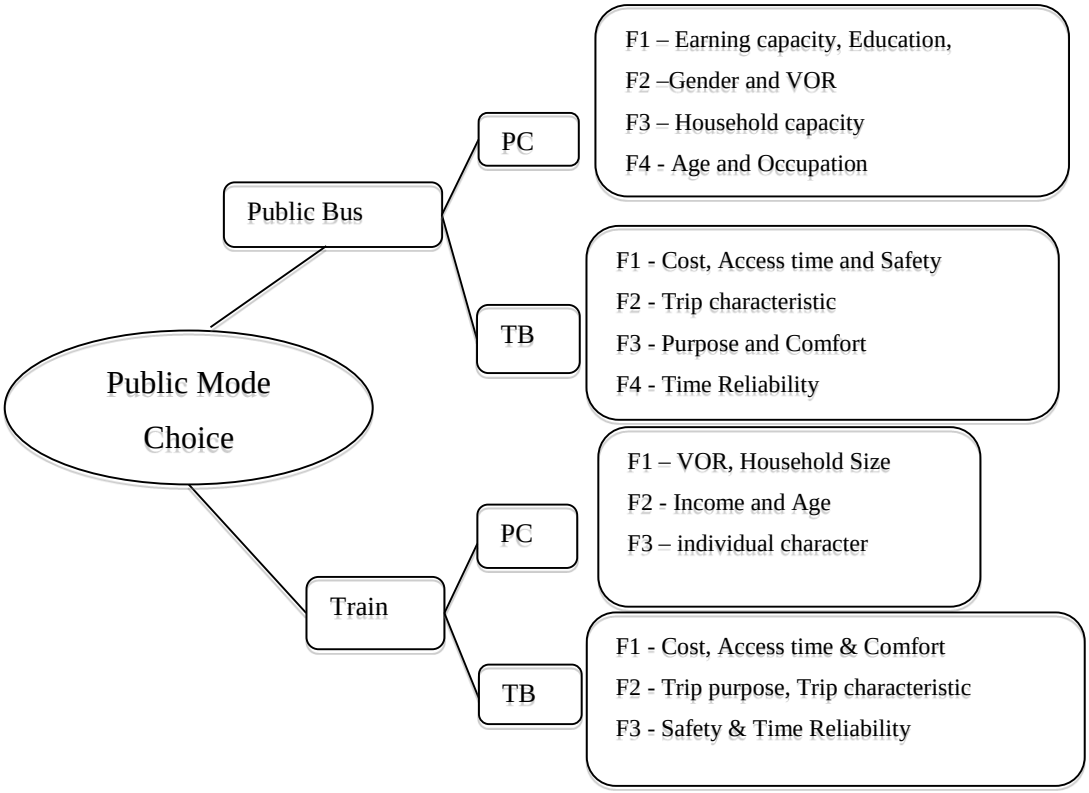


**Figure 3.4**: Factors Influencing to Choose the Mode of Public Transport

For selecting public transport, some of travelers, think about the cost, access time, safety and comfort level. When people go for a long journey, they tend to select public bus or train, but some of them are think much about the high comfort level, they definitely select the public train rather than public bus. However, people much think about the safety of the journey when they are selecting public train rather than public buses as in the peak hours public trains are crowded and unsafe as well as the less frequency of trips rather than public buses. When selecting both bus and train, peoples much think about the time reliability since time reliability is very low in Sri Lanka for the public bus and the trains. Thus peoples think twice when they are going to select public transport with the aspects of time reliability.

### 3.7.2.3 *Factors Influencing to Choose the Private Mode*

As the private modes, Motor Cycle, Three Wheelers, Car, Walk and the other modes such as taxi, private van for school service, and other transport vehicles that are provided by the working place are considered for this category. The influencing factors to choose these private modes are measured with the same aspects of two segments namely PC and the TB characteristics. There are 10 variables and the 11 variables are analyzed under the segments of PC and TB characteristics respectively. But for the PC segment, there are only 9 variables that analyzed for the mode of three wheelers and the walk.

**Table 3.6:** Varimax Rotated Component and the Total Variance of Private Transport for Travel-Based Characteristics

| Travel- Based Characteristics | Motor Cycle | | | Three Wheeler | | | Car | | | | Walk | | | Other | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Component | | | Component | | | Component | | | | Component | | | Component | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 1 | 2 | 3 |
| Waiting time | .78 | | | .84 | | | .90 | | | | .81 | | | | .90 | |
| Vehicle Travel Time | .70 | | | .65 | | | .71 | | | | .59 | | | | | |
| Subsidized Cost | .84 | | | .69 | | | | .79 | | | .77 | | | .80 | | |
| Access Time | .88 | | | | | .70 | .86 | | | | .78 | | | .66 | | |
| Comfort | | | .84 | .80 | | | .60 | | | | .77 | | | | .68 | |
| Safety | .68 | . | | | | .76 | .66 | | | | .65 | | | | | .95 |
| Time Reliability | .73 | | | .81 | | | | .85 | | | | -.74 | | -.91 | | |
| Trip Purpose | | . | .81 | | | .60 | | | 86 | | . | .72 | | .87 | | |
| Trip Distance | . | .83 | | | .84 | | | | -.64 | | | | .83 | | -.77 | |
| Trip Time | | .87 | | | .84 | | | | | .79 | | .61 | | | -.72 | |
| Total Cost | | .83 | | | .71 | | | | | .78 | .838 | | .67 | .83 | | |
| **Total variance** | **69.89** | | | **67.68** | | | **74.85** | | | | **64.53** | | | **80.71** | | |

Table 3.6 and Table 3.7 show the component loadings for each factors and the total variance contribution from the significant components only. The all total variance contributions after extraction are greater than 60% and the remaining factors are not significant since their eigen values are less than 1 and therefore explain less variance that a single variable. Figure 3.5 shows the affecting factors to select the private modes.

The PC and TB factors affecting to choose the motor cycle are individual types (Age, Education and Occupation) and household type. Most young working peoples are using motor cycle and middle class households tend to use this mode for working purpose. The most dominant people are the male who tend to own a motor cycle. Most peoples who has middle to low level income use at least a private vehicle like motor cycle. As TB characteristics, peoples who use the motor cycle, think about the time with a private vehicle for a low cost. This mode is an ideal solution for the high traffic congestion. Motor cycle users like fulfill their trip purpose comfortably.

**Table 3.7**: Varimax Rotated Component and the Total Variance of Private Transport for Personal Characteristics

| Personal Characteristics | Motor Cycle | | | Three Wheeler | | | Car | | | | Walk | | | Other | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Component | | | Component | | | Component | | | | Component | | | Component | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 1 | 2 | 3 |
| Family Income | . | | .75 | | .87 | | .87 | | | | | | -.68 | | .84 | |
| Residence Type | -.80 | | | -.88 | | | | | .86 | | | | .84 | | -.50 | |
| Household Size | .86 | | | | .70 | | | | .74 | | | .61 | | | .73 | |
| Earning Member | | | .85 | | .84 | | .61 | | | | | | | | .69 | |
| Vehicle Ownership | | -.93 | | | | | | -.93 | | | -.71 | | | .85 | | |
| Gender | | .82 | | | | .588 | .63 | | | | .60 | | | | -.42 | |
| Age | .44 | | | .74 | | | -.66 | | | | -.56 | | | .72 | | |
| Education | -.85 | . | | | | .813 | | | | -.68 | .55 | | | .68 | | |
| Occupation | .64 | | | .84 | | | | | | .88 | | .922 | | | | .89 |
| License Holder | | .91 | | | | | | .90 | | | .82 | | | -.88 | | |
| **Total Variance** | **72.45** | | | **71.71** | | | **74.89** | | | | **63.95** | | | **67.90** | | |

PC factors affecting to select the three wheeler are residence type, age and the occupation. Most elder peoples who are unemployed or kids who are going school, that use three wheelers as the travel mode. Who are living in rented house that tend to use this mode. The middle level income families use three wheelers and the ladies highly hire to use this mode for their shopping, recreational or kids dropping activities as a high level of Safety mode. And also they use this as a private vehicle with low cost with saving their time and more conveniently. This situation can be confirmed by using TB factors**.**

With analyzing the PC factor for affecting to choose the private cars, it is identified that the majority level of peoples who are the male and have high level of income tend to use the private car. And also the people who have greater level of education and a good occupation are more likely to have their own private vehicles such as cars. The other factors are the safety, comfort and the time, which are high in the car than the public vehicles. When using the cars, people think about the purpose and the distance of the trip before traveling by cars.

The factors influencing to select the mode of walk are individual types such as age, gender, and education. The peoples, who have low educational level and women who are unemployed that fulfill their traveling requirement by walk. Majority of the peoples who are going by foot have low-income level and they do not bear the expenses for a vehicle and its maintenance cost and most of they have low educational background. On the other hand, the common thing for the women who are going by foot of their trip purpose are the kids dropping, going market and other recreational activities. They are considering about the cost and the distance before going by foot.

The factors affecting to choose the other modes such as taxi, private vehicles for the trip purpose are depend with concerning time, cost and safety. The majority of the students and the employees in the private sector are using this kind of vehicles. comfort and the distance of the trip are most valuable factors for these modes that are being considered. For examples, parents should select the mode of three wheeler or a van for their children as a private service if that service is more safety. Figure 3.5 depicts the all private vehicle related factors.

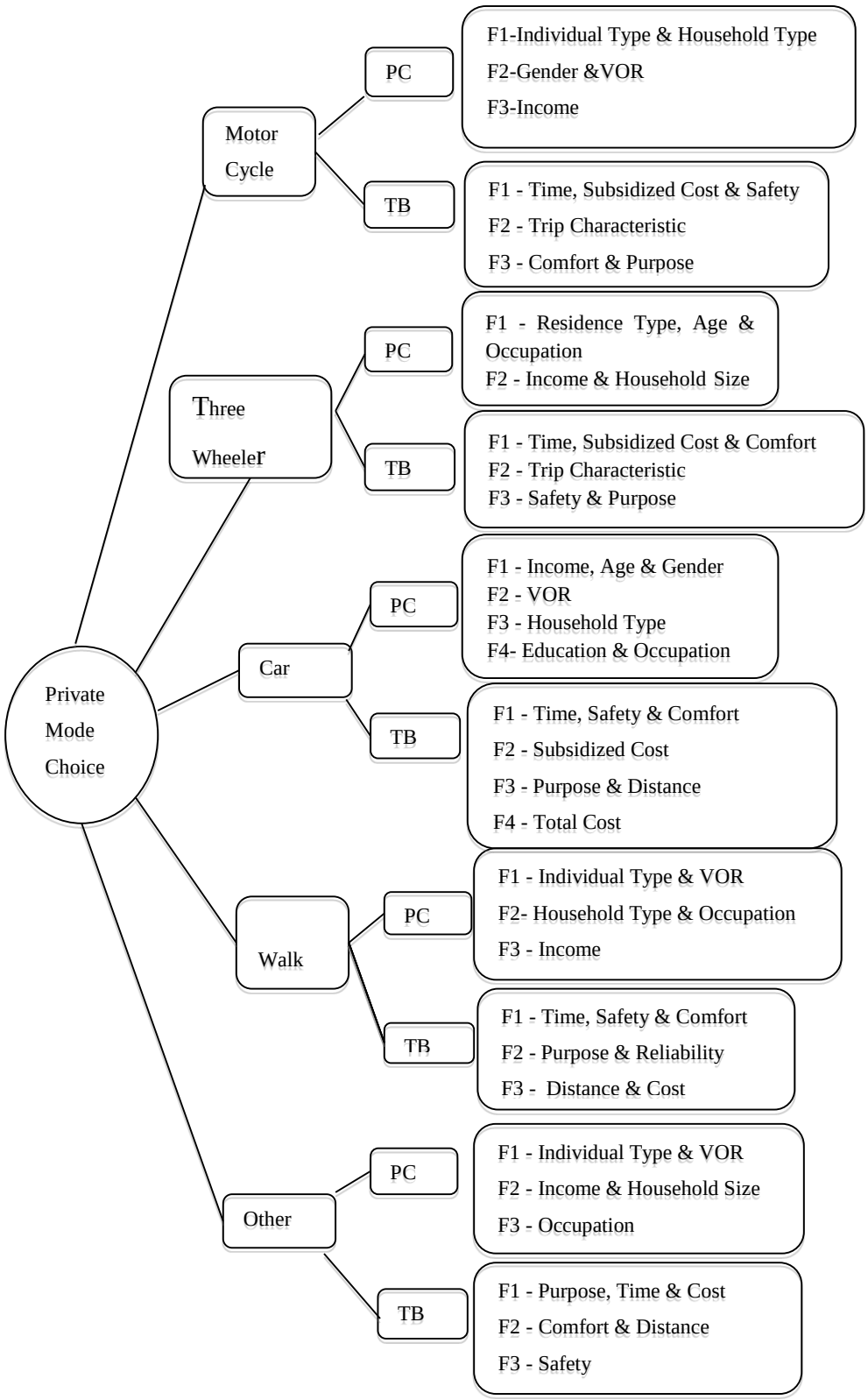


**Figure 3.5**: Factors Influencing to Choose the Mode of Private Transport

### 3.7.3 Descriptive Analysis for the Questionnaire

#### 3.7.3.1 *Socio Demographic Characteristics from the Questionnaire*

Figure 3.7 shows the several socio demographic characteristics with public private transport mode usage. As the public mode, car/van, motor cycle, three wheelers, walk and other, and as the public modes, bus and train were considered. Vehicle ownership shows that, if a person has at least one vehicle, that person do not try to use much public transport. The owners who have a motor cycle (65.8%) and a three wheeler (85.7%), they always use their vehicle and very less probability to use the public transport. The majority traveler who does not have their own vehicle, tend to use public transport without using private transport services like taxi or other private office transport or school service vehicles.

Furthermore, workers and students have the greater use of public transport than the private vehicle for their regular traveling. When the number of earning members are increased, usage of public also increased as the number of people in the household may be large and their number of journeys and requirements are different. Under the age condition, age of 16-35 young people use public transport. On the other hand, the peoples with low income level tend to use more public transport.

#### 3.7.3.2 *Trip Purpose*

Figure 3.6, shows about the trip purposes with the selecting mode. According to that figure, majority of traveler fulfilled their travel by the public modes for work and education purposes. Recessional, shopping and business purposes, people select a private mode as these trip purposes are not being occurred everyday even they are regular activities. Specially, for the shopping and recessional activities, people choose three wheel, foot cycles as a private mode.

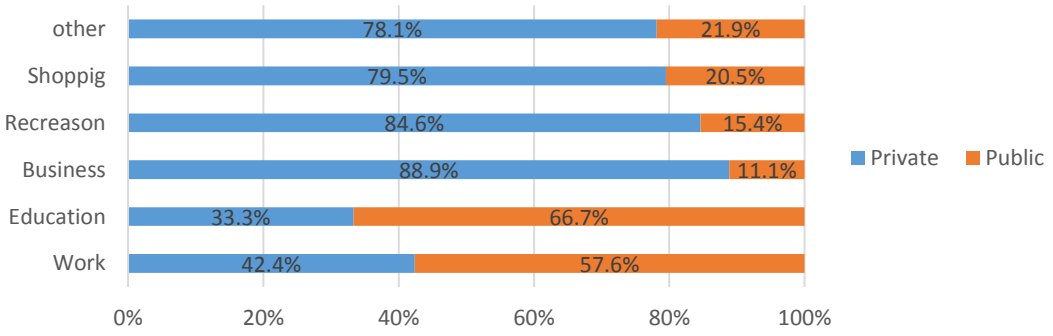


**Figure 3.6:** Trip Purpose of the Residence by the Private/Public Transportation Mode

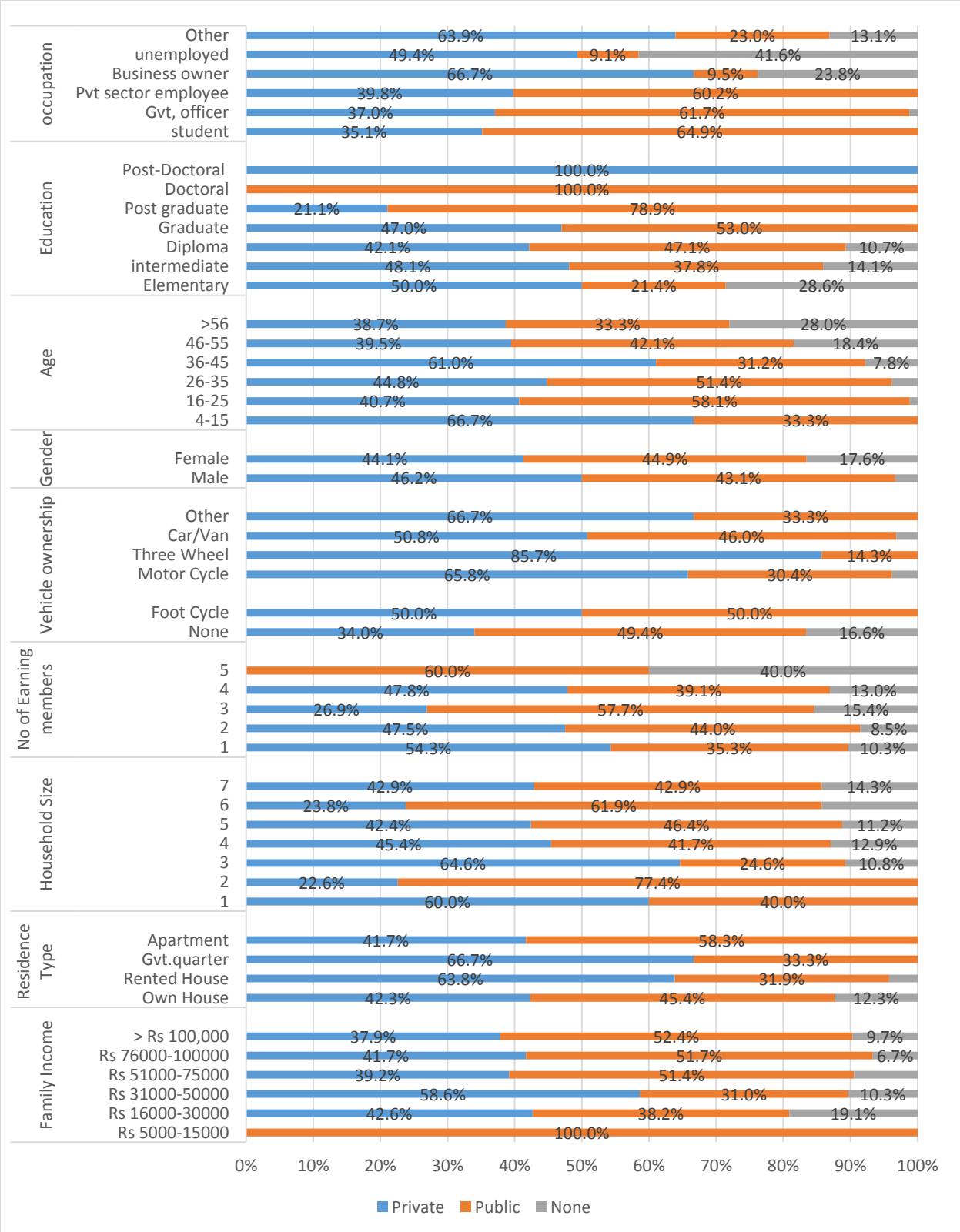


**Figure 3.7:** Socio Demographic Characteristics of the Residence by the Private/Public Transportation Mode

### 3.7.3.3 *Trip Distance*

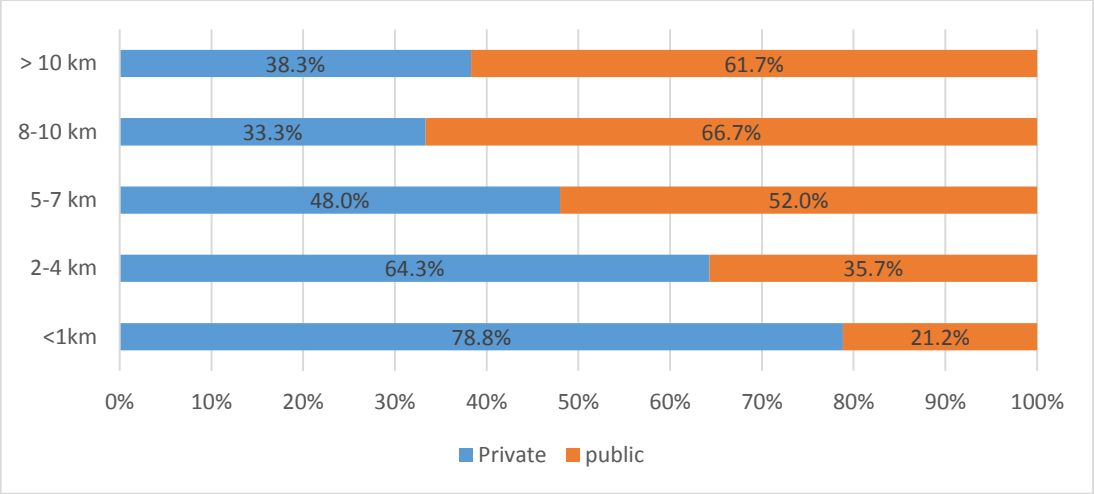


**Figure 3.8** Trip Distance of the Residence by the Private/Public Transportation Mode

Figure 3.8 shows for the short distance journey, the traveler tends to use private vehicle and for long distance journey, public transport is chosen. Peoples may concern about the comfort and cost of the journey when they are selecting a travel mode.

### 3.7.3.4 *Time Duration for the Trip*

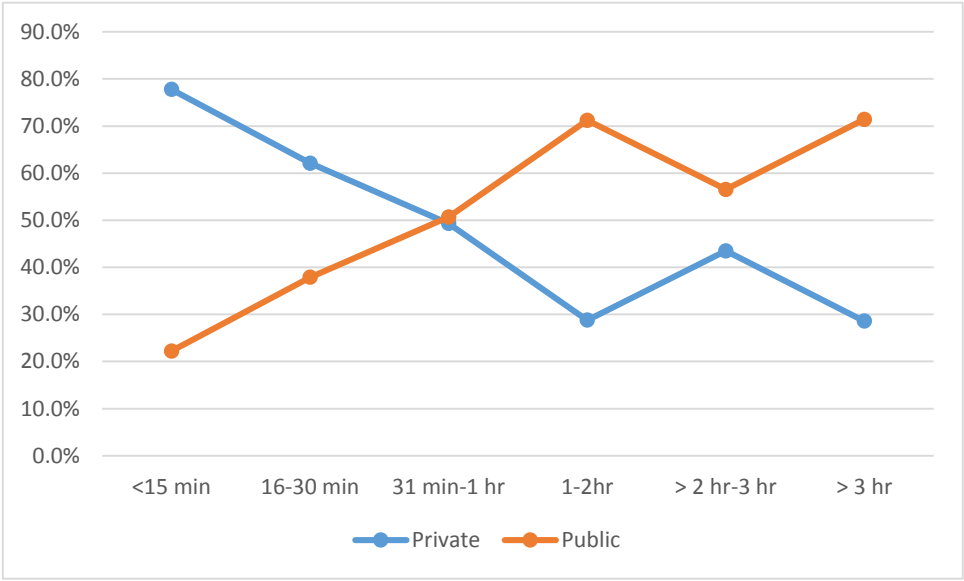


**Figure 3.9**: Trip Time of the Residence by the Private/Public Transportation Mode

According to the Figure 3.9, Peoples use private vehicles for a short time period and also for a short distance. Because of this situation, in the peak hours, the roads are filled with private vehicles and it creates high traffic congestion. The study area has a high density of economic activities and the subjects are the residence in this area. Hence, if most of residence are trying to use private vehicles for their regular works and trip purposes, it will be a critical problem for economic development in the country.

#### 3.7.3.5 *Mode Split Distribution*

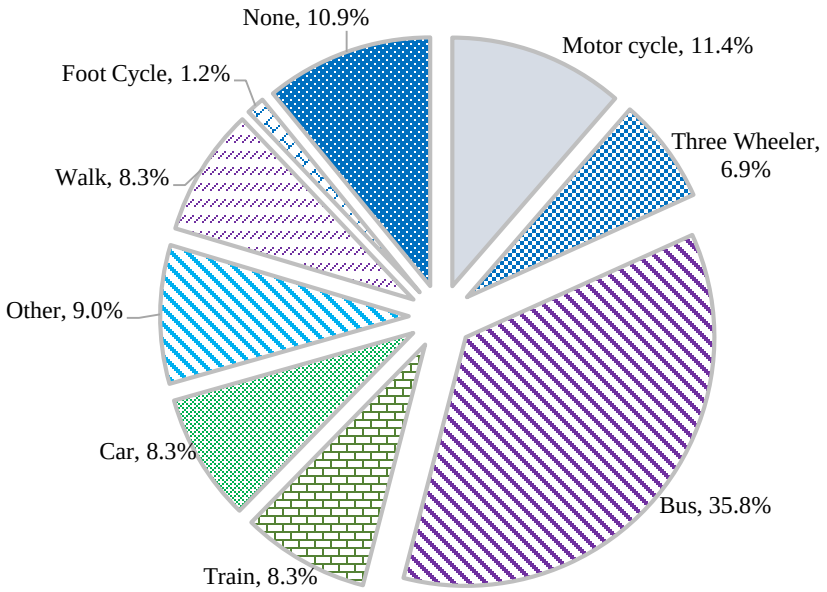


**Figure 3.10**: Model Split of the Sample Population

The model split in Figure 3.10 shows the highest share for the public bus. The public bus and the train contribute 44.1% of the total share. As an entity, motor cycle, car, three wheelers and other mode contribute 37.6%. The model split of walk and the foot cycle share is 9.5%. When the share of walk and the foot cycle is being considered as private mode, altogether 47.1% of residences use private mode for their regular trips. It shows that the 47.1 % of people fulfill their traveling requirement privately without using public transport modes. Thus, the residences are relied on both private and public transport around equally.

## 3.8 Appraising the Strongly Associated Impacts to Choose the Mode of Public Transport

This section examines a model to evaluate the probability of choosing the mode of public transport with finding the most significant aspects related to the characteristic of the journey, characteristic of the traveler and the personal behavior of the traveler. Traffic congestion is a main problem associated with increasing the risk of road accidents in the urban areas and greater use of private vehicle on roads is to increase the traffic congestion. As well as the "poor quality of public transport contributes to increase market share of private motorized traffic, which in turn leads to increase congestion" [51]. On the other hand, there is a direct relationship between the ridership on public transport and the usage of private vehicle. Because there are several reasons that taken place to use of private vehicles without using the public transport such as unreliability and the low quality of the public transport. With this situation, the traffic congestion is increased due to the greater use of private vehicles without using public transport.

However public transport service is an effective solution for the traffic congestion in the urban areas [52]. Also another research shows that "A well-performing public transport system provides a credible alternative to drive for many trips in a metropolitan region, and therefore has the potential to mitigate road traffic, alleviate auto dependency, and reduce greenhouse gas emissions" [53].

As above section-mentioned, the public transport is vital, encouraging people for the public transport is an essential requirement for the economic development through reducing traffic congestion and the road accidents. According to the previous researchers, "reliability of public transport systems has been considered critically importance by most public transport users because passengers are adversely affected by the consequences associated with unreliability such as additional waiting time, late or early arrival at destinations and missed connections, which increases their anxiety and discomfort" [54]. And the travel behavior of the peoples and their perceptions regarding the public transportation are essential to analyze for the development of public transport [55]. Hence, these findings understand the important of the identification about

the traveler perception of the mode choice to increase the development of public transport. Understanding mode choice is important since it affects how efficiently we can travel, how much urban space is devoted to transportation functions as well as the range of alternatives available to the traveler [56].

Thus objective of this section was to evaluate the probability of choosing the mode of public transport with finding a model by the most significant aspects related to the traveler's selection of public transport. With considering about previous emerging researches related to the analysis of mode choice behavior of the travelers, most of the studies have been focused on one regular trip for their analysis and/ or considered about one particular subject for their analysis. For instance, Naveen, Vincer and Ahmed have focused their study for the trip of only work/school trip for their university student and staff members [57]. Van Can [58] has examined domestic tourist's behavior only who come to Nha Tran, Vietnam by using Multinomial Probit Model. Further, Julien, Hichem and Philippe investigated the travel mode choice behavior of both resident and cross border workers in Luxemburg [59]. However, this study attempted to evaluate the travel behavior of the subject who belongs to a particular household. The households were selected by randomly in the selected area and their regular travel activities were considered for the evaluation rather without concerning only one particular categorized subject or a particular trip. All the members who were greater than fifteen years old of that household were evaluated as it was a best way to identify the regular lifestyle of that household in a specified area. Not only that, but also the difference of this study compares to the other related studies was the evaluation methodology.

### 3.8.1 Methodology for Probability Tendency Model for Choosing Public Transport

The very first step of this study was the problem identification related to the transportation sector and it was identified from the previous section what the public transport sector development is vital and as well as the literature review shows that peoples were unhappy and unsatisfied about the mode of the public transport in CMA of Sri Lanka [10]. Then the obtained data from the questionnaire was analyzed with binary logistic method to find the model of mode choice. The logistic model was developed after several steps as revealed in the analysis part of Figure 3.11. Finally, the evaluation process was completed by interpreting the model with giving a number of recommendations to the responsible policy makers.

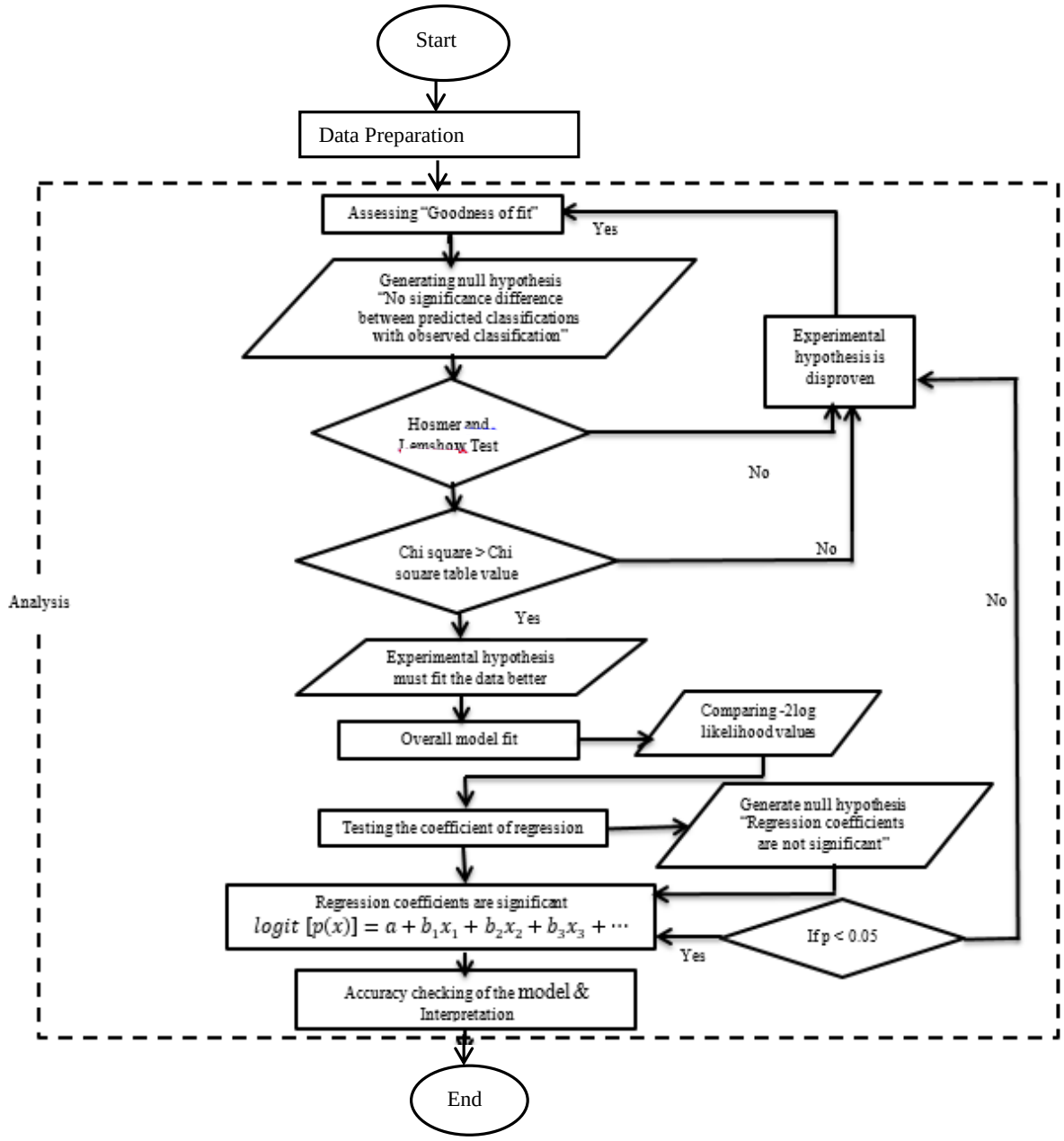


**Figure 3.11:** Flow Chart of the Analysis

The data sample is the same as the previous section which is collected from the pre-formatted questionnaire. The subjects of this study were selected randomly and belonged to the all types of class residents with emphasis their regular travel patterns. Every members of the family who were greater than fifteen years old that considered with regarding the categories of the characteristics of the trip maker, journey and transport facilities.

The data obtained from the travel maker were analyzed by using binary logistic regression. Logistic regression can be used to find the strongly associated variables with the probability of a particular category in another variable occurring [60]. Logistic regression determines the impact of multiple independent variables $X_1$, $X_2$, $X_3$…….$X_k$ presented simultaneously to predict membership of one or other of two depended Y variable categories. The software SPSS was used to estimate the model through maximum likelihood function. The procedure to analysis the probability of choosing the mode of public transport by using this logistic regression is illustrated in Figure 3.10.

### 3.8.2 Parameter Estimation

Logistic regression was applied to determine the relationship between most significant factors related to the mode choice of public transport. The Subjects who selected the public transport were coded as 1 while those who selected the private transport were coded as 0. The outcome is not a prediction of a Y depended value, as in linear regression, but a probability of belonging to one of two conditions of Y.

The log transformation of the P (probability) values to a log distribution enables to create a link with the normal regression equation as follows.

$$logit\ (p) = \log\left[\frac{p}{(1-p)}\right]$$

Where;

p = probability

logit (p) = log (base *e*) at the odds ratio or likelihood ratio

The formula below shows the relationship between the usual regression equation and the logistic regression equation.

$$logit\ [p(x)] = \log\left[\frac{p(x)}{\left(1-p(x)\right)}\right] = a + b_1x_1 + b_2x_2 + b_3x_3 + \cdots$$

Then the p can be calculated by using the following formula

$$p = \frac{exp^{(a+b_1x_1+b_2x_2+b_3x_3+\cdots)}}{1+exp^{(a+b_1x_1+b_2x_2+b_3x_3+\cdots)}}$$

Where:

p = the probability that choosing a mode of public transport

exp = the base of natural logarithms (approx 2.72)

a = the constant of the equation and

b = the coefficient of the predictor variables related to the travel maker

This uses a maximum likelihood method, which maximizes the probability of getting the observed results given in the fitted regression coefficient [61].

### 3.8.3 Feasibility of the Model

Hsmer and Lemshow test values which is similar to chi-square test can be used to find weather the model is well- fitting or not. The well-fitting models show non-significance on the goodness of fit test. It implies that the model prediction that is not significantly different from observed values. The hypothesis can be generated as follows.

$H_0$: There are no significant differences between predicted classifications with observed classification

$H_1$: There are significant differences between predicted classifications with observed classification

**Table 3.8:** Hosmer and Lemshow Test

| Step | Chi-square | df | Sig. |
|---|---|---|---|
| 1 | 10.141 | 8 | .255 |

The significant value of the Table 3.8, is 0.255, which is greater than 0.05. It indicates that $H_0$ is accepted and there are no significant differences between predicted classifications with observed classification. This result suggests that the binary logistic regression for mode choice is feasible to

be used for further analysis. The chi-square value of the table is 10.141 which is less than the table values of 15.5073 (df=8 and 0.05 level). According to this chi-square value is also implied that the $H_0$ is accepted and the model related to mode choice is feasible to be further analysis.

### 3.8.4 Measuring the Overall Model Fit

To determine whether the model is statistically significant or not, log-likelihood ratio test is conducted by comparing the Log Likelihood (LL) function of the estimated model to that of the LL function of base model [62]. The likelihood ratio test is based on -2LL ratio. It is a test of the significance of the difference between the likelihood ratio (–2LL) for the researcher's model with predictors (called model chi square) minus the likelihood ratio for baseline model with only a constant in it.

**Table 3.9:** Iteration History (Block 0: Beginning Block)

| Iteration | | -2 Log likelihood | Coefficients Constant |
|---|---|---|---|
| Step 0 | 1 | 514.313 | .005 |
| | 2 | 514.313 | .005 |

**Table 3.10:** Model Summary (Block 1: Method=Enter)

| Step | -2 Log likelihood | Cox & Snell R Square | Nagelkerke R Square |
|---|---|---|---|
| 1 | 348.134 | .361 | .481 |

The score of -2 log likelihood is 514.313 in the Table 3.9 (Block 0) and the same score in Table 3.10 (Block 1) is 348.134. The decreasing of that value illustrates that the mode choice regression model is a better model since the Likelihood of the Binary Logistic similar with the definition of 'sum of squared error' in regression model.

### 3.8.5 Results from the Logistic Regression

Table 3.11 depicts the Wald statistic and associated probabilities provide an index of the significance of each predictor in the mode choice equation. The Wald statistic has a chi-square distribution [63]. There were 21variables that considered for the model. The variables related to the travel maker that have the value of less than 0.05 under the column of significant were considered for the equation. The 11 variables out of 21 variables were needed to drop independents from the mode choice model when their effect was not significant by the Wald statistic. The Exp (B) column in the table presents the extent to which raising the corresponding measure by one-unit influences the odds ratio. The 'B' values are the logistic coefficients that can be used to create a predictive equation. According to the table, the selected variables are the significant variables for the model.

The predictive equation can be written with the 10 significant variables, which the significant values are less than 0.05. From the Table 3.11, the 'B' values are the logistic coefficients that can be used to create the mode choice equation.

$$logit\,[P(X)] = \log\left[\frac{P(X)}{(1-P(X))}\right]$$

$$logit\,[P(X)] = 3.01 + 0.532X_4 - 0.716X_5 - 1.071X_6 + 0.252XX_7 + 0.414X_8 - 0.552X_9 + 0.520X_{12} + 0.643X_{13} - 0.985X_{14} - 0.773X_{20}$$

The peoples who are living at Colombo area within the CMA, considered about ten significant factors related to the choice of public transport since the Table 3.11 verifies the values. Earning members ($X_4$), Vehicle Ownership ($X_5$), Gender ($X_6$), Age ($X_7$), Education ($X_8$), Occupation ($X_9$), Trip Distance ($X_{12}$), Trip Time ($X_{13}$), Total Cost ($X_{14}$) and safety ($X_{20}$) were the factors that the peoples mostly consider about the public transport.

**Table 3.11**: Variables in the Equation

| | Variables | B | S.E. | Wald | df | Sig. | Exp (B) |
|---|---|---|---|---|---|---|---|
| Step 1 | Family Income ($X_1$) | -.213 | .132 | 2.585 | 1 | .108 | .808 |
| | Residence Type ($X_2$) | .036 | .222 | .027 | 1 | .870 | 1.037 |
| | Household Size ($X_3$) | -.120 | .147 | .672 | 1 | .412 | .887 |
| | Earning Members ($X_4$) | .532 | .212 | 6.308 | 1 | .012 | 1.702 |
| | Vehicle Ownership ($X_5$) | -.716 | .128 | 31.421 | 1 | .000 | .489 |
| | Gender ($X_6$) | -1.07 | .346 | 9.607 | 1 | .002 | .343 |
| | Age ($X_7$) | .252 | .124 | 4.145 | 1 | .042 | 1.287 |
| | Education ($X_8$) | .414 | .179 | 5.354 | 1 | .021 | 1.512 |
| | Occupation ($X_9$) | -.552 | .134 | 16.879 | 1 | .000 | .576 |
| | License Holder ($X_{10}$) | -.625 | .447 | 1.954 | 1 | .162 | .535 |
| | Trip Purpose ($X_{11}$) | .005 | .131 | .001 | 1 | .970 | 1.005 |
| | Trip Distance ($X_{12}$) | .520 | .154 | 11.430 | 1 | .001 | 1.683 |
| | Trip Time ($X_{13}$) | .643 | .178 | 13.074 | 1 | .000 | 1.901 |
| | Total Cost ($X_{14}$) | -.985 | .208 | 22.358 | 1 | .000 | .373 |
| | Waiting Time ($X_{15}$) | -.216 | .171 | 1.591 | 1 | .207 | .806 |
| | Vehicle Travel Time ($X_{16}$) ($X_1$) | .155 | .241 | .412 | 1 | .521 | 1.167 |
| | Subsidized Cost ($X_{17}$) | .160 | .229 | .487 | 1 | .485 | 1.174 |
| | Access Time ($X_{18}$) | .242 | .227 | 1.140 | 1 | .286 | 1.274 |
| | Comfort ($X_{19}$) | .198 | .153 | 1.670 | 1 | .196 | 1.219 |
| | Safety ($X_{20}$) | -.773 | .204 | 14.444 | 1 | .000 | .461 |
| | Time Reliability ($X_{21}$) | -.035 | .225 | .024 | 1 | .877 | .966 |
| | Constant | 3.01 | 2.00 | 2.262 | 1 | .133 | 20.404 |

- The significant value for the variable ($X_4$) of "Earning Members" was 0.012 and it implies that there is a significant influence from the number of earning members of a household for the decision of using public transport. The Odds probability to use public transport as much

of affecting value was Exp (B)= 1.702. According to the questionnaire survey, even the households that had large number of earning members (more than 5), they mostly used the public transport. Even though that household with public transport users had large number of earning members, the majority of their income level was low to middle level (Sri Lankan Rupees 15,000-75000, 54.8%).

- The significant value for the variable ($X_5$) of "Vehicle Ownership" was 0.00. It means the factor vehicle ownership was highly affected to the decision of public transport. The peoples who had an own vehicle, they did not use the public transport. The minus sign for the B value interpreted that if the peoples have their own vehicle it will decrease the odds probability to use public transport as much Exp (B)= 0.489.

- The variable ($X_6$) "Gender" was also a considerable factor for the selection of public transport. The survey results showed that the female travelers had a greater choice to use the public transport than the male users. It is clear that the most of the females in Sri Lanka are not the vehicle license holders and vehicle owners. Therefore, females tend to use public transport than the male travelers. The variable of gender was affected for the choice of public transport with the value of Exp (B) = 0.343.

- The next imperative variables were the "Age" ($X_7$), "Education" ($X_8$) and "Occupation" ($X_9$) as those significant values were less than 0.05. According to the survey conducted, the young people (age between 15- 35 years old) used public transport for their regular trips. Most of these young people made their trip purpose for the education and yet they depended with their parents or others and did not have their own profession. Hence they did not have their own vehicles and then tended to the public transport.

- The significant values for the variables of "Trip Distance" ($X_{12}$), "Trip Time" ($X_{13}$) and "Total Cost" ($X_{14}$) were less than 0.05 and it illustrates that those variables highly affected to the decision of getting public transport. The decision for the factors of trip distance, trip time and the total cost were very important for the people's regular trips. If the destination was so far from the home and the trip was getting too much time, the people tended to select the

public transport as the people regularly do not like to ride their own vehicles for a long time and so far to the destination of the regular trips. The Odds probability to use public transport as much of affecting value was Exp (B)= 0.373.

- Next significant factor was "Safety" ($X_{20}$) with the value of 0.00. It indicates that the safety is very important factor for the travelers. But the B value (- 0.773) was negative and it illustrates that the peoples argued the safety and the security of the public transport was lack in Sri Lanka. Thus they did not have trustworthiness about the public transport with the aspect of safety and the security. Even the public transport had low safety and security, peoples used the public transport due to the low income levels.

### 3.8.6 Accuracy of the Model

The accuracy of the model can be measure by comparing predicted values from the dependent variables and the actual observed data value. In this Table 3.12, the cut off value is 0.5 implies that the probability value more than or equal with 0.5 means the probability tendency will go to public transport, while if the probability value is less than 0.5 it means the probability will go to private transport. According to the table, the overall percentage was 78.4%. It indicates that the accuracy of the model was 78.4% and the model can be predicted with this much of accuracy

**Table 3.12:** Classification Table [a]

| | Observed | | Predicted | | |
|---|---|---|---|---|---|
| | | | Public Transport | | Percentage Correct |
| | | | No | Yes | |
| Step 1 | Public Transport | No | 146 | 39 | 78.9 |
| | | Yes | 41 | 145 | 78.0 |
| | Overall Percentage | | | | 78.4 |

a. The cut value is 0 .5

As a result of this model, the people of the selected area can be categorized that he/she has this much of probability tendency for the usage of public transport. For instance, if a particular male

person in the area had 3 number of earning members of his household and he was in the age category of 46-55 years and a government employee. He was included to the education level of diploma and an owner of a motorcycle. For his regular work trip, he has to spend a time around 30 minutes to 1 hour and the trip distance was 6 to 10 Km. His perception about the total cost is important while safety is very important when he travels for his regular trip purposes. Hence, according to the model, it can be found that how mush his possibility to use public transport for his regular trips. Table 3.13 indicates the categories and the relevant category number for each of the selected above person.

**Table 3.13**

Example: A particular person's details and the relevant categorical numbers

| | Category | Categorical |
|---|---|---|
| No. of Earning Members ($x_4$) | 3 | 3 |
| Vehicle Ownership ($x_5$) | Motor Cycle | 3 |
| Gender ($x_6$) | Male | 1 |
| Age ($x_7$) | 46-55 years | 6 |
| Education ($x_8$) | Diploma | 3 |
| Occupation ($x_9$) | Gvt. Employee | 2 |
| Trip Distance ($x_{12}$) | 6-10 Km | 4 |
| Trip Time ($x_{13}$) | 30 min-1 hr | 3 |
| Total Cost ($x_{14}$) | Important | 3 |
| Safety ($x_{20}$) | Very Important | 4 |

Odds Probability = $P(X) = 3.016 + 0.532X_4 - 0.716X_5 - 1.071X_6 + 0.252X_7 + 0.414X_8 - 0.552X_9 + 0.520X_{12} + 0.643X_{13} - 0.985X_{14} - 0.773X_{20}$

Odds Probability = P(X) = 3.01 + 0.532*(3) -0.716* (3) -1.071*(1) +0.252* (6) +0.414* (3) - 0.552* (2) +0.520* (4)+0.643*( 3)- 0.985*(3) - 0.773*(4)

= 1.005

Probability = $\exp(\beta 0 + \beta 1 + \beta 2 + \beta 3 + \beta 4) / (1+\exp(\beta 0 + \beta 1 + \beta 2 + \beta 3 + \beta 4))$

= exp(1.005) / (1+exp(1.005))

= 0.73

This implies that the person which above category will tend to choose public transport of the 73% rather than private vehicle since the p value is greater than 0.5.

## 3.9 Evaluation of the relationship between access mode choice and public mode choice behavior

Travelers make the decision of choosing the travel mode for their journey from a set of travel modes and that mode depends on their destination and the main part of the journey [63]. If they decide to go for public transport by bus or train, they have to decide the way of accessing the railway station or bus stop. The decision of choosing access mode is a vital part of the whole process of journey and it is depended on the quality of access mode. Hence the quality of the access mode may influence the demand of the public transport. For instance, walking distance and walking time is important factors to influence people whether or not to choose public transport. The straight-line distance from home to urban rail transit stations can also directly reflects the influence of urban rail transit and service areas around transit stations [64]. Therefore, it is in the best interest for the decision makers in the transportation sector to obtain information about the access mode behavior of travelers. On the other hand, measuring successful introduction of the access mode choice behavior is vital to improve the attractiveness of the service sector of public transport.

The study area is Colombo Metropolitan Area (CMA) in Sri Lanka. According to the experts in the transportation sector in Sri Lanka, the overall public transport system still remains at a primitive level [65]. For instance, the lack of a passenger transfer terminal at the Colombo Fort Railway Station causes severe inconvenience to passengers. This kind of poor facilities might be cause to damage the image of public transport and people tend to purchase private vehicles, hoping that this is the ultimate solution to their travel woes. Soon, the roads are clogged with private vehicles in urban areas with high traffic congestion [66].

The experts in the field of transportation in Sri Lanka identify that an efficient and modernized railway system covering most of the island be popularized, providing parking facilities for vehicles and easy access for buses, very pleasant environment with smart card, escalators, ticketing options and connecting buses and taxis are the vital supportive solutions for encouraging people to the

public transport in Sri Lanka [65], [66]. Thus the measuring behavioral model of access mode choice of the traveler is one method to make a way to provide an easy and better access method for public transport as well as it is an essential requirement for attracting to public transport. This study began a conversation to enhance the quality of traveling for public mode choice riders with concerning the access mode. Hence the objective of this section is to find the relationship between access mode choice and public mode choice by establishing a hypothesized model with statistical theory of Structural Equation Modeling (SEM) approach to increase the attractiveness of the public transport through concerning the experience of the traveler for the access mode choice behavior.

### 3.9.1 Methodology for model identification of the Access Mode to Public Mode

The part of the data collection of this study was completed through the same pre-formatted questionnaire survey with applying random sample technique.

The included criteria in the questionnaire can be divided into main three parts as previously mentioned (Figure 3.3), the first part is integrated about the social demographic characteristics of the subjects to gain the general view of their profiles, the second session is considered about the travel behavior of the subjects and the third part of the questionnaire is considered about the attitude and the perception of the traveler to choose the mode for traveling with including their access mode. Figure 3.12 depicts, the trip characteristic data variables which are some important variables that were considered for this analysis part. These data variables also were collected from a particular section of the same pre-formatted questionnaire. The structure of area residents' traveling pattern is illustrated in Figure 3.13. There are seven different travel modes defined under the category of private mode and two travel modes under the category of public mode. The travel mode of "Other" is included, private staff carry van, school van, taxi or other personal lorry, tractor which are being personally used for their regular trip purposes. To access the public transport, any other traveling modes which are mentioned in the figure that used as an access mode. In this figure, where the rectangles indicate the observable or manifest variables, and the ellipses indicate the unobservable or latent variables. For the public transport service, public bus and rail are considered in this area.

There were 422 subjects in the selected area responded and out of that sample population 10.9% of respondents were not making any trips. Remaining 88.1% of respondents made on their regular

trips for the purpose of work, education, business, shopping or recreational activities. 44.3% of respondents choose their mode as a public transport for their regular trip purposes. This analysis considered only the residents who choose public transport services and they are 44.3% of the sample population. It focused on Structural Equation Modeling (SME) technique by using AMOS 23.0 computer software package which provides an interface to create path diagrams of the analysis using drawing tools, rather than by writing equations or by typing commands [67].

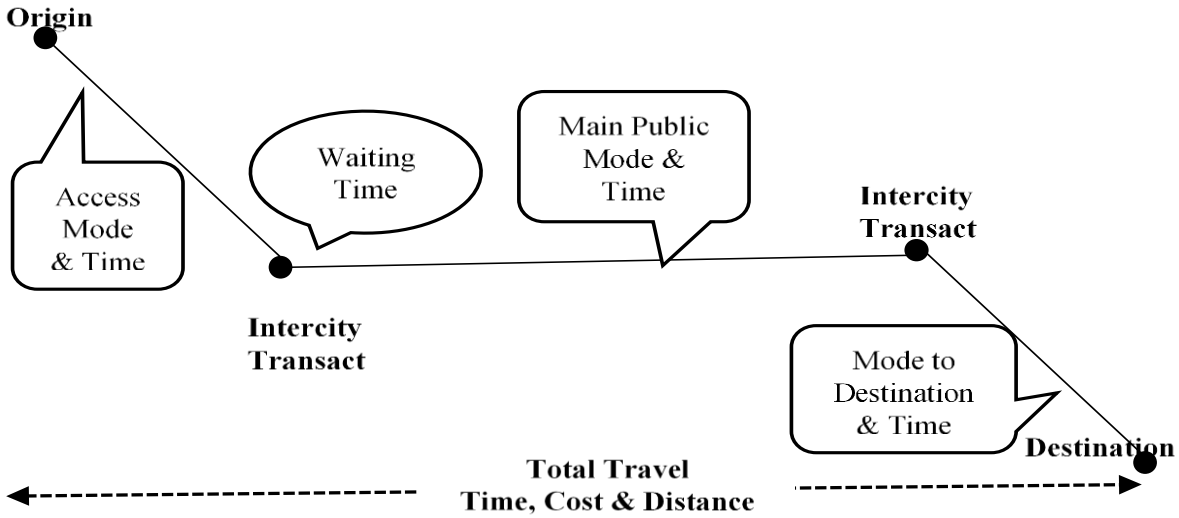


**Figure 3.12:** The Collected Data related to the Trip Characteristics

SEM is a model statement about a relationship between the variables with covariance. It is tests hypotheses about relationships between variables [68]. SEM analysis is often used by the researchers who are in the field of behavioral sciences. It is helpful in working to distinguish between latent variables that are exogenous and those that are endogenous. Latent variables are not observed directly but they are rather inferred (through a mathematical model) from other variables that are observed [69]. In other word, latent variables link observable data in the real world to symbolic data in the modeled world. For example, in this study, "Attitude & Perception towards to Mode" is a latent variable. Typically, SEM model communicates by drawing a picture of it and these pictures commonly name as Path Diagrams [70] which are simple mathematical representations of the proposed theoretical model [68].

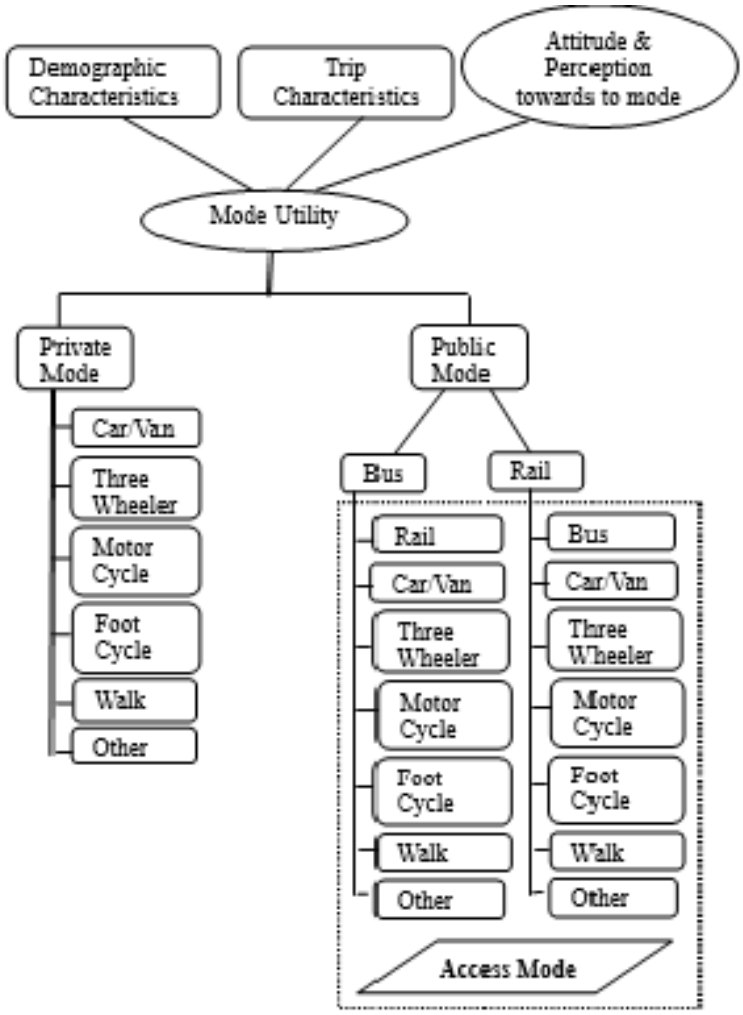


**Figure 3.13:** Structure of Resident's Traveling Pattern of the Area

Confirmatory Factor Analysis (CFA) with aspects of SEM was used in this analysis to test the proposed theoretical model. According to the knowledge with previous studies of this analysis, the structure of the latent variables and the observed variables was postulated a priori as shown in Figure 3.14. And then the hypothesized structure was tested statistically.

### 3.9.2 Model Development

This analysis mainly hypothesized that individuals decide on their public mode first and then on their access mode which implied that the access mode choice is affected by the public mode choice.

With the previous studies related to the mode choice analysis in same study area for the same sample population, it was easy to propose the structure of the model and to identify the latent variables with concerning the assumptions given below.

- There are really unobserved common dimensions that may be established to account for the correlations among observed variables.
- Main mode choice is responded by the first-order factors, namely Trip characteristics, Demographic and Attitude and one second—order factor is Access-Mode.
- Residuals are normally distributed and uncorrelated.
- There is a linear relationship between observed and predicted values of the dependent variable

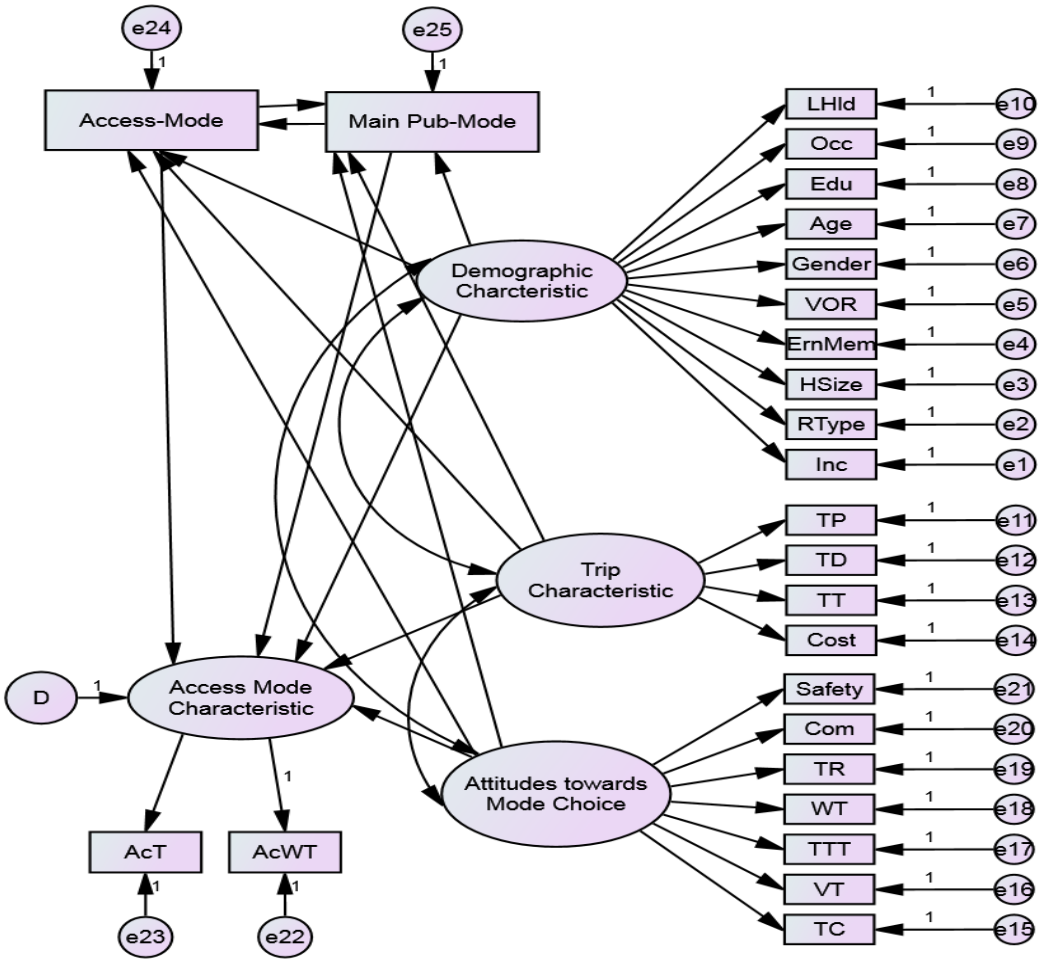


**Figure 3.14:** The First Hypothesized Model

**Table 3.14:** Description of the Variables

| Variable | Description | Category of range |
|---|---|---|
| Inc | Family Income | 1 if no any income, 2 if < Rs. 5000, 3 if Rs 5000-15000, , 4 if Rs 16000-30000, 5 if Rs 31000-50000, 6 if Rs 51000-75000, 7 if Rs 76000-100,000, 8 if >Rs 100,000 |
| RType | Residence Type | 1 if Own House, 2 if Rented House, 3 if Gvt.quarter, 4 if Apartment, 5 if Employer Provided, 6 if Other |
| HSize | Household Size | Numeral |
| ErnMem | Earning Members | Numeral |
| VOR | Vehicle Ownership | 1 if, none, 2 if Foot Cycle, 3 if, walk, 4 if Motor cycle, 5 if Three Wheeler, 6if Car/Van, 7 if other |
| Gender | Gender | 1 if Male, 2 if Female |
| Age | Age | 1 if <3, 2 if 4-15 years, 3 if 16-25 years, 4 if 26-35 years, , 5 if 36-45 years, , 6 if 46-55 years, 7 if > 56 years |
| Edu | Education | 1 if Elementary, 2 if intermediate, 3 if Diploma, 4 if Graduate, 5 if Post graduate, 6 if Doctoral, 7 if Post-Doctoral |
| Occ | Occupation | 1 if student, 2 if Gvt, officer, 3 if Pvt sector employee, 4 if Business owner, 5 if unemployed, 6 if other |
| LHld | License Holder | 1 if yes, 2 if No |
| TP | Trip Purpose | 1 if Work, 2 if Education, 3 if Business, 4 if Recreation, 5 if Shopping, 6 if other |
| TD | Trip Distance | 1 if < 1 Km, 2 if 2-4 Km, 3 if 5- 7 km, 4 if 8 -10 km, 5 If > 10 km |
| TT | Trip Time | 1 if < 15 min, 2 if 16- 30 min, 3 if 31 min-1 hr, 4 if 1-2 hrs, 5 if 2-3 hrs, 6 if > 3 hrs |
| Cost | Traveling Cost | 1 if none, 2 if < Rs 50, 3 if Rs 51-150, 4 if Rs 151-300, 5 if Rs 301-500, 6 if Rs501- 750, 7 if Rs 756- to 1000, 8 if> Rs 1000 |
| TC | Total Cost | 1 if Not Important |
| VT | Vehicle Travel | |
| TTT | Total Travel Time | 2 if Barely Important |
| WT | Waiting Time | |
| TR | Time Reliability | 3 if Important |
| Com | Comfort | |
| Safety | Safety | 4 if Very Important |
| AccessMod | Access Mode | 1 if, walk, 2 if Foot Cycle, 3 if, motor Cycle, 4 if Three Wheeler, 5 if Car/Van, 6 if public Bus, 7 if Train, 8 if other |
| AcT | Access Time | 1 if 0-5 min, 2 if 6-10 min, 3 if 11-15 min, 4 if 16-20 min, 5 if 21-25 min, 6 if 26-30 min, 7 if > 30 min |
| AcWT | Access Waiting Time | 1 if 0-5 min, 2 if 6-10 min, 3 if 11-15 min, 4 if 16-20 min, 5 if 21-25 min, 6 if 26-30 min, 7 if > 30 min |
| Main Pub_Mod | Main Public Mode | 6 if public Bus, 7 if Train |

This proposed hypothetical has four factors which are represented the ellipses and they are labeled as Trip Characteristic, Demographic, Attitude and Access Mode. The factor of Access Mode is act as a second-order factor. The first-order factors are inter-correlated as indicated by the two headed arrows. There are 25 observed variables which are represented by the rectangles and each variables loads only on one factor. Associated with each observed variable is an error term (err1–err25), and with the factor being predicted (Access Mode Characteristic), a residual term (D), there is an important distinction between the two.

Figure 3.14 depicts the proposed model that is a specific hypothesized model based on the hypothesis which says the access mode choice is affected by the public mode choice. The aim of this study is to test this hypothesis model with using CFA within the framework of SEM. Table 3.14 shows the explanation of the model variables.

### 3.9.3 Results for Model Development

The main target of this section is to find whether the access mode choice behavior of the traveler in the selected area is directly affected to the public transport mode choice behavior. Accordingly, the hypothesized model, which represents in Figure 3.14 was designed for this study. The main endogenous variables were Demographic characteristics, Trip characteristic of main public modes, Attitudes towards the mode choice and Access mode characteristic. These all endogenous variables were performed their relationship with two exogenous variables, which were Access_Mode and Main Pub_Mode.

With the path diagram was being analyzed, the output of the p values of standardized regression weight for several moral indicators were quite large than the conventional 0.05 level. Thus the factor of Demographic characteristic was divided into two factors, Demographic _ Family Characteristic and Demographic _ Personal Characteristic while the factor of Attitudes towards mode choice was divided in to two factors, Attitude toward Time & Cost and Attitude toward Safety & Comfort.

**Table 3.15:** Parameter Summary

| | **Weights** | **Covariance** | **Variances** | **Means** | **Intercepts** | **Total** |
|---|---|---|---|---|---|---|
| **Fixed** | 26 | 0 | 0 | 0 | 0 | 26 |
| **Labeled** | 0 | 0 | 0 | 0 | 0 | 0 |
| **Unlabeled** | 20 | 8 | 25 | 0 | 19 | 72 |
| **Total** | 46 | 8 | 25 | 0 | 19 | 98 |

Figure 3.15 shows the final model with the standardized regression weights (factor loadings) for the common factor and each of the indicators. The squared multiple correlation coefficients ($R^2$) are describing the amount of variance the common factor accounts for in the observed variables, are also displayed. The model with 137 degrees of freedom (Degrees of Freedom = No. of distinct sample moments (209) – No. of distinct parameters to be estimated (72) = 137). The minimum calculated by the maximum likelihood method was achieved; thereby assuring that the estimation process yielded an admissible solution with the chi-square ($\chi^2$) value of 523.910 together with its degrees of freedom of 192 and probability value of 0.000. Hence, the null hypothesis that the model is a good fit to the data is easily rejected and it implies that a good modal fit**.**

Table 3.15 depicts the parameter summary of the model. There are 46 regression weight 26 of which are fixed and 19 of them are estimated. There are 8 correlations and 25 variances that freely estimated. In total from 98 parameters, 72 parameters are freely estimated.

The appropriateness of the model describes with various indices as shown in Table 3.17, CMINDF is the value of chi-square divided by its degrees of freedom. This value is 3.79 and it is in the acceptable range (1.0 to 5.0) for this model fit.

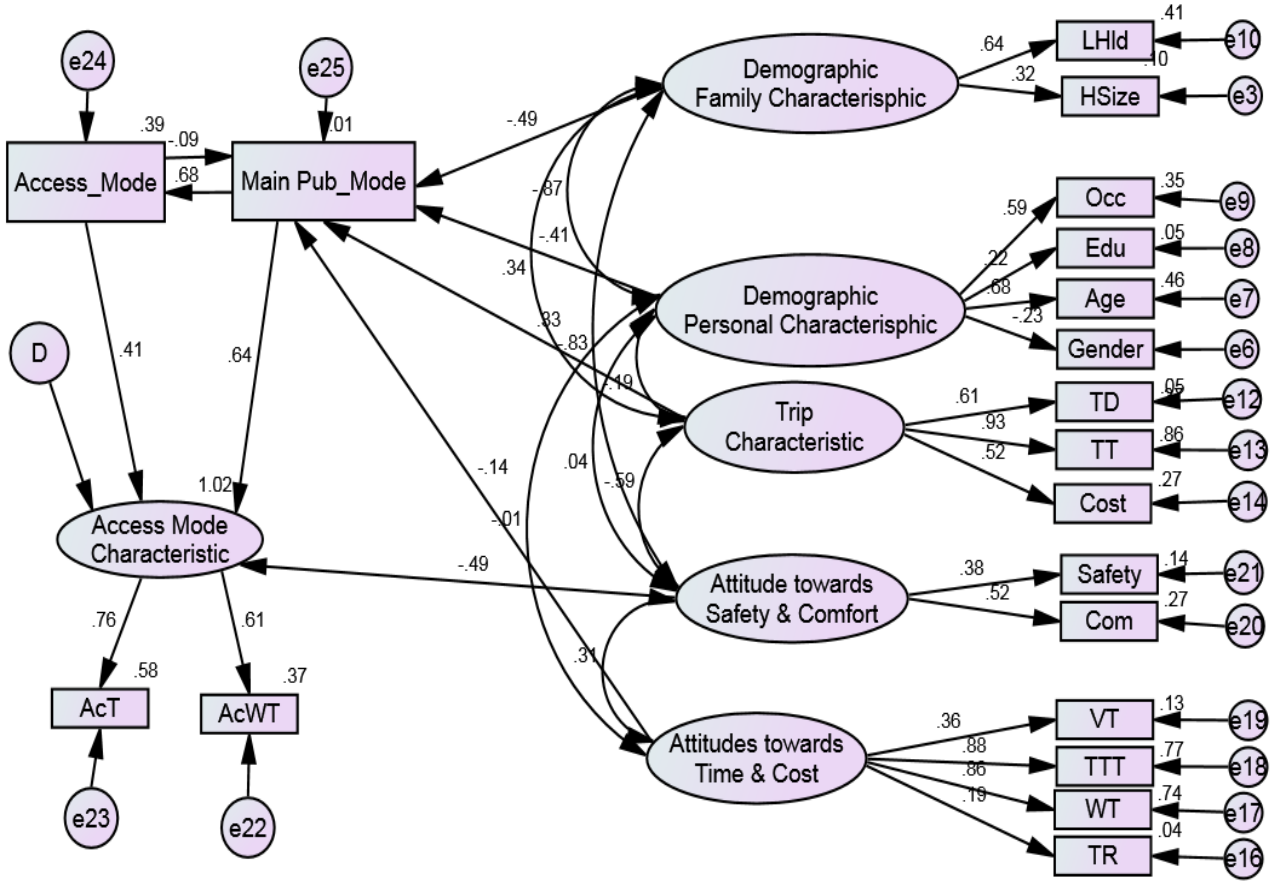


**Figure 3.15:** Final Hypothesized Model with Standardized Model Estimates

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NFI [Normed Fit Index] shows how far between the (terribly fitting) independence model and the (perfectly fitting) saturated model is [71]. In this case NFI value is 0.617 indicating that the model is 62% better fitting than the null (Independence) model. RFI [Relative Fit Index] is the NFI standardized based on the df of the models. Also IFI [Incremental Fit Index], TLI [Tucker-Lewis Coefficient], and CFI [Comparative Fit Index] are act same as RFI and values of those indices are in the acceptable range represents the quite well fit of the model. Acceptable range for these indexes should be within the range of zero to one [71].

Under the Regression Weight in Table 3.16 heading the unstandardized loading appear along with Standard Errors (SE). Critical Ratio (CR) and p value. All of the table values for the unconstrained estimates without only one variable (Access_Mode to Main Pub_Mode) are reasonable and statistically significance since the CR values are greater than 1.96 in the table

**Table 3.16**: Summary of Regression Weight

| | | | Estimate | S.E. | C.R. | P |
|---|---|---|---|---|---|---|
| Main Pub_ Mode | <--- | Trip Char | .122 | .048 | 2.538 | * |
| Main Pub_ Mode | <--- | Demographic_Personal | -.168 | .088 | -1.917 | * |
| Main Pub_ Mode | <--- | Demographic_Family | -.481 | .236 | -2.043 | * |
| Access Mode Char | <--- | Attitude towards Time & Cost | -.624 | .128 | -4.894 | *** |
| Access Mode Char | <--- | Access_Mode | .131 | .027 | 4.897 | *** |
| Access Mode Char | <--- | Main Pub_ Mode | .932 | .145 | 6.413 | *** |
| Gender | <--- | Demographic_Personal | -.123 | .048 | -2.550 | * |
| Age | <--- | Demographic_Personal | 1.000 | | | |
| Edu | <--- | Demographic_Personal | .235 | .100 | 2.362 | * |
| Occ | <--- | Demographic_Personal | .868 | .166 | 5.214 | *** |
| TD | <--- | Trip Char | .722 | .104 | 6.959 | *** |
| TT | <--- | Trip Char | 1.000 | | | |
| Cost | <--- | Trip Char | .427 | .069 | 6.189 | *** |
| Com | <--- | Attitude towards Safety & | 1.000 | | | |
| Safety | <--- | Attitude towards Safety & | .655 | .163 | 4.025 | *** |
| AcWT | <--- | Access Mode Char | 1.000 | | | |
| AcT | <--- | Access Mode Char | 3.170 | .367 | 8.637 | *** |
| VT | <--- | Attitude towards Time & Cost | .331 | .072 | 4.603 | *** |
| TTT | <--- | Attitude towards Time & Cost | 1.000 | | | |
| WT | <--- | Attitude towards Time & Cost | .948 | .116 | 8.149 | *** |
| TR | <--- | Attitude towards Time & Cost | .208 | .087 | 2.404 | * |
| HSize | <--- | Demographic_Personal | 1.000 | | | |
| LHld | <--- | Demographic_Personal | .802 | .207 | 3.870 | *** |
| Main Pub_ Mode | <--- | Access_Mode | -.020 | .071 | -.276 | .783 |
| Access_Mode | <--- | Main Pub_ Mode | 3.100 | .852 | 3.639 | *** |

*<0.05, **<0.01, ***<0.001

The standard errors also in a considerable order. In this table shows that on the equation of access mode choice, the public mode variable has a positive significant coefficient (3.001). But the main interest is on the public mode choice equation, the access mode choice equation has a negative significant coefficient (-0.020) and CR value also less than 1.96 and *p* value is greater than 0.05. It implies that the decision of access mode choice is affected by their public mode choice and traveler more likely to make their decision on public mode choice prior to make the decision on access mode choice.

In addition to that demographic characteristics related to personal and family, main trip characteristic and the attitudes towards the time and cost, safety and comfortable are important determinants of mode choice since CR values for all variables of that factors are greater than 1.9 and *p* values are also significant. There were two variables (RType and FInc) which belonged to the factor of "Demographic Characteristic_Family" that removed from the model of Figure 3.14 as these variables were not significant. It is implying that the residence type and the family income are not much affected to the decision of their mode choice. The variable of TC (Total Cost) of the factor of "Attitudes towards Time & Cost" was not significant and that should be removed from the model inferring that the traveler is not thinking much about the total cost of their journey when choosing the access mode for traveling. These indicate that a traveler considers being on total travel time, vehicle travel time waiting time for the mode, comfort and safety of the access mode rather the travel cost.

## 3.10 Chapter Summary

This chapter discussed about the background of the mode choice behavior and its theoretical background, the current studies that researchers are focusing about the mode choice behavior analysis and data collection procedure in the study area. Afterward this chapter mainly focused about three parts; factors influencing to select the traveling modes of public modes and private modes. Probability tendency model for choosing public transport and finally the impact of access mode choice selection for the public mode choice were analyzed.

The section of factors influencing to mode choice can be identified that the public transport mode choice is affected by several factors. One of the factors is earning capacity when selecting public bus.

**Table 3.17**: Summary of the Model Fit

| Fit Measure | Model | Saturated | Macro |
|---|---|---|---|
| Discrepancy (Chi-Square) | 523.9 | .000 | CMIN |
| Degrees of freedom | 137 | 0 | DF |
| P | .000 | | P |
| Number of parameters | 72 | 209 | NPAR |
| Discrepancy / df | 3.824 | | CMINDF |
| Normed fit index | .617 | 1.000 | NFI |
| Relative fit index | .522 | | RFI |
| Incremental fit index | .686 | 1.000 | IFI |
| Tucker-Lewis index | .597 | 1.000 | TLI |
| Comparative fit | .677 | 1.000 | CFI |
| Parsimony ratio | .801 | .000 | PRATIO |
| Parsimony-adjusted NFI | .494 | .000 | PNFI |
| Parsimony-adjusted CFI | .542 | .000 | PCFI |
| Noncentrality parameter estimate | 386.9 | .000 | NCP |
| NCP lower bound | 320.4 | .000 | NCPLO |
| NCP upper bound | 460.9 | .000 | NCPHI |
| FMIN | 2.817 | .000 | FMIN |
| F0 | 2.080 | .000 | F0 |
| F0 lower bound | 1.723 | .000 | F0LO |
| F0 upper bound | 2.478 | .000 | F0HI |
| RMSEA | .123 | | RMSEA |
| RMSEA lower bound | .112 | | RMSEALO |
| RMSEA upper bound | .134 | | RMSEAHI |
| P for test of close fit | .000 | | PCLOSE |
| Akaike information criterion | 667.9 | 418.0 | AIC |
| Browne-Cudeck | 685.2 | 468.3 | BCC |
| Expected cross validation index | 3.591 | 2.247 | ECVI |
| ECVI lower bound | 3.224 | 2.247 | ECVILO |
| ECVI upper bound | 3.989 | 2.247 | ECVIHI |
| MECVI | 3.684 | 2.518 | MECVI |
| Hoelter .05 index | 59 | | HFIVE |
| Hoelter .01 index | 64 | | HONE |

Normally peoples who have low income level, use the public mode. Some peoples who do not have their own vehicle and particularly female are traveling by bus. Young people greatly use the public transport for education purposes. For logistic regression, it is emphasized and prove that the earning capacity, vehicle ownership, gender, age, education, occupation, trip characteristics and safety are highly affected to the public transport mode choice and the formatted model can be predicted the travel behavior of wide variety of people and their mode choice as a probability with these significant factors. The model accuracy is 78.4%. This model is a better model as the sum of squared error or the Likelihood of the Binary Logistic value was reduced from 514.313 to 348.134.

The last section was aimed to establish a model to assess the affection of access mode choice behavior to the public transport mode. For the model development, SEM mode approach was run. The developed model shows that the access mode choice is affected to the public mode choice. First select the public mode and then select the access mode for the journey. Hence improving access mode facilities is one critical point to increase the attractiveness of the traveler for the public transport.

# CHAPTER 4

# Assessment of Road Accident and Safety Facilities

## 4.1 Background of the Road Safety

### 4.1.1 Road Safety on the World

"Over 1.2 million people die each year on the world's roads, and between 20 and 50 million suffer non-fatal injuries" [72] and continues increase the rate of road accidents. Low-income and middle-income countries have high number of road fatality accidents (over 90%) rather than high-income countries. Road traffic accident rates for the low-income and middle-income countries are 21.5 and 19.5 per 100,000 populations respectively. But that rate for the high-income countries is 10.3per 100,000 populations. World Health Organization (WHO) predicts that the road traffic accidents will be the 5$^{th}$ leading reason to death by 2030. But according to the data in 2004, the reason of road accident was in the 9$^{th}$ place implies that the road traffic accidents are increasing rapidly [72].

Most road fatalities in the high-income countries occur for car owners while majority of road fatalities from pedestrian, cyclist, moped and motor cycle riders in low-income and middle-income countries. Roughly 1% of cost for road traffic injuries is estimated of Gross National Production (GNP) of low-income countries while it is 1.5% for middle -income countries and 2% for high-income countries [73].

Lack of attention for the road safety and traffic injuries at the level of international and local, is an undesirable problem to increase the rate of road accident in the world. On the other hand, no one or no any agency is responsible for the road accidents and fatalities as a whole at any country. If there is a particular department or agency that responsible for the road safety and traffic crashes, they can get the decision with the aspects of the design of the road network, rural/urban transport planning and even the design of the vehicles with concerning to reduce the road traffic crashes and safety facilities [73].

### 4.1.2 Road Safety and Public Transport

Vehicle population and the pattern of traffic crashes on road are very different in the less motorized Asia countries when comparing to high motorized countries. Public buses are a significant mode that involve for a considerable rate of crashes due to very crowded situation inside the buses. Sometimes peoples knock and die when they are travelling on footboard and on the roof of the buses [74]. P.S. Kharola, Geetam and Dinesh have analyzed road crash involvement with related to the public buses in India and identified the major factors of such crashes. They came to a solution that should be changed the interior design of the bus with low floors, automatically-closing doors and safer bus fronts as well as increased the infrastructure facilities to pedestrians and bicycle riders to reduce the road crashes [75]. These solutions were originated from the research to Indian public transportation sector. The transportation sector in India, Sri Lanka and other south Asian countries is fairly similar and thus reviewing the solution and decision of the related research that are aided for this study as well.

Lidia P. Kostyniuk has analyzed about the pupil fatalities on public transit buses and private school buses as a comparison and found that the rate of pupil fatality on public transit buses are larger than the private school buses [76]. Donald Katz and Laurie A. Garrow have analyzed how bus design factors influence door crowding and quantifies how door crowding is affected to the operational performance and passenger safety in Dhaka, Bangladesh and they found multiple bus design factors of bus design are affected to the door crowding and identified the importance of educating conductors about door crowding [77]. Public buses and rail trains in middle-low income countries are fully crowded specially in the peak hours as majority of inhabitants in such kind of countries are depended on the public transports. Public transport accidents in both Nepal and Zimbabwe countries also appear to be involved in a high rate. According to the Transport Research Laboratory (TRL), poor driver behavior, pedestrian/other road user behavior and mechanical condition of bus are the main reasons for public bus accidents in developing countries [78].

### 4.1.3 Pedestrian Safety with Public Transport

A term "'pedestrian' is a person on foot, or in or on a contrivance equipped with wheels or revolving runners that is not a vehicle" The pedestrians have been categorized into three ways, on foot, on small wheels and mobility impaired [79]. The majority of pedestrians go by foot to access

the other mode such as walking from a parked car or walking to and from public transport, shopping or social and recreational activities [80]. Particularly in developing countries, majority of pedestrians are walking for a public transport. According to WHO, almost half of the world's annual road traffic fatalities of approximately 1.3 million people are pedestrians, cyclists, and motorcyclists, and more than 90% occur in developing countries [72]. Figure 4.1 shows around 22% of all road fatalities from pedestrians in the world. In region wise distribution of pedestrian fatalities are high in African region (38%) and lowest in the South East Asian region (12%) [81].

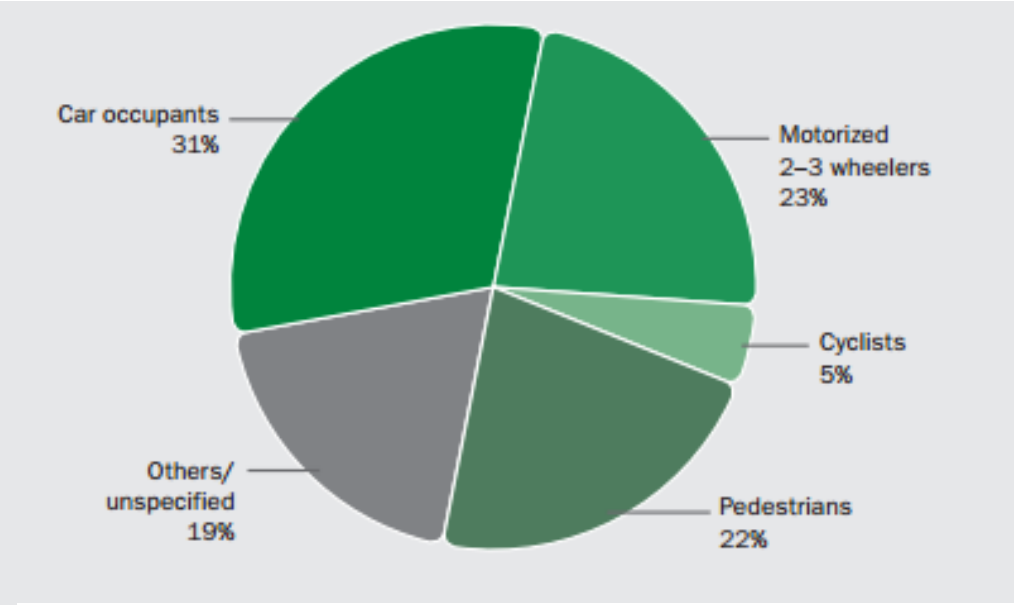



**Figure 4.1:** Distribution of road traffic deaths by type of road user, global, 2010

*Source: WHO, 2012*

Action to increase the safety of pedestrian can be divided as to Engineering Action and Education and Enforcement Action. Through the engineering action, the following action can be conducted to increase the pedestrian safety [80];

a. Sidewalk Design

   A separate place at the road ways that the pedestrian can walk. It is very important to build appropriately with considering right width, surface and separating from main road in order to increase the safety for pedestrians.

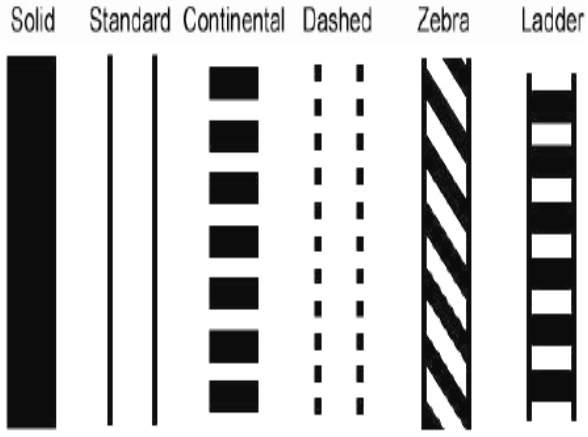
*Example for a sidewalk that pedestrians are safer and more comfort with separating trees and other*

*A narrow sidewalk that space is not enough for pedestrians*

*Source: US Dept, 2008*

b. Road way crossing

Pedestrian should have to cross the roads and thus to increase the safety for pedestrians, it should be installed a designated place to cross the roads. When some places are complicated for both drivers and pedestrians such as signalized/ non signalized intersections, rounder bounds etc., the road design must be created carefully to ensure the safety for pedestrians. For example, introducing curb extension, waiting island at the right places, drawing more visualized crossing lines, installing traffic signals and pedestrian warning symbols etc.




*Types of crossing lines*

*An example for a curb ramp*

*An example for a refuge waiting island*


*A high intensity activated cross walk*

*Pedestrian Signal with Animated Eye*

*Right-turn Slip Lane*

*Source: US Dept. of Transportation*

c. Pedestrian crossing of railway system

Pedestrian need to cross from time to time railroad or light rail tracks. Introducing a warning system before crossing those places is vital since the result of the crashes on a train is very critical. There are several safety actions in the places of railway crossing such as introducing pole gates, flashes or bells as a warning to inform for the pedestrians about the coming of train, installing fens to discourage pedestrian to cross the rail track etc. Using tunnel to cross the road for pedestrian is another example for safety action for railway crossing [80].


*Examples for Pole, flashing light and road design for crossing*

*Source: Australian Railway Association,2014*


*Road design and fence, at the* railway *crossing*

*Source: Track Safe Foundation, Newzealand,2014*

d. Bicycle Consideration

Bicycle riders may safe when they have a separate path for riding without car, trucks and other vehicles on their path. But bicycle riding must not be impended for pedestrians. Thus bicycle lanes should be installed separately with sidewalk at road.

*A well-designed bicycle pathway separated from the motorized road*

Source: Institute for Transportation and Development Policy, India, 2016

e. Transit vehicle design

   Safety of the pedestrian can be increased by designing the transit vehicle with several technologies such as introducing front break light which are indicated to the pedestrian when bus stops or moves and using strobe light on top of the buses to get the attention of pedestrian when buses reach to the bus stop and an alarm rigging when pedestrian or objects are closing to the bus etc.

f. Transit stop location design on top of the business

   Pedestrian stops or wait locations are vital with the aspect of safety. Design a proper way of that places specially bus stops are very important. For instants, bus stops should be installed with concerning to minimize the total walking distance and closer to the road crossing areas and bus stop should be designed in a comfortable way with enough space for waiting as well as that waiting places should be cleaned without dirt or grass etc. [80].

The other important actions for the pedestrian safety are the education and enforcement action. As an instance, as an enforcement activity, traffic police officers can be trained the bicycle riders and pedestrian about the safety of their riding or walking. District of Colombia Police officers handed out over 2500 citations and distributed more than 9.000 safety hand leaflets [80].

## 4.2 Road Safety in Sri Lanka

Sri Lanka is a developing country where road accident is a main social problem. Approximately 1 in 50 deaths is due to a road accident. In 2002, over 1000 accidents per week with 5 to 6 people killed every day. The economic cost of these account was over Rs 10,000 million annually. That was 1% of GDP of Sri Lanka. Even this is a threat to the country, the information and strategic plans with analytical approaches are less in the country. Particularly, the largest share (59%) of the road accidents occur in the western province of Sri Lanka [82] that depicts in Figure 4.2.

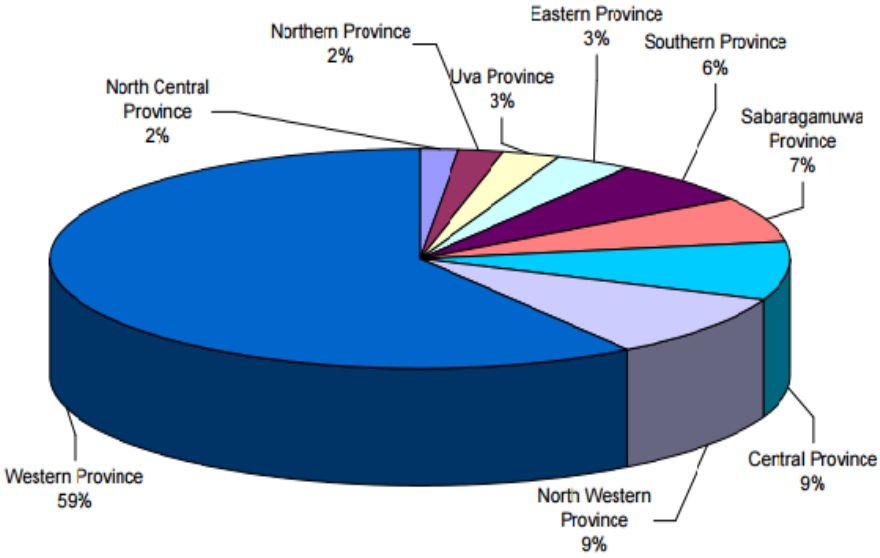



**Figure 4.2:** Percentage of Road Accident by Province

*Source: Report on Analysis of Road Accident in Sri Lanka, 2002*

The main reasons are, rapid increase in the amount of travel, switching from the safer mode of public transport mode to unsafe modes such as motor cycle, three wheelers etc., violation of road rules and less punishment for the violation, poor road design, lack of safety interventions and poor maintenance program [82].

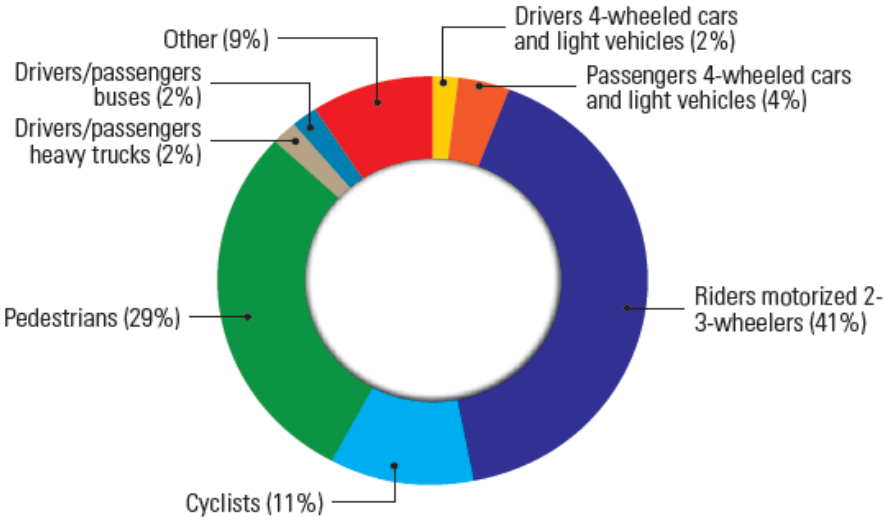



**Figure 4.3:** Death by Road User Category

*Source: Sri Lanka Police Accident Database, 2013*

Figure 4.3 shows that the 2 tal road accident in Sri Lanka and then the next considerable amount of deaths from the road accidents are come from the category of Pedestrians [83]. The 29% of fatal accidents from the category of

Pedestrians, but including non-fatal accident, the pedestrian accidents come to the highest place of road accidents in Sri Lanka.

According to the WHO, the figure 4.4 depicts road traffic crashes per 100,000 populations in between 1938 to 2013. Even through, the overall road crashes have increased a threefold from 61.2 crash rate in 1938 to 183.6 crash rate in 2013, it was not continuously increased in between 75 years. Traffic crashes gradually increased by 180% in 1935 to 1955 but from 1955 to 1974, it decreased by 36%. Again, it increased by 185% in between 1974 to 2003. In 2003 to 2007, again crash occurrences decreased by 49%. The highest increase was in 2003 at 310.7 crashes per 100,000 populations [84].

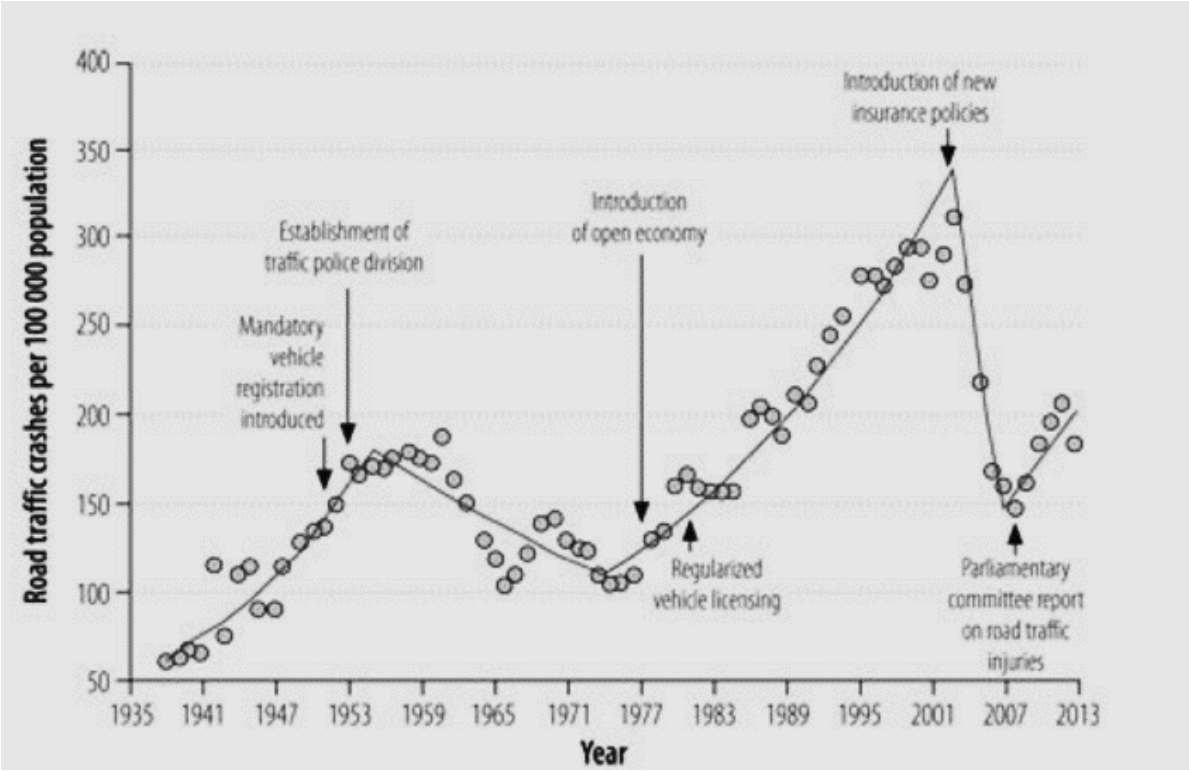



**Figure 4.4:** Trend in Road Traffic Accident

*Source: Sri Lanka Police Accident Database & Dept. of Census & Statistic*

### 4.2.1 Comparison between Sri Lankan Road Safety with other Countries

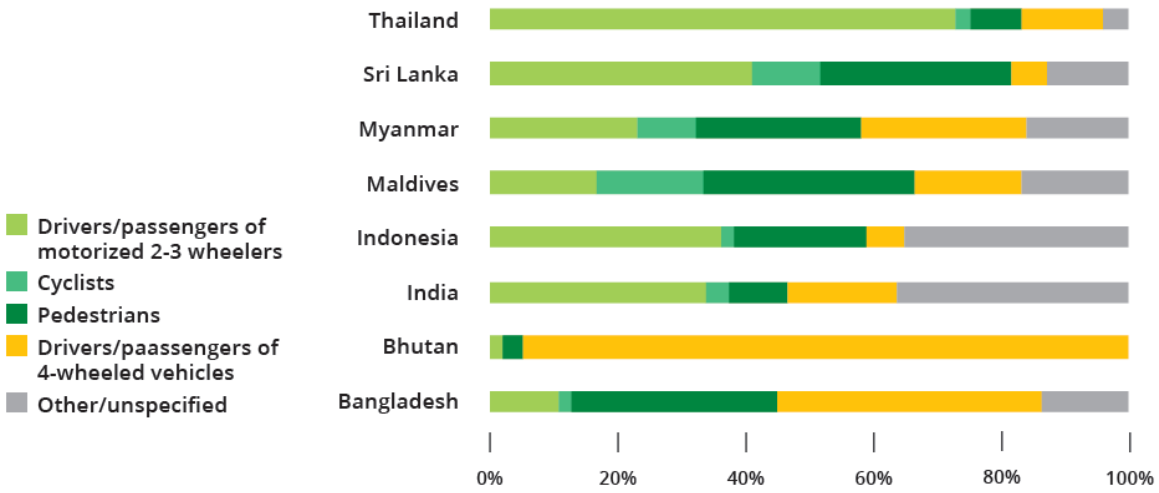



**Figure 4.5:** Distribution of road traffic deaths by type of road user

*Source: Road Safety in the South-East Asia region, 2015*

When comparing South East Asian countries, Figure 4.5 shows that the pedestrian accidents and 2-3 wheelers accidents are the significant type of accident occurrences in Sri Lanka, Bangladesh and Maldives. In Butan, the car occupants are highly face for the road accidents while around 83% of road accidents occur for the users of 2 to 3 wheeler vehicles.

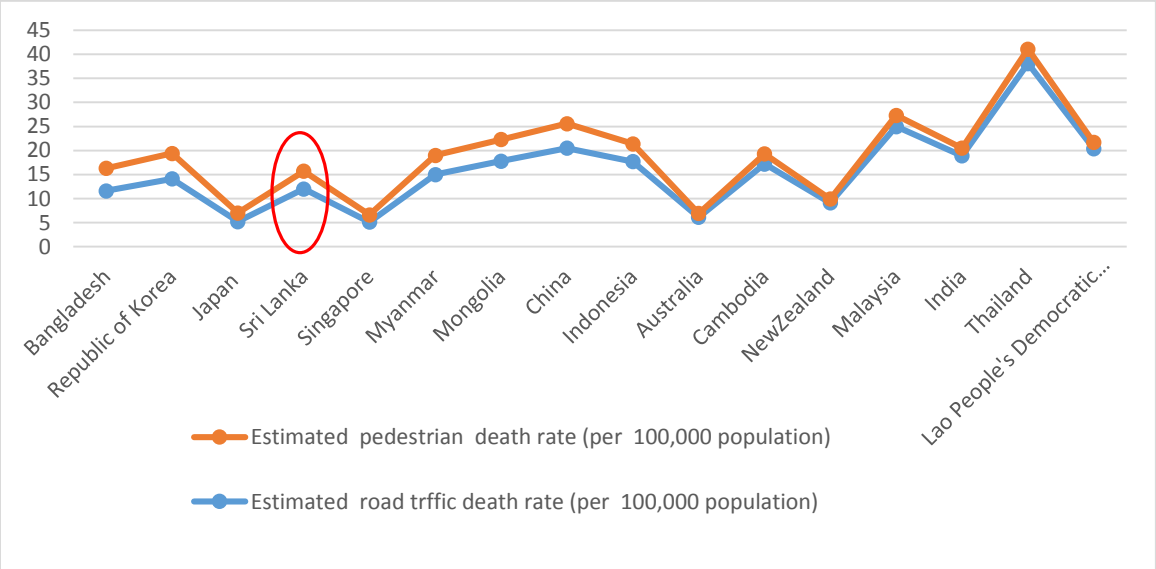



**Figure 4.6:** Estimated Pedestrian Death Rate and Road Traffic Death Rate with Population

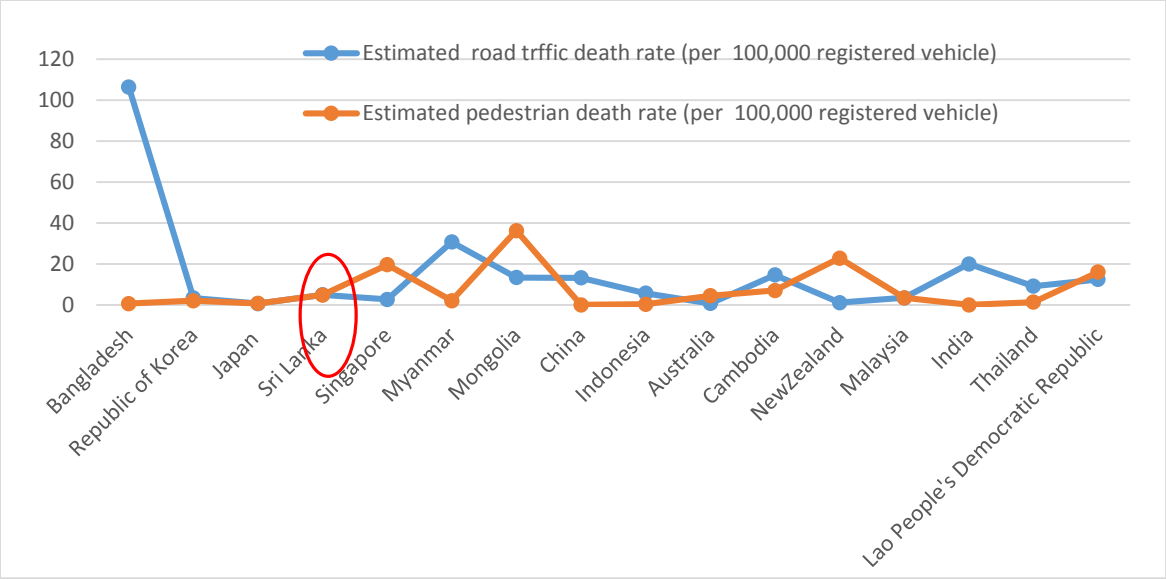



**Figure 4.7:** Estimated Pedestrian Death Rate and Road Traffic Death Rate with Registered Vehicle

Figure 4.6 and Figure 4.7 show the traffic accidents and pedestrian accident details of the western pacific and south east Asian countries which have a population of more than one million. There are sixteen countries are compared in these figures. In Sri Lanka, the number of road traffic fatalities per population and per registered vehicle is not so high when comparing other selected countries. However, rate for pedestrian fatalities per population and per registered vehicle is significantly high and ranked 6$^{th}$ for each. The pedestrian fatalities are ranked in the top four out of all traffic fatalities [12].

Road fatal accident per 100,000 inhabitances in 2013 versus average percentage change in road traffic fatalities in 2012 to 2013 for the countries of Argentina (Arg), Australia (Aug), Austria (Aut), Belgium (Bel), Canada (Can), Chile (Ch), Czech Republic (Cze), Denmark (Den), Finland (Fin), France (Fra), Germany (Ger), Greece (Gre), Hungary (Hun), Iceland (Ice), Ireland (Ire), Israel (Isr), Italy (Ita), Japan (Jap), Korea (Kor), Lithuania (Lith), Luxembour (Lux), Netherland (Net), New Zealand (New), Norway (Nor), Poland (Pol), Portugal (Por), Slovenia (Slo), Spain (Spa), Sri Lanka (Sri), United Kingdom (UK) and United States (US) are shown in Figure 4.8. This figure has been drawn based on the data from the annual report of Road Safety in 2015 by the International Traffic Safety Data and Analysis Group (IRTDA) and the data from the Department of Census and Statistics in Sri Lanka.

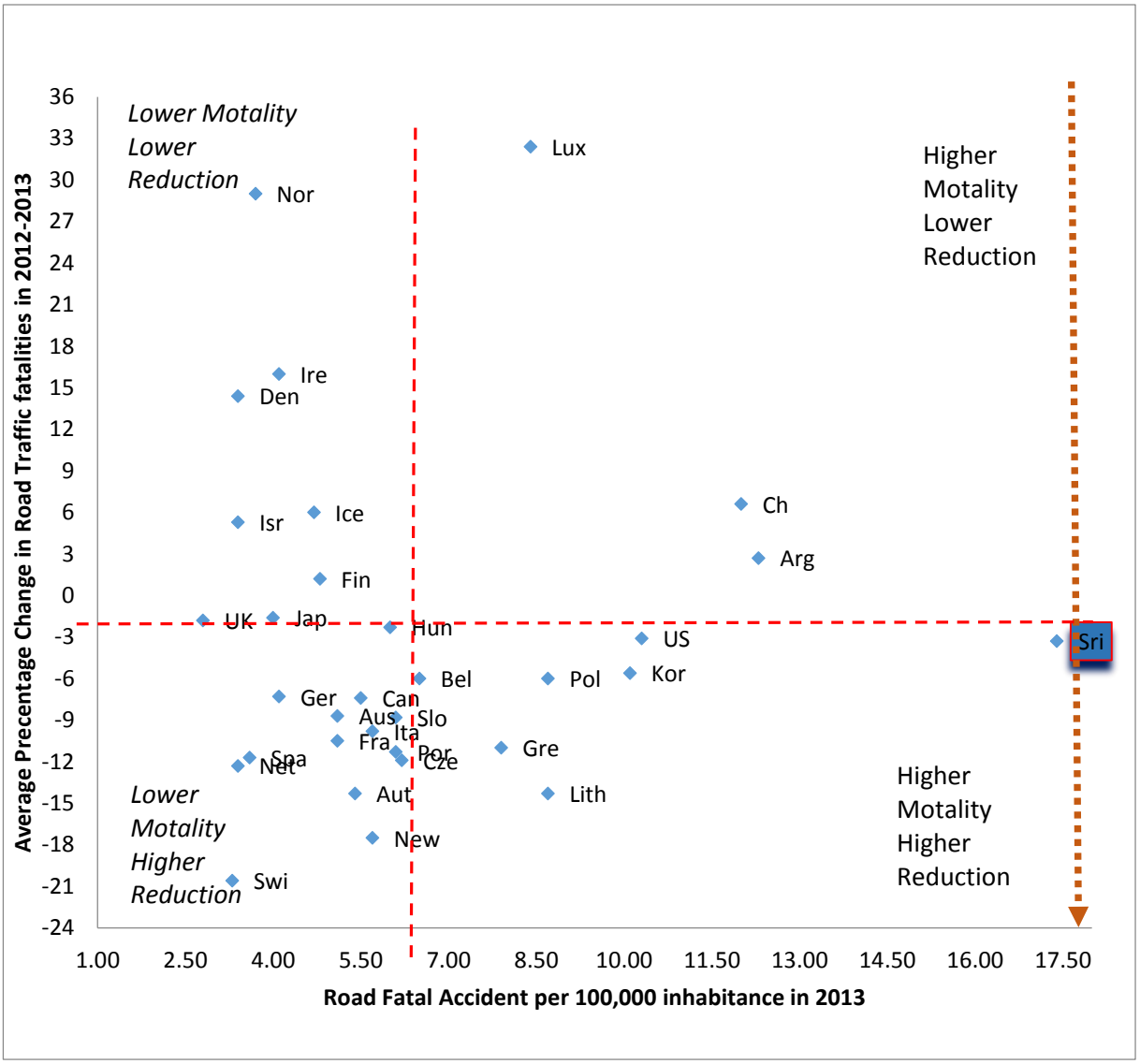



**Figure 4.8:** Fatality rate per 100,000 Population in each Country in 2013 versus the Average Percentage Change in Road Traffic Fatalities in the Year of 2012-2013

According to this figure, Sri Lanka is included to the category of "Higher Mortality and Higher Reduction of fatal Accidents". United States, Belgium, Poland, Korea, Greece and Lithuania are also included to this category, but Sri Lanka had the highest number of fatal accidents when comparing with other countries. On the other hand, even Sri Lanka was included to the category of higher reduction of fatal accidents, that reduction rate was at the margin of the average reduction

rate and it was the lowest rate when comparing with other countries in the same category [85], [86].

The previous studies of traffic accidents in the world and Sri Lanka imply the importance of the analysis of road accidents for the development of a country. However, the previous chapter also discussed the road safety is a main considerable factor when they travel in their regular purposes. Hence the one of the objectives of this research is to assess the road crashes and explore the significant points for the development of public transport.

## 4.3 Data Collection

The study area is the entire Western Province of Sri Lanka. The traffic accident data set was collected from the Traffic Police Division in the Western Province. The data set is included information of road accidents within the period of 2010-2014. These data should be filled out with a pre-designed form by a police officer for every accident which occurred on the road. The data set is included 99,558 traffic accidents. The data set consists a rich source of information in different three ways named as Attendance Circumstances (Number of vehicles, time, road surface, weather condition, road number….), Casualty Details (Casualty gender, age, severity…… ) and Vehicle Details ( Vehicle type, ownership, age of the vehicle……..). Table 4.1 gives the detail description about the data variables for the main three categories.

**Table 4.1:** Description of the Accident Data

| Category | Variables | Variable Range |
|---|---|---|
| Attendance Circumstances | No. of Vehicles | Numeral |
| | No. of Casualties | Numeral |
| | Divisional Secretariat Division | Text |
| | Station Number | Numeral |
| | Class of Accident | 1- Fatal, 2-Grievous ,3-Non-Grievous, 4-Damage only |
| | Urban/Rural | 1-Urban, 2-Rural |
| | Workday/Holiday | 1-Normal working day,2-Normal weekend, 3-Public holiday, 4-Festive day, 5-Election day or May 1st |
| | Day of the week | 1-Sunday, 2-Monday, 3-Tuesday, 4-Wednesday, 4-Thursday, 5-Friday, 6-Saturday |
| | Road number/ Street number | Numeral |
| | Nearest lower Km post | Numeral |
| | Distance from nearest, lower Km post in meters | Numeral |
| | East/North Coordination | Numeral |
| | Collision Type | Sketch Diagram of the accident |

| | | |
|---|---|---|
| | Second collision type | 1-With other vehicle, 2-With pedestrian, 3-With fixed object, 9-Others, 0-Not known |
| | Road surface | 1-Dry, 2-Wet, 3-Flooded with water, 4-Slippery surface (mud, oil, garbage, leaves), 9-Others, 0-Not known |
| | Weather Condition | 1-Clear, 2-Cloudy, 2-Rain, 3-Fog/Mist, 9-Others, 0-Not known |
| | Lighting Condition | 1-Daylight, 2-Night, no street lighting, 3-Dusk, dawn,4-Night, improper street lighting, 5-Night, good street lighting, 9- Other, 0-Not known |
| | Location Type | 1-Stretch of road, no junction within 10m, 2-Four leg junction, 3-T-junction, 4-Y-junction, 5-Roundabout, 6-Multiple road junction, 7-Entrance, by-road, 8-Railroad crossing, 9-Others, 10-Not known |
| | Pedestrian Location | 1-On pedestrian crossing,2-Pedestrian crossing within 50m, 3-Pedestrian crossing beyond 50m, 4-Pedestrian over pass bridge or under pass tunnel within 50m, 5-Hit outside sidewalk, 6-Hit on sidewalk, 7-Hit on road without sidewalk, 9-Other, 0-Not known |
| | Traffic Condition | 1-Police, 2-Traffic light, 3-Stop sign/ marking, 4-Give way sign/ marking, 5-Controlled by traffic warden, 6-No control, 9-Other, 0-Not known |
| | Posted Speed Limit Sign | 1-Yes, 2-No |
| | Speed Limit light vehicle/ Heavy vehicle | Numeral |
| Causality Details | Severity | 1-Fatal, 2-Grievous, 3-Non-grievous |
| | Category | 1-Driver/Rider, 2-Pedestrian, 3-Passenger/ pillion rider, 4-Passenger/ pillion rider falling off vehicle, 5-Passenger entering or leaving bus, 0-Not known |
| | Sex | 1-Male, 2-Female, 3-Not known |
| | Protection | 1-Safety belt, worn, 2-Safety belt, not worn, 3-Helmet, worn, 4-Helmet, not worn, 5-Child restrain seat used, 0-Not known |
| | Hospitalized | 1-Injured and admitted to hospital at least 1 day, 2-Injured but not admitted to hospital or admitted less than 1 day |
| Vehicle Details | Vehicle Type | 1-Car, 2-Dual purpose vehicle, 3-Lorry, 4-Cycle, 5-Motor cycle, moped, 6-Three wheeler, 7-Articulated vehicle, prime mover, 8-SLTB bus, 9-Private bus, 10-Intercity bus, 11-Land vehicle tractor, 12-Animal drawn vehicle or rider on animal, 13- |
| | Vehicle ownership | 1-Private vehicle, 2-Private company own vehicle, 3-Government vehicle, 4-Semi-Government vehicle, 5-Service vehicle, 6-Police vehicle, 0-Not known |
| | Driver/Rider/Pedestrian Sex | 1-Male, 2-Female, 3-Not known |

| | | |
|---|---|---|
| | Validity of Driving license | 1-Valid license for the vehicle, 2-Without valid license for the vehicle, 3-Leaner permit, 4-Probation license, 5-International license, 0-Not known |
| | Human pre-crash factors | 1-Speeding, 2-Aggressive/ negligent driving, 3-Error of judgement, 4-Influenced by alcohol/drugs, 5-Fatigue/fall asleep, 6-Distracted/inattentiveness (handling radio, |
| | Pedestrian pre-crash factor | 1-Unexpected pedestrian movement, 2-Disobey designated crossing, 3-Influenced by alcohol /drugs, 4-Poor visibility, 9-Other, 0-Not known |
| | Road pre-crash factor | 1-Defective road surface, slippery road, pot holes, water puddles, large cracks, high or low sewer covers etc., 2-Defective, absent or badly maintained road markings or sign, 3-Road works without adequate traffic control devices, 4-Weather |
| | Vehicle pre-crash factor | 1-Brakes, 2-Tyres, wheels, 3-Steering, 4-Lights, lamps, 5-Poor mechanical condition, 6-Overloaded or wrongly loaded vehicle, 9-Other, 0-Not known |
| | Crash factor contributing to accident severity | 1-Hitting tree, 2-Hitting pole/post, 3-Hitting stone or boulder, 4-Hitting road island, curb, 5-Hitting barrier or guard rail, 6-Hitting other fixed object, 7-Rolled over, 9-Other, 0-Not known |
| | Other factors | 1-Avoiding maneuver, 2-Hit and run, 3-Road works, 4-Post crash violence, 5-Stolen vehicle, 0-Not known |
| | Alcohol Test | 1-No alcohol or below legal limit, 2-Over legal limit, 3-Not tested, 0-Not known |
| | Driver/ Rider/ pedestrian at fault | 1-Yes, 2-No, 0-Not known |

## 4.4 Descriptive Statistics for the Road Accidents in the Western Province

### 4.4.1 Total number of accidents

Figure 4.9 depicts the total number of road accidents for the year of 2010 to 2014 in the western province. Averagely, the all type of accidents continuously increased from 2010 to 2012, but in 2013, accidents slightly decreased and again increased in 2014. Fatality, grievous and non-grievous accidents were not change considerably within the period of five years.

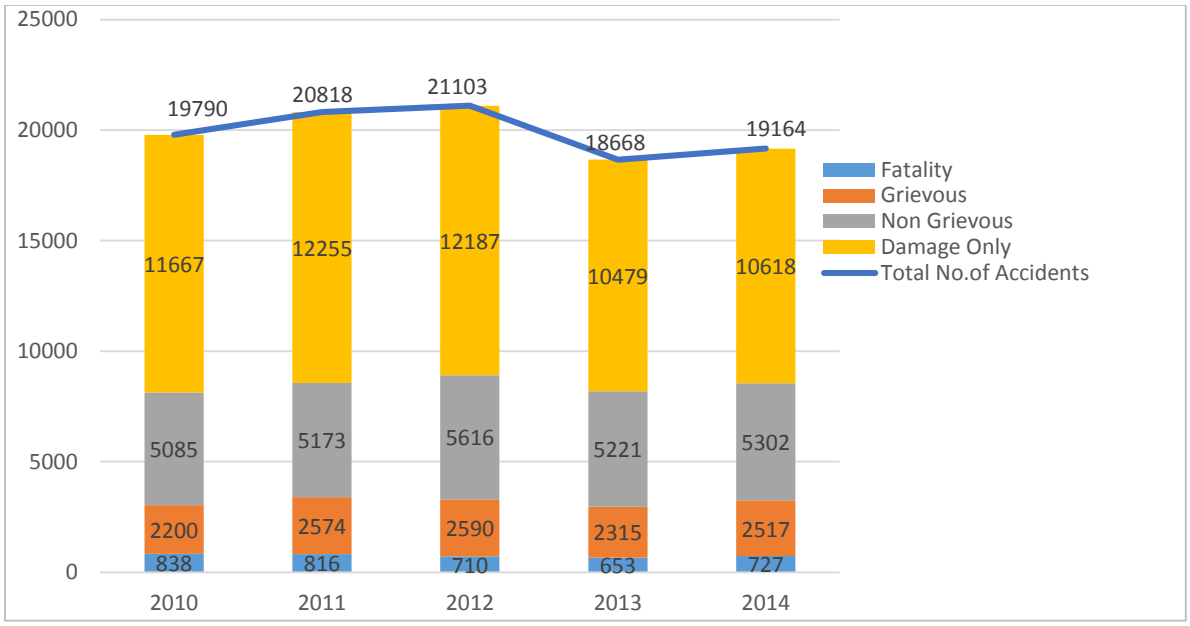



**Figure 4.9:** Total Number of Road Accidents

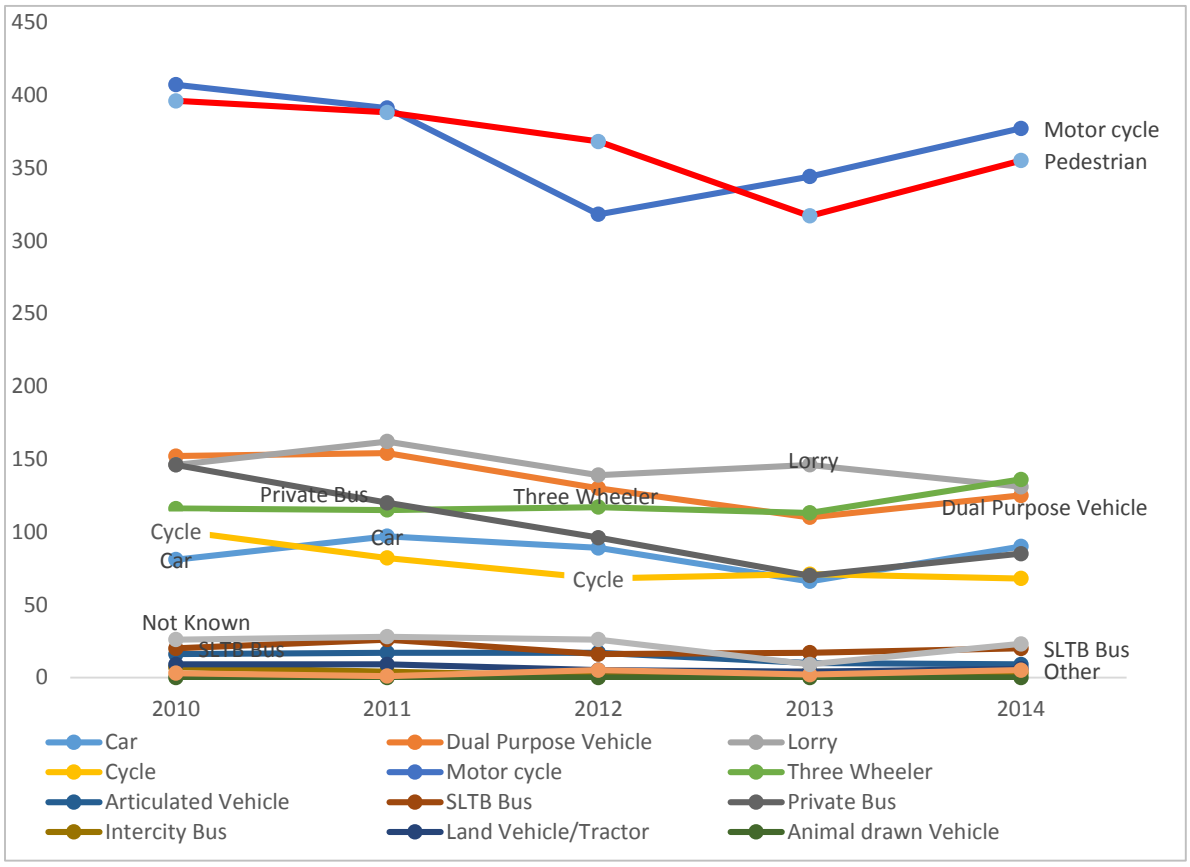



**Figure 4.10:** Total Number of Fatal Road Accidents by Modes

### 4.4.2 Fatal Accidents by the Type of Mode in the Western Province

Figure 4.10 shows the number of fatal accidents by the modes. Pedestrian and motor cycle crashes were very high in the western province. The three-wheel vehicle accidents were increasing rapidly from the rate of 15%. Fatality and grievous accident by the mode of pedestrian and motor cycle were highly significant than the other modes. As an example, Figure 4.11 (a,b,c) show the very first recent year, 2014 accidents distribution for the fatality, grievous and non-grievous crashes respectively. Combinely, more than 50% fatality accidents and grievous accidents were from the pedestrian and motor cycles. More than 46% non-grievous accidents also came from the mode of pedestrian and motor cycles.

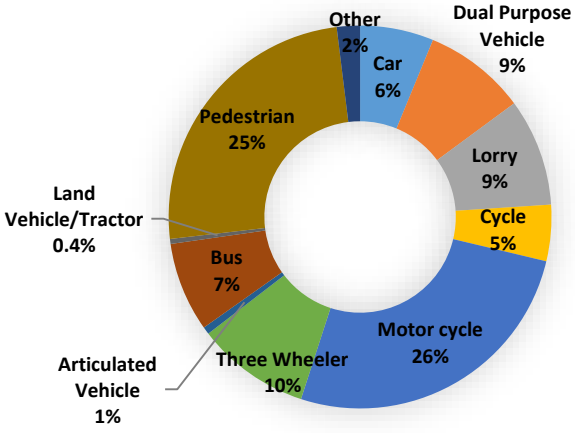



**Figure 4.11 (a):** Total number of fatality accidents by modes in 2014

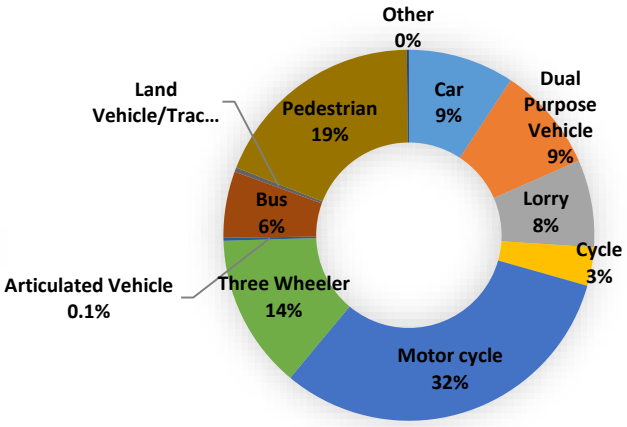



**Figure 4.11 (b):** Total number of grievous accidents by modes in 2014

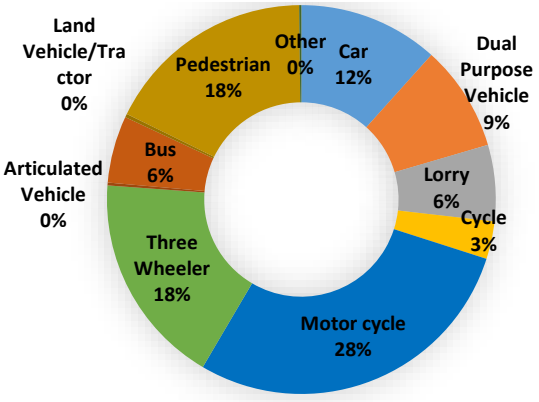



**Figure 4.11 (c):** Total number of non-grievous accidents by modes in 2014

### 4.4.3 Road Accidents by the Location Type in the Western Province

Figure 4.12 depicts the location type for the accidents. Around 70% of accidents occurred at the location of "No Junction within 10 meters". The second largest (16%) location type for the accidents was T- junctions.

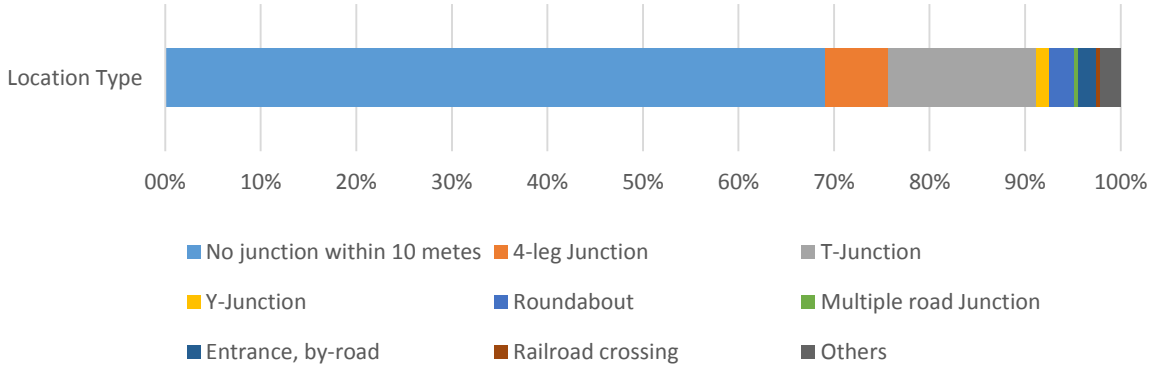



**Figure 4. 12:** Accidents by its Location Types

## 4.5 Accident Severity Measures with Structural Equation Modeling

### 4.5.1 Data Preparation

This analysis measures about how the obtained variables related to the accidents that mainly affected to the severity of the accident in the area. The data set was included with main five different endogenous variables, known as Vehicle Characteristic, Driver/ Pedestrian Characteristics, Road Condition, Cause of Accidents and Attendant Circumstances of the accidents in the year of 2014. The details of these variables included in Table 4.1. The sample size was more than 19,500 road accidents in the western province of Sri Lanka. Beyond the conventional modeling approaches, this study attempts to formulate a model with running Structural Equation Modeling (SEM) method.

### 4.5.2 Methodology for Accident Severity Modeling

This analysis mainly hypothesized that the accident severity is affected by endogenous variables which are shown in Figure 4.13 and that figure is the first hypothesized model. Confirmatory factor analysis with Structural Equation Modeling was run to find the best model. There are main five endogenous variables that categorized for the hypothesized model namely Vehicle, Ped/Driver, Road, Attendance Circumstances and Case of Accidents. These all variables are performed their relationship with one exogenous variables. That variable is the "Severity" which is categorized the accidents as fatality, grievous, non-grievous accidents and Damage only. The first path diagram was being analyzed the *p* values of the standerized regression weight for several moral indicators that were quite large than the 0.05 level. Thus the hypnotized model was modified with ignoring some factors and several observed variables. Accordingly, the final best model shows in Figure 4.14 with standerized regression weight for the common factor and each of the indictors.

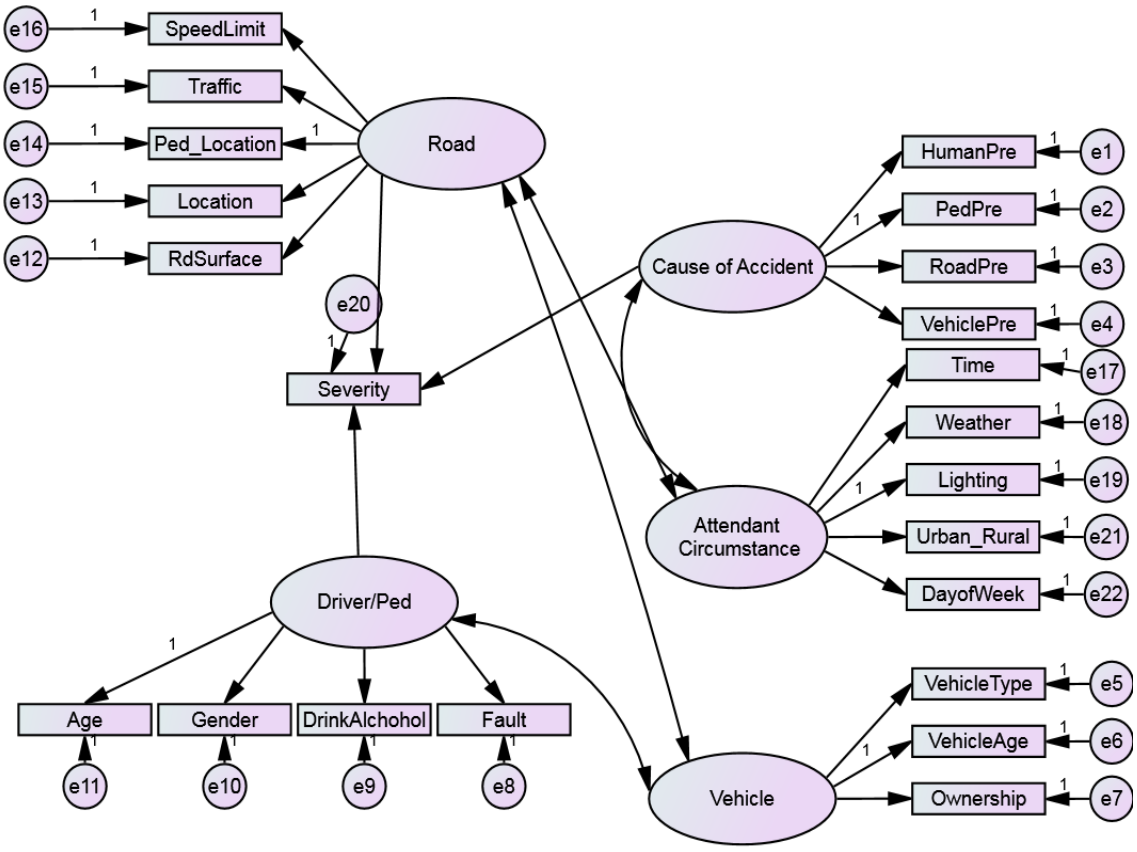



**Figure 4. 13:** First Hypothesized model for Accident Severity

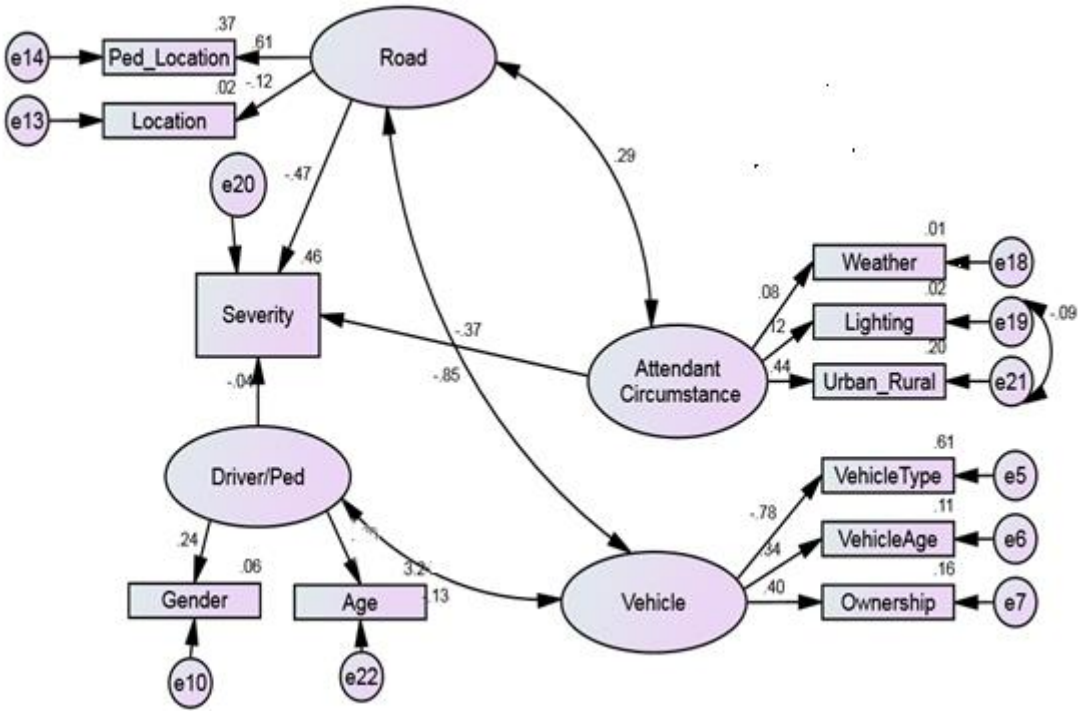



**Figure 4. 14:** Final Model for Accident Severity

### 4.5.3 Results for Accident Severity Modeling

The main target of this analysis is to find the most affected factors to the severity of the accident. Accordingly, the first hypothesized model was designed and conducted SEM approach. The exogenous variable of "Cause of Accident" was completely removed from the first model as it is not significant. Because the relationship with that factor to severity in the table of Regreesion Weight shows that the *p* value is greater than 0.05 and CR (Critical Ratios) value is less than 1.96. In addition to that several obtained variables also were removed from the first model as they are not significant to the severity and finally Figure 4.14 was selected as the best model to explain the accident severity with other related factors.

The Regression Weight table shows in Table 4.2. For the all variables, the CR values are greater than 1.96 and *p* values are less than 0.01 level, imply that the variables are significant and reasonable. The Pedestrian Location and Location Type under the factor of "Road", Weather, Lighting Condition under the factor of "Attendance Circumstances ", Gender and Age of causality under the factor of "Driver/Ped" direct affected to the severity of the accident. In addition to that

Vehicle Type, Age of the Vehicle and Ownership of the vehicle are also indirectly affected to the accident severity. On the other hand, the indices in the table of Summary of the Model Fit (Table 4.3) are shown their values and the all the values are in the acceptable range statistically. Acceptable range for these indexes should be within the range of zero to one [71]. It implies that the model is a well fitted model. The explanation of that indices has been mentioned in section 3.9 of Chapter 3.

**Table 4.2**: Regression Weight

| | | | Estimate | S.E. | C.R. | P |
|---|---|---|---|---|---|---|
| VehicleEliment | <--- | Vehicle | -1.154 | .024 | -48.409 | *** |
| AgeofVehicle | <--- | Vehicle | 1.000 | | | |
| VehicleOwnership | <--- | Vehicle | .109 | .002 | 44.200 | *** |
| Gender | <--- | DriverPed | 6.234 | 1.125 | 5.542 | *** |
| LocationType | <--- | Road | -.162 | .008 | -19.323 | *** |
| PedestrianLocation | <--- | Road | 1.000 | | | |
| Weather | <--- | Attendant | .150 | .021 | 7.201 | *** |
| LghtingCondition | <--- | Attendant | 1.000 | | | |
| Severity | <--- | Road | -.393 | .006 | -61.706 | *** |
| Severity | <--- | DriverPed | -.057 | .011 | -5.100 | *** |
| Urban_Rural | <--- | Attendant | 1.192 | .096 | 12.392 | *** |
| Severity | <--- | Attendant | -1.814 | .292 | -6.211 | *** |
| Age | <--- | DriverPed | 1.000 | | | |

**Table 4.3:** Summary of the Model Fit

| **Model** | **NFI** | **RFI** | **IFI** | **TLI** | **GFI** | **CFI** |
|---|---|---|---|---|---|---|
| Default model | .903 | .859 | .904 | .861 | .982 | .904 |
| Saturated model | 1.000 | | 1.000 | | 1.000 | 1.000 |
| Independence model | .000 | .000 | .000 | .000 | .807 | .000 |

When considering all factors, the factor of "Road" affected to the severity. Under the Road condition, variables of Pedestrian Location and Location Type are significant and factor loadings for the variable of Pedestrian Location is high than the other variables. Then the analysis of the pedestrian accident is very important to find the critical location for pedestrian accidents. In

addition to that, from the literature review related to the Sri Lankan road safety and the descriptive statistic of the past road accident data emphasized the pedestrian accidents are high in Sri Lanka. Hence it is good to reduce pedestrian accidents by considering location analysis for critical places for pedestrian accidents in the study area. The next section aims to identify the high rate of pedestrian accident locations and pedestrian safety deficient in the study area.

## 4.6 Analysis of Hot Spots for Pedestrian Accidents

This section aims to determine the critical places for the pedestrian accidents and pedestrian safety deficient in the western province of Sri Lanka. For this purpose, the pedestrian road accident data for the years of 2010 to 2014 has been used with GIS (Geographic Information System) software. GIS is a technology for managing data with visualizing, analyzing and interpreting to understand relationship, pattern and trends [87].

Hotspot Analysis with GIS was used to assess the statistically significant high and low accident severity clusters in the focusing area. Then selecting only, the hotspots area, the "Density" function which is available in the Spatial analyst extension of the Arc GIS software was apply to find the most pedestrian accident areas in the western province.

### 4.6.1 Data preparation for Hot Spots Analysis

The pedestrian accident data for the five years (2010-2014) from the same data of Traffic Police Division was selected and sample size was more than 15,800 pedestrian accidents in the selected area. The severity of the crashes (Fatality, Grievous and non-Grievous) with a specific key number were included to GIS database. The latitude and longitude coordinate details for each accident were used to map the real point using GIS. In order to determine the accident prone places, the map of the road network in the western province was also included to the map additionally. That road map is scaled to 1: 50,000 and collected from the Survey Department of Si Lanka. It has been included the details of road type, road number, road length etc.

### 4.6.2 Methodology for finding Hot Spots for Pedestrian Road Accidents

In order to find the hot spots in the selected area, Arc GIS 10.1 software was used. The following steps are given below;

1. Make sure the selected data is projected. It is important to map the data in the exact study area.
2. Map each and every accident points and these points represent the pedestrian crashes only for five years. Figure 4.15 shows the map.
3. Then project the accident data using Projected Coordinate System with concerning the appropriateness of the selected area using a special filter.
4. Aggregate the accident data prior to the hot spots analysis. Since these coincide data points are in short distance of one another, Integrate with Collect Event tool in Arc GIS is used.
5. Run Hot Spots Analysis with Getis-OrdGi* [92] approach to find the statistically significant, high risky places for road accident in the pedestrian point of view.
6. Visualize the data with clustering hot pots and cold spots with concerning Z and P values of the points. Figure 4.16 shows the visualizing map. Red points are the hot spots and blue points are the cold points.

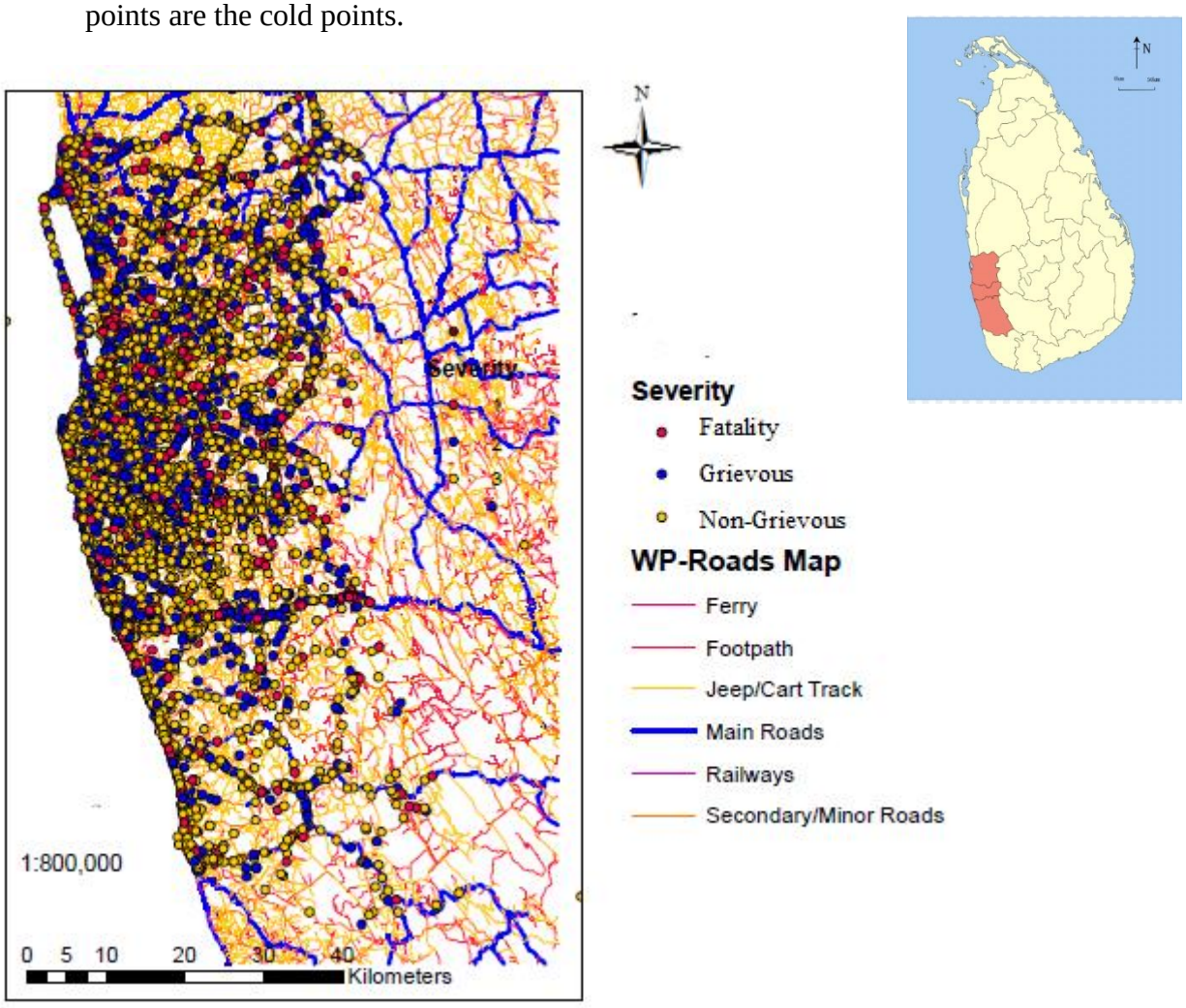



**Figure 4. 15:** Map for Pedestrian Accident in Western Province of Sri Lanka

7. Selecting only hotspots and then conduct the Point Density measures under the Spatial Analysis tool in Arc GIS to calculate the density of point features around each output cells. (Figure 4.17)
8. Then identify the high rate of pedestrian accident spots with referring road network layer and image of Google Earth. Figure 4.18 (a) to Figure 4.18 (d) show the way of finding the critical point for the pedestrian accidents.

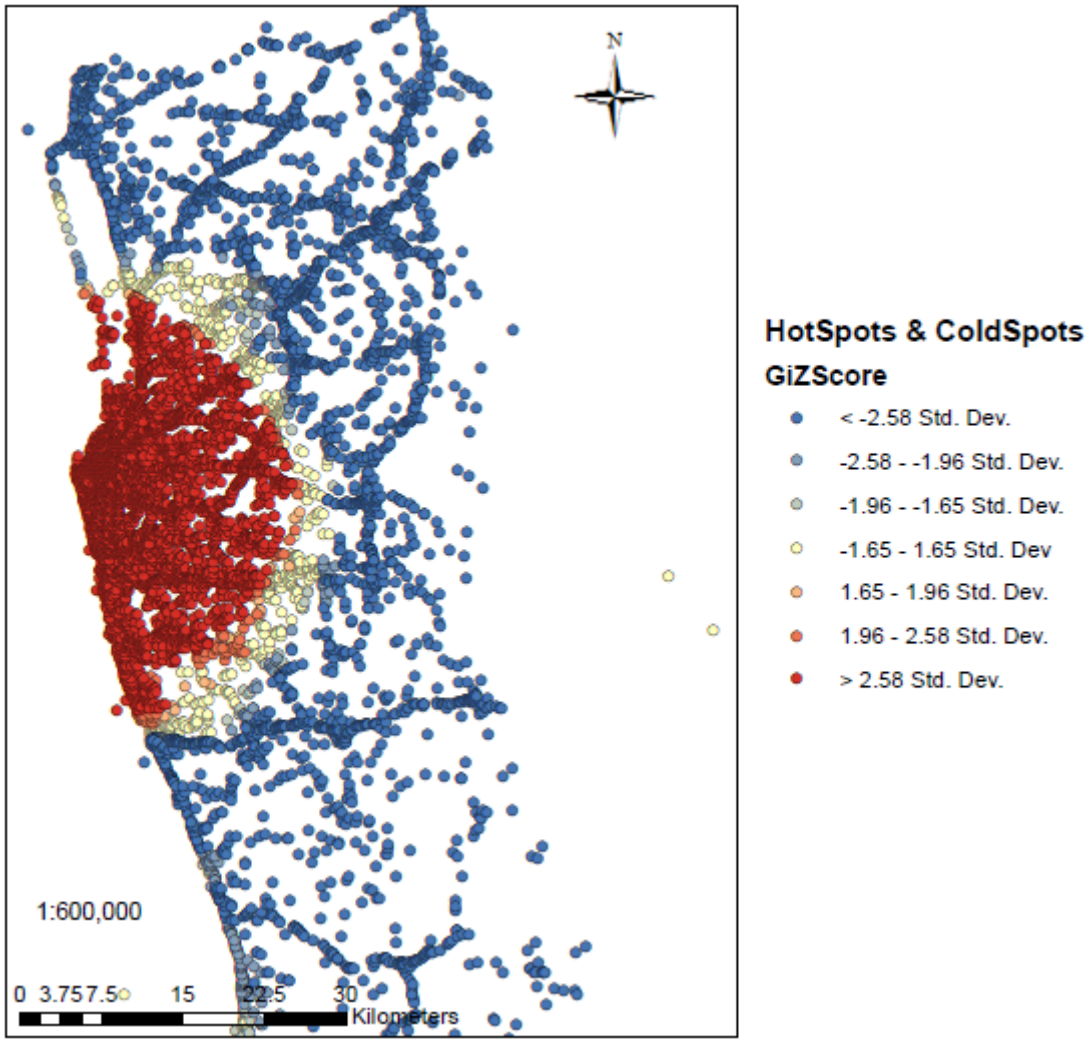



**Figure 4. 16:** Hotspot Map for Pedestrian Accident in Western Province of Sri Lanka

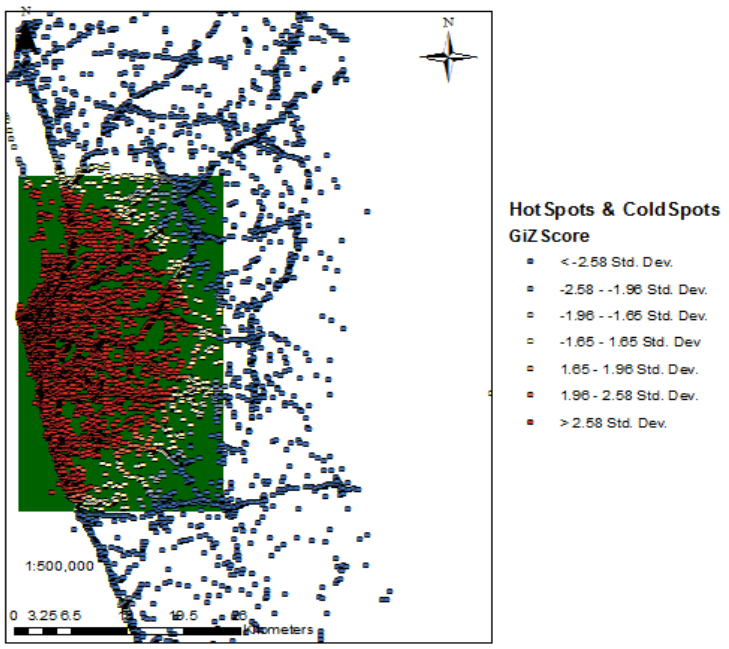



**Figure 4. 17:** Selecting only Hot Spots for Point Density

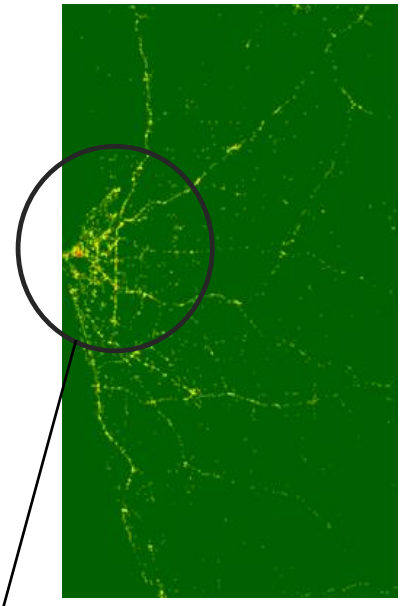


**Figure 4. 18 (a):** After applying Point Density

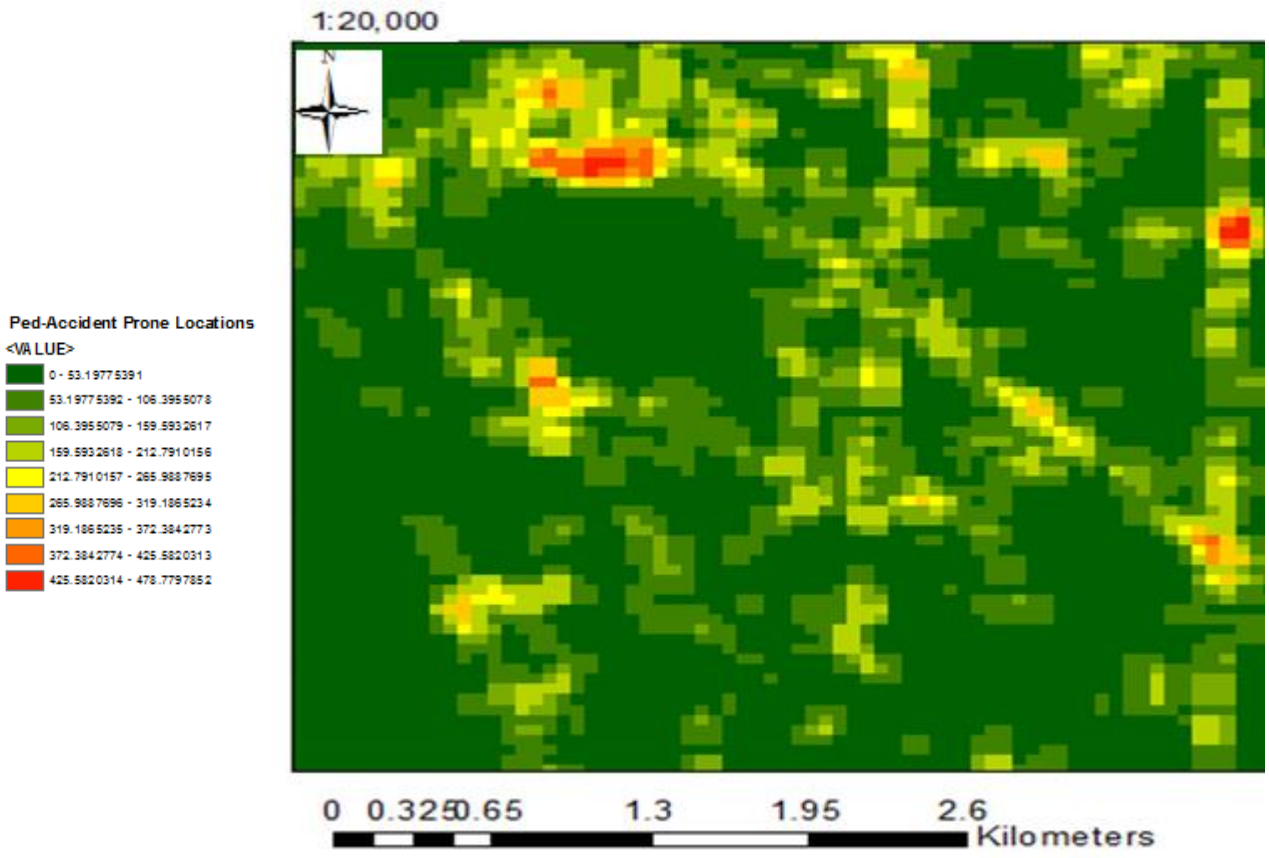



**Figure 4. 18 (b):** Zoom image of Density Points

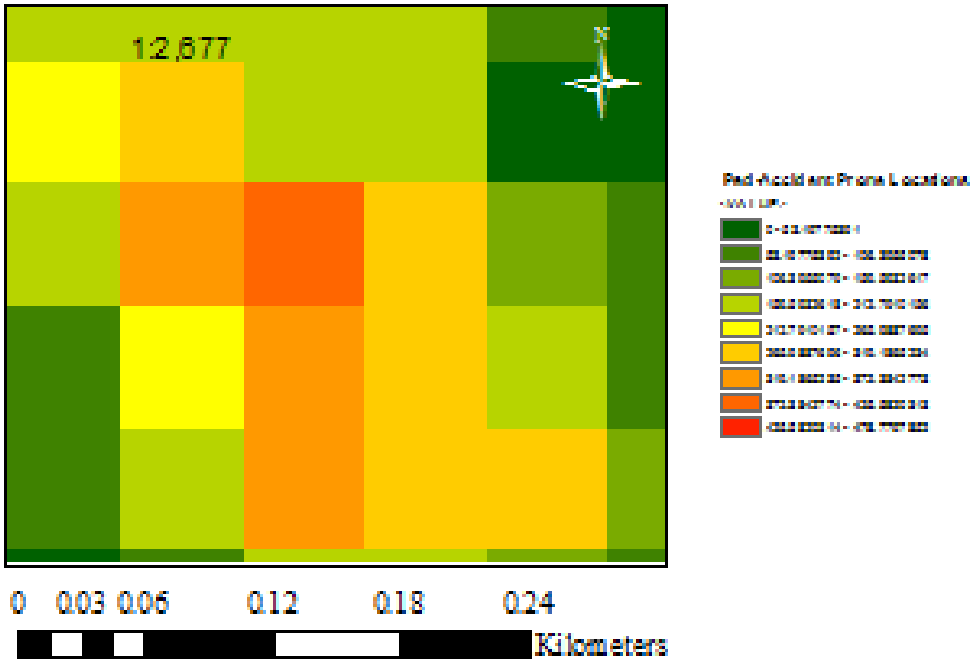



**Figure 4. 18 (c):** High Zoom image of a point Location

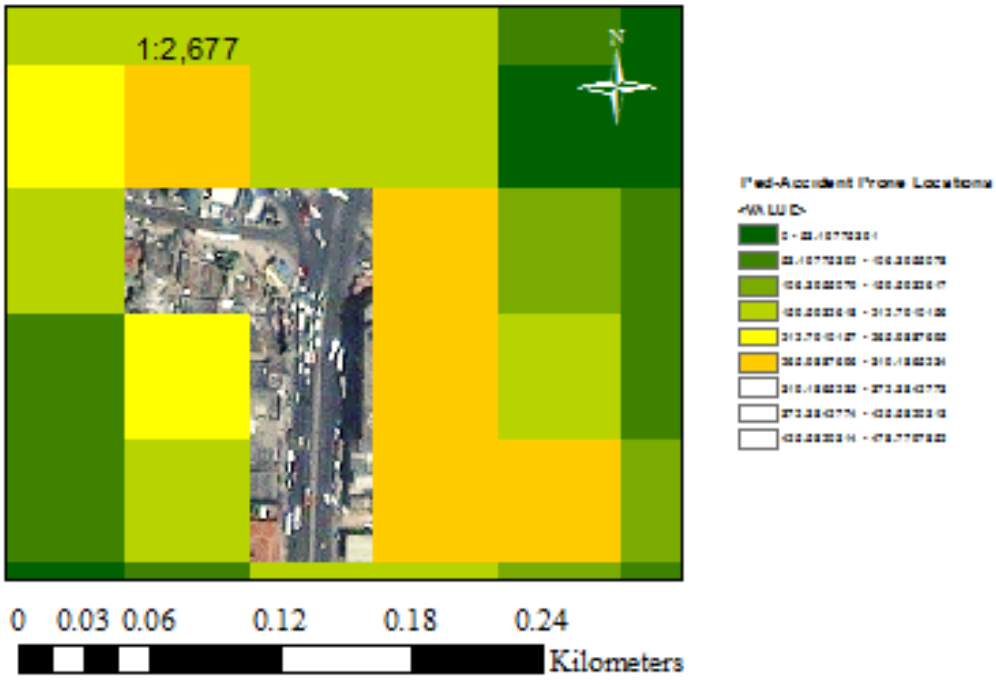



**Figure 4. 18(d):** After finding the point with referring the image of Google Earth layer

### 4.6.3 Results from the Hot Spots Analysis for the Pedestrian Accidents

With the purpose of determining high rate of pedestrian road accident locations, Hot Spots analysis was conducted. Accordingly, there are main nine locations have been identified as the critical places for the pedestrian accidents in the western province. There are three districts in the western province, Colombo, Gampaha and Kalutara. Six critical locations out of nine locations are situated in Colombo district and other remaining three locations are included to Gampaha district. The nine locations are namely as follows;

1. Bodhiraja Mawata, Olcatt Mawata and Bastian Mawata
2. Dematagoda Junction, Baseline Road
3. Borella Junction
4. Uswatta Junction, Galle Road
5. Library Road, High level Road
6. Stanly Thilakawaradane Road, High level Road
7. New Kelani bride Road
8. Kiribathgoda Junction,Kandy Road
9. Kadawata Junction, Kandy Road

When these accident prone locations are evaluated with concerning pedestrian safety deficient, it may be easily improved the safety facilities for the pedestrians.

## 4.7 Chapter Summary

One of the main crux problem in the world is road accidents. Most fatalities from the road accident in high-income countries occur for car owners while majority of road fatality accidents in the low and middle income countries for pedestrian and motor cycle riders. On the other hand, public transport accidents are high in low to middle income countries since the peoples in such countries highly use public transport for their daily traveling purposes rather than high income countries. Sri Lanka is also middle income country and around 1% of GDP losses due to road accidents. The largest share of road accidents is in the Western Province of Sri Lanka. Pedestrian and Motor cycle accidents are the highlighted mode type for the road accident. When comparing with other

countries, Sri Lanka is included to the section of "Higher mortality and Higher reduction" of road accident. It implies that the road fatalities are very high and accident reduction is also high, but that reduction level is very low when comparing to other country in the same category.

Accident data information from the Traffic Police Division in the Western Province of Sri Lanka for five years was collected with the intension of assessing the crashes and safety facilities to develop the public transport in the selected area. More than 99,500 crash data was evaluated in this section. Within this five years of period, trend and the pattern of the accident were not much changed. Pedestrian and Motor cycle accidents are very high when comparing with other modes in the selected area. Most influencing measures for the severity of the accident were evaluated using SEM approach. Road locations, weather, lighting condition, urban/rural area, age and gender of the casualty directly influence to the severity of the accidents. Pedestrian road locations are highly significant for the severity of the accidents. Pedestrians are the public transport users and improving pedestrian facilities is vital for the improvement of public transport. With this point of view, pedestrian accidents were evaluated within the five years of period by using Hot Spots analysis with Arc GIS package to find high rate of pedestrian accident locations. According to that analysis, there are nine pedestrian accident prone locations have been identified for the improvement of safety facilities.

# CHAPTER 5

# Discussion

Transport is one of the most vital aspect in the day-to-day life of the people as their activities cannot be fulfilled without moving. On the other hand, transportation sector is a main sector for a country development. Hence monitoring traveler behavior with related to the transportation activities is important for a country development with aspects of economically and sociologically. Currently the main issues in the transportation sector are the high traffic congestion due to high trip demand by private vehicle without using public transport by the traveler and rapid increment of road accidents.

The study area is the Colombo Metropolitan Area (CMA) in the Western Province of Sri Lanka. According to the previous research studies, over 50% of peoples in the area is unhappy about the public transport and its facilities and they spend more time than the expected for a journey in Colombo area [10]. As well as roughly half of the country's economic activities are concentrated in this area and the nation's largest international seaports and the airports are located within the area too [12]. Hence the development of this area is vital and it will be directly affect to the economic development of the Country. The experts in the transportation sector in Sri Lanka say that the public transport facilities are still in a primary level [13]. Thus the measuring behavioral model of traveler mode choice and understanding factors influencing to mode choice are the way to provide a better solution to develop the public transport and to encourage people for the public transport. On the other hand, when considering the safety for the pedestrians, it is in a high risky level in Sri Lanka. Pedestrian injured and fatality rate is very high when compare to the other accidents in the Western Province in Sri Lanka [12]. It implies that the safety for public transporter is very low in the area. Thus, this study aims to explore the most effective inducing impacts to improve the public transport. Hence, identifying factors influencing to choose to mode choice by the traveler in the selected area and analyzing road safety and crashes are the main approaches which this study has been focused.

## 5.1 Mode Choice Behavior Analysis

Analyzing traveling behavior with the aspects of travel mode for the CMA region in the Western Province of Sri Lanka is an objective of this section. The analysis data was collected from a designed questionnaire. The data was analyzed under the three categories. The first one categorized to find the factors influencing to select the mode choice, second one categorized as to find a probability tendency model with most significant factors for selecting a public mode. The last category was found a model for understanding the relationship between access mode and public mode choice behavior.

### 5.1.1 Factors Influencing to Travel Mode Choice

The influencing factors were found for the public and private transport modes separately under the two categories. Personal characteristics and Travel-based characteristics are the two categories. When considering about the public buses, there are 4 factors can be identified for the 10 variables under the personal characteristics and 11 variables were reduced to 4 factors for travel based characteristics. The procedure is same as for other all modes and reduce the dimension with factor analysis. Several graphs from the descriptive analysis were also aided to identify the influencing factors with proving the findings from the Factor Analysis.

When choosing public buses, the decision is mainly depending on the earning capacity, vehicle ownership, education and gender, house hold capacity and age with occupation. In addition to that, as the travel-based characteristics, cost, access time and safety, trip characteristic, purpose with comfort and time reliability are the factors that influenced for choosing public buses. Specially for long distance trips, people select public transport rather than private vehicles. In that case when selecting train as the mode, traveler think about safety rather than safety on buses. The residence use private vehicles for short distance regular trip might be cause to increase the traffic congetions. Even people think about the comfort level, it is not much affected for selecting pubic transport specially for bus. But time reliability is an importance factors for both modes. Because the image of time reliability has damaged in the public transport as they are no coming on time.

When selecting private mode as a motor cycle, traveler think about income level, comfort and trip purpose, trip cost, time and distance. Basically young male workers use the motor cycle for daily

travelling. Motor cycle users does not much think about the safety but think about the time and cost.

Most of three wheel travelers are selecting by thinking comfort, time and subsidized cot. Low to middle income level people usually use the three wheelers. Residence type, age and occupation are also affected to the decision for selecting three wheelers. Majority of people use three wheelers as a taxi for the purpose of education as it is safe, comfort, time reliable and cost effective.

Most car owners think about time, safety and comfort for selecting their car for a short distance journey. Purpose, distance and the cost of the journey also are considerable for choosing car as a mode. High income with a reputed educations and occupation level influenced to use a car.

When people think to walk for a particular purpose, they much think about the distance and the cost. Income level is also influenced for the decision. Some people walk as a recreation activity. Individual types (Age, gender, education level, occupation level) and vehicle ownership also depend on the decision. On the other hand, the "other" mode can be categorized as school bus, staff bus, lorry, truck and etc. Occupation is a significant factor as the lots of respondents for other modes as school buses and staff buses. They are much think about the comfort, distance, cost, time of the journey and the safety of the mode.

### 5.1.2 Probability Tendency Model for Public Mode Choice

When analyzing influencing factors for selecting mode for the regular trip purposes, it is confirmed that encouraging people for the public transport is a best way for the development of the transportation sector. Thus next step was to design a model to evaluate the probability of selecting the mode of public transport with finding most significant aspects related to the traveler's point of view of the public transport. The analysis has found that, 10 variables out of 21 variables were significantly affected to the model design. Number of earning members in the household, Vehicle ownership, Gender, Age, Education, Occupation, Trip Distance, Trip Time, Total Cost and Safety were the significant factors that mostly affected to the mode choice of public transport with the 78.4% of model accuracy.

Earning member is a significant factor in this model. According to the questionnaire survey, even the households that had large number of earning members (more than 3), they mostly use the public transport. Even though that household with public transport users have large number of earning members, the majority of their income level is low to middle level (Sri Lankan Rupees 15,000-75000, 54.8%). Hence this type of household has not enough financial situation to grab their own vehicle even their family included a large number of earning members. Occasionally though a particular household had a greater number of members with a private vehicle, the workers of that household tended to use public transport with offering private automobiles to the other members of the family. On the other hand, the small size households do not have enough financial situations to go for a private automobile and therefore less likely to own an automobile and use the public transport.

Vehicle ownership is an another significant factor. Obviously, ownership was highly affected to the decision of public transport. The peoples who have an own vehicle, they less likely to use the public transport. The next significant factor is gender. The survey results showed that the female travelers had a choice to use the public transport than the male users. It is clear that the most of the females in Sri Lanka are not the vehicle license holders and vehicle owners. Therefore, the females tend to use public transport than the male travelers.

The next imperative variables are the Age, Education and Occupation. Most of the young people (age between 15- 30 years old) use public transport for their regular trips as young people made their trip purpose for the education and yet they depend with their parents or others and do not have their own profession. Hence they do not have their own vehicles and then tend to the public transport. With concerning the variable of Education, the peoples who had a low educational level and do not have a considerable income level and an occupation, those people also tend to use the public transport. But when analyzing descriptive data, educated peoples also tend to use public transport. When considering the variable of occupation, student, government and private sector peoples tend to use public modes and business peoples who are very rich use private vehicles for their regular trips. On the other hand, unemployed means, the house wives and other peoples who not doing job now tend to use foot cycles or walk for their journey, those modes also categorized as private mode.

The next important variables are, trip distance, time and cost. The decision for the factors of trip distance, trip time and the total cost are very important for the people's regular trips. If the destination is so far from the home, the people tend to select the public transport as the people regularly do not like to ride their own vehicles for a long time and so far to the destination of the regular trips. However, if the total cost for the regular trips is too much high, then the peoples considered about the mode and compared the benefits of each. When the cost is high in public transport, it is possible to get the private mode for the travel as usually the peoples believe that the comfort and the cleanliness are lack in the public transport.

Next significant factor is Safety. It indicates that the safety is very important factor for the travelers. But the B value (- 0.773) was negative and it illustrates that the peoples argued the safety and the security of the public transport was lack in Sri Lanka. Thus they did not have trustworthiness about the public transport with the aspect of safety and the security. Most public transport is involved in more than 50% of all accidents and driver behavior that may be contributing to a high incidence of their involvement in road accidents [88]. But most of the peoples used the public transport due to their low income situation. The peoples, who are living in developing countries like Sri Lanka, tend to use public transport as their low income and are not the vehicle owners. Even the public transport had low safety and security, peoples used the public transport due to the low income levels. As this model covers the ten momentous factors, it will be predicted the travel behavior of wide variety of peoples. With the finding of this study, we can recommend some points for the further development of the sector of the public transport.

### 5.1.3 Model for the Relationship of Access Mode Choice and Public Mode Choice Behavior

From the factor analysis, Access Time shows an important variable when choosing public transport. In addition to that, experts in the transportation sector in Sri Lanka have identified that the important of the development of public transport. According to their knowledge, introducing easy access ways for the public transport is very essential option for encouraging people for the public transport [66], [67]. Hence this section is going to be designed a model to identify the relationship between access mode and public mode. Analysis method is the SEM approach for the same data sample of the public transport use only. The developed model shows that the access mode choice is affected to the public mode choice and first, select the public mode and then select the access

mode choice by the traveler. Hence improving the access mode is a one critical point to increase the attractiveness of the people for the public transport.

Demographic characteristics related to personal and family, main trip characteristic and the attitudes towards the time, cost, safety and comfort are indirectly affect to the decision of access mode choice. When the access time and waiting time of the access mode are increased, traveler does not much think about the safety and comfort of the access mode and they want to reach to the public mode quickly. Thus the traveler satisfaction can be increased with introducing a faster travel mode service with a proper time schedule and the conditions with safe and comfortable rather than cheap service. The decision makers can focus their attention to these facts when they are getting decision on introducing easy and better access modes for developing public transport in Colombo Metropolitan Area of Sri Lanka

## 5.2 Road Crashes and Safety Facilities in the Study Area

Rapid increment of road accident in the world is demanding urgent attention. World Health Organization has predicted that the road accident will be the fifth leading reason to death by 2030, which was taken the ninth place in the list of death reasons in 2004. A large portion of the burden in developing countries is accounting from the road accidents, the 85% of annual fatalities and the 90% of disability life [89]. Sri Lanka is a developing county where, there was a significant number of road accidents occurred particularly around 60% were accounting from the Western Province (WP) of the country. Moreover, the exposure potential fact that the WP contributes more than 50% to the country GDP [82] and losses considerable amount due to road accidents. Hence it is vital to investigate the most vulnerable impacts with the aspects of accident severity. Thus 4$^{th}$ Chapter calibrates a statistical model to ensure the most affected impacts for the severity of accidents. Beyond the conventional modeling approaches, this study attempts to formulate a model with running SEM modeling method.

More than nineteen thousands of accidents within the year of 2014 were analyzed with main five different endogenous variables, known as Vehicle Characteristic, Driver/ Pedestrian Characteristics, Road Condition, Cause of Accidents and Attendant Circumstances of the accidents. These all endogenous variables were performed their own variables and relationship with only

exogenous variable, which was the Severity. The hypothesized model is well fitted as a powerful index are within the well fitted range. Several directions identified from the results of model formulation particularly pedestrian related locations, urban-rural road conditions, age and gender of the causality are playing most significant role while vehicle conditions are indirectly affected to the accident severity. However, the endogenous variable of Cause of Accident, are not significant for the model of road accident severity.

In addition to that, when analyzing all five years of accident data (2010-2014), the pedestrian and motor cycle accidents are very high rather than the other types of road accidents in the western province of Sri Lanka and the literature surveys are also proved it. And also, from the previous section for analyzing accident severity, the model depicts that the pedestrian location is a critical point for the accident severity. With considering all above situations and since the motivation of this study is to improve the public transportation sector, the pedestrian accidents are map with GIS software with the function of density point to find the high rate of pedestrian locations in the Western province. Accordingly, there are nine prone locations as the high density of pedestrian locations that have been identified. Specially these locations can be improved when analyzing pedestrian facilities properly. For instance, several identified locations have been not installed proper sidewalk for pedestrians and poor visibility of crossing road and their design etc. Once these locations are focused about the pedestrian facilities and its faults with analyzing past crashes, those can be modified to reduce the crashes.

## 5.3 Specific Solution for the Locations of High Rate Pedestrian Accidents as a Proposal

The aim of this section is to give some specific solutions to the founded nine locations. Even though, giving solution for the locations is beyond from the objectives of this study, as a fulfilment and as a proposal, the following solutions are presented for seven each locations in the Colombo district of the Western Province of Sri Lanka. The steps for the proposal solutions are as follows;

- When considering about the collision map which was design by selecting the points from the GIS plotted map, the locations were monitored by Street View of Google Map.

- location characteristics are also identified from analyzing crash data of the locations and previous survey data.
- Afterwards, with considering street view of the google map, the specific points were designed for the existing locations by using trial version of Infrawork 360 software.
- Then the proposed location with the founded solution was designed with the same version of Infrawork 360 software.

Even analyzing location characteristics with the aspects of past crashes and with other secondary data and also the designing road location are time consuming, the finding of the study will be aided for transport engineers to develop road safety design more effectively. The proposed design location of each point with the solution of the proposal as follows. As an example, the analysis of the characteristic and the summary of the location were given only for the first location and the same procedure was conducted for each locations.

### 5.3.1 Description of the Location Characteristics

For instance, the description of the specific characteristics is given for the first location. For the first location from the hotspots analysis has identified main three points; Olcott Mawata at the Gunainghepura Junction, Bodiraja Mawata at the Central Bus stand and the Batian Road at the Bastian Bus Stand. The Figure 5.1 depicts the area exactly that is found by the hotspot analysis. And it is obvious that the road is filled with the pedestrians around this area as the main three bus terminals are around this location. The Figure 5.2 also shows that the summary of the departure passenger loading level and access mode for the bus stand. Accordingly, Bodiraja Mawata and Bastian road may have crowded with pedestrians as the loading factor is very high at their nearest bus stands. In addition to that the crash data shows that the non-intersection has large number of accident than the intersections (Ocott mawata and Bodiraja mawata). Figure 5.4 shows, when police men control vehicle at the traffic peak hours, the occurrences of accidents are high and next highest category is, when the traffic control is not working, it may cause as at the night time, the traffic light are going to be switch offed and poor visibility of crossing roads.

Figure 5.5 shows the location that pedestrian accidents were occurred, high rate of accidents occurred on the pedestrian crossings and at the crossing roads are within the 50 m. It implies that

the behavior of the pedestrian may influenced more for the crashes, it may due to less traffic control, less of sign board and signals or poor view of crossing road or crossing roads are far from each etc. Figure 5.8 also proves it because the most accidents did not occur at the driver/rider fault. Most accidents occurred at the peak hour (6-9 am and 2-5 pm) at both intersection and non-intersection according to Figure 5.6.

### 5.3.2 Summary and the Benefits of the proposal

Table 5.1: Summary of the Specific Proposal

| Location 1 | Proposed Solutions | Benefits |
|---|---|---|
| **Point1**-Olcott Mawata at the Gunasinghepura Road, Colombo, Western Province | • Expand sidewalk with replacing Hawkers<br>• Remove unnecessary build board and replace traffic light bar from the island<br>• Increase visualization with Zebra Crossing, Line, Arrows & "STOP" mark<br>• Expand with painted curb<br>• Remove the concrete refuge round island & cross line. Expand the sidewalk with attached to a refuge island<br>• Bring bus stop closer from the existing place and expand with painted curb | • Improve the pedestrian safety<br>• Increase waiting space for pedestrian<br>• Improve the pedestrian confidence for crossing road and increase safety<br>• Smooth the traffic flow<br>• Reduce the walking distance for the bus stop and then reduce the unnecessary crossing without crossing lines |
| **Point2-**Bodhiraja Mawatha at the Central Bus Terminal Colombo , Colombo, Western Province | • Make sidewalk and replace and reorganized Hawkers properly<br>• Expand Sidewalk | • Increase walking space for pedestrian and increase the safety<br>• Increase visualization and confidence for crossing correctly |

| | | |
|---|---|---|
| | • Increase visualization with Zebra Crossing, Line, Arrows & "STOP" mark<br>• Expand median with painted curbs | • Reduce unnecessary injuries with collision and increase waiting space<br>• Smooth the traffic circulation |
| **Point3-**Bastian Mawatha at the Bastian Bus Terminal Colombo, Western Province | • Add side walk continuously and expand sidewalk where it is available<br>• Mark painted curb extension to the side walk and introduce ramp for each side of the crossing walk<br>• Line up all vehicle parking to one side and separate parking area with white line<br>• Remove unnecessary median and introduce side walk behind to the parking area | • Increase pedestrian safety<br>• Reduce unnecessary collision<br>• Reduce road way and simplify the parking space and road way |

The proposed designed with comparing existing situation in each location is as followed.

**Location 1- Characteristics**

Olcatt Mawata, Bodhiraja Junction, Batian Mawata in Colombo, Western Province


**Figure 5.1: Bus Terminals and Bus Stops**

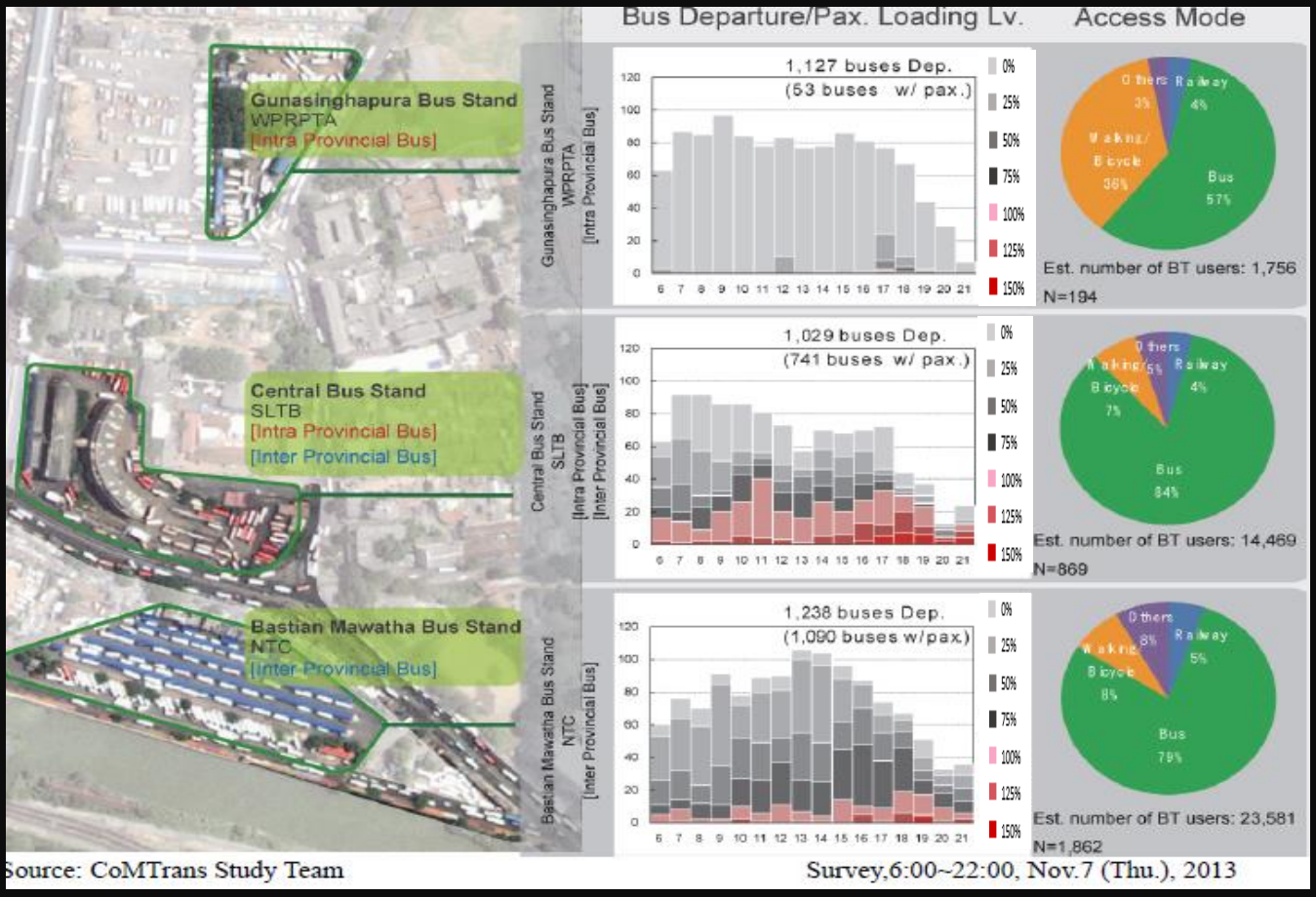



**Figure 5.2: Survey Results for 3 Bus Terminals**

| Severity | Intersection (Olcatt Mawatha & Bodhiraja Mawatha) | Non intersection (Bastian Mawata) |
|---|---|---|
| Fatal | 4 | 11 |
| Grievous | 10 | 17 |
| Non grievous | 15 | 29 |


**Figure 5.3: Number of Crashes by Severity**

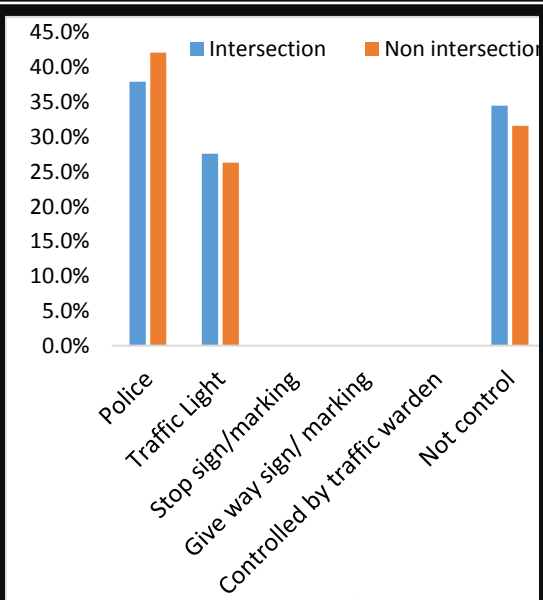



**Figure 5.4: Percentages of Crashes by Traffic Control Device**

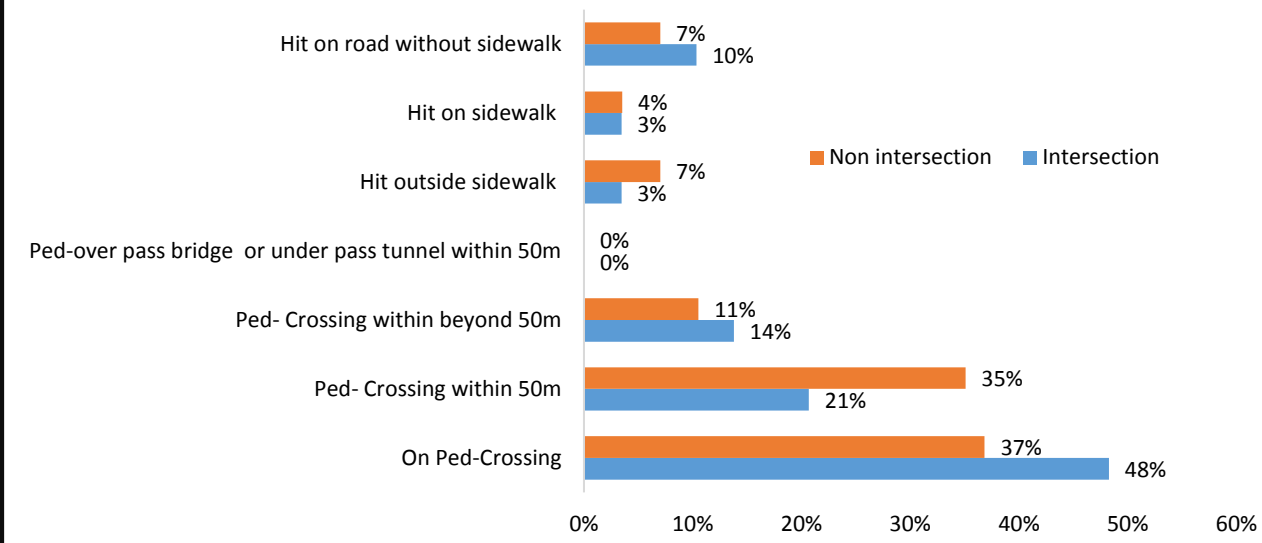



**Figure 5.5: Precentage of Crashes by Pedestrian Location**

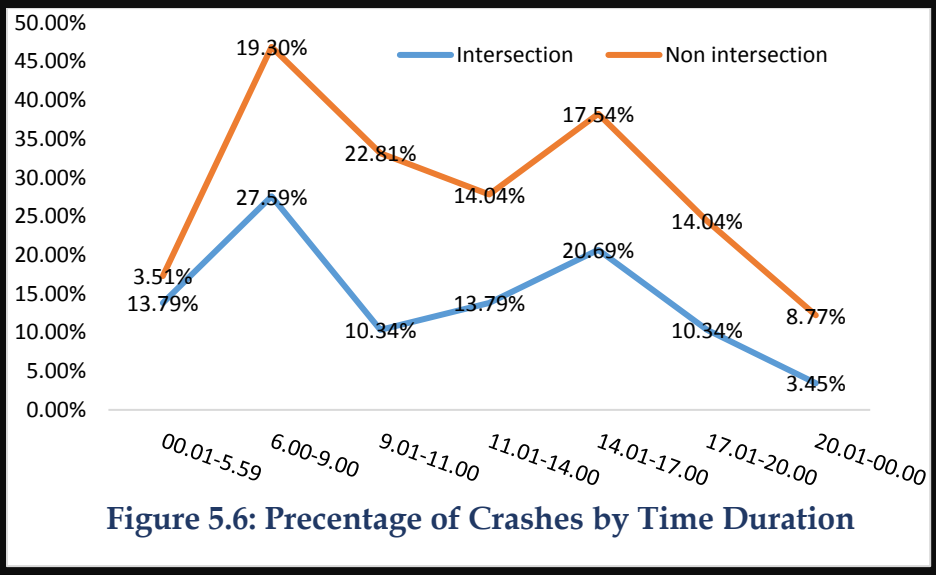



**Figure 5.6: Precentage of Crashes by Time Duration**

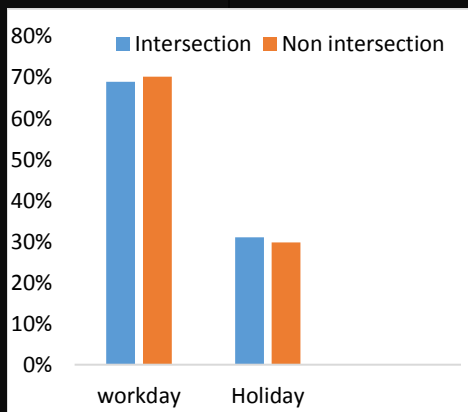



**Figure 5.7: Precentage of Crashes by Work/ Holidays**

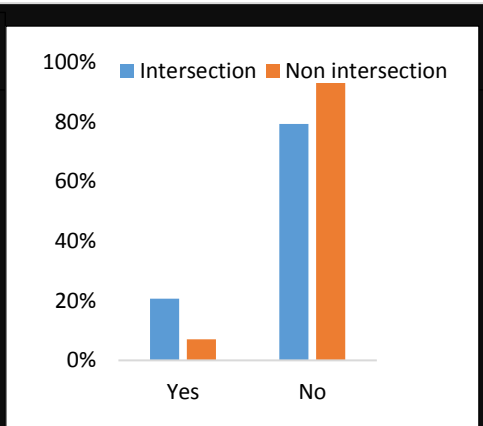



**Figure 5.8: Percentage of Crashes by Driver/Rider at Fault**

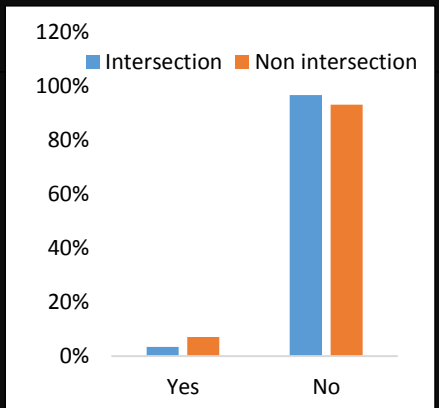



**Figure 5.9: Percentage of Crashes by Speed Limit Posted**

# Location1-Point 1

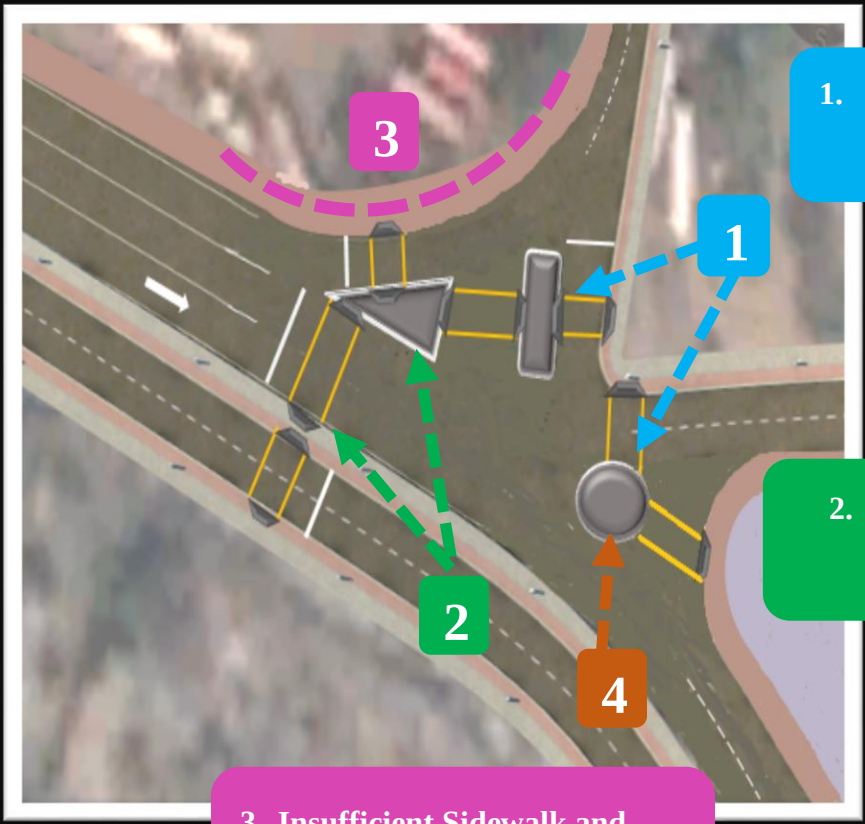
## Olcott Mawata,Colombo, Western Province



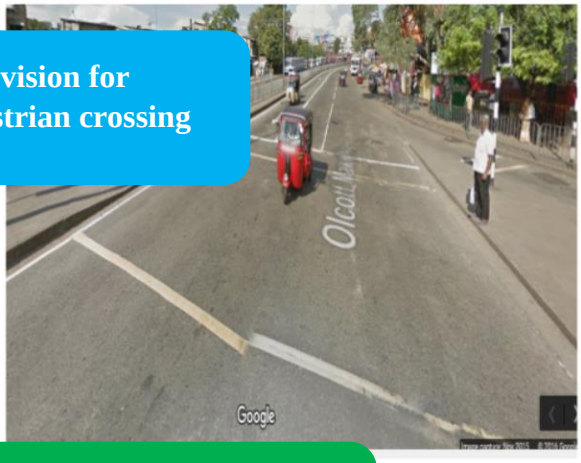
Collision Map in Olcatt Mawatha

# Existing - Situation

## Olcatt Mawatha, Colombo, Western Province




1. Poor vision for pedestrian crossing



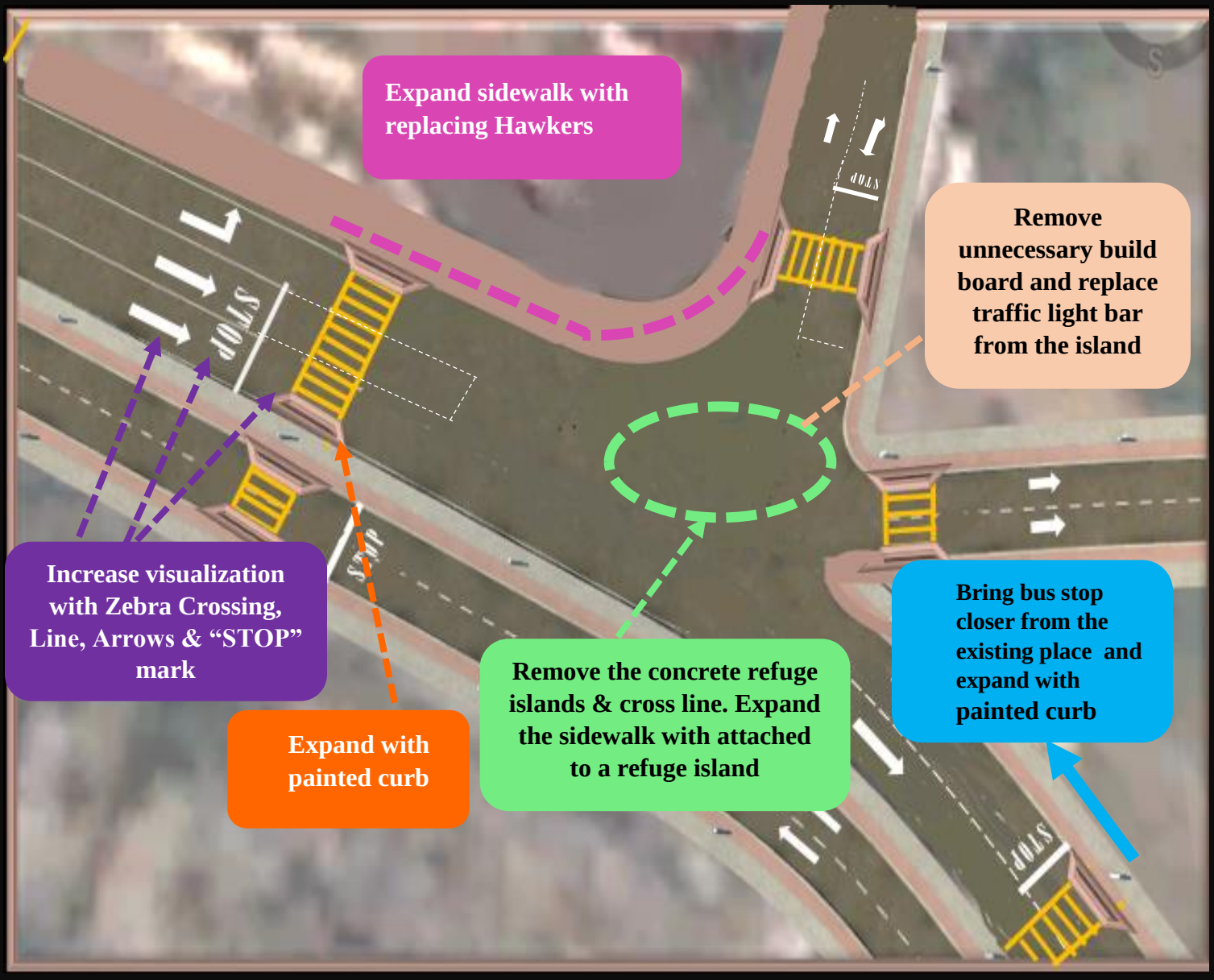

2. No enough waiting space in pedestrian refuge island

3. Insufficient Sidewalk and Unnecessary Hawkers


4. Unnecessary concrete refuge island and No Concrete ramp

# Proposal

## Olcatt Mawath, Colombo, Western Province

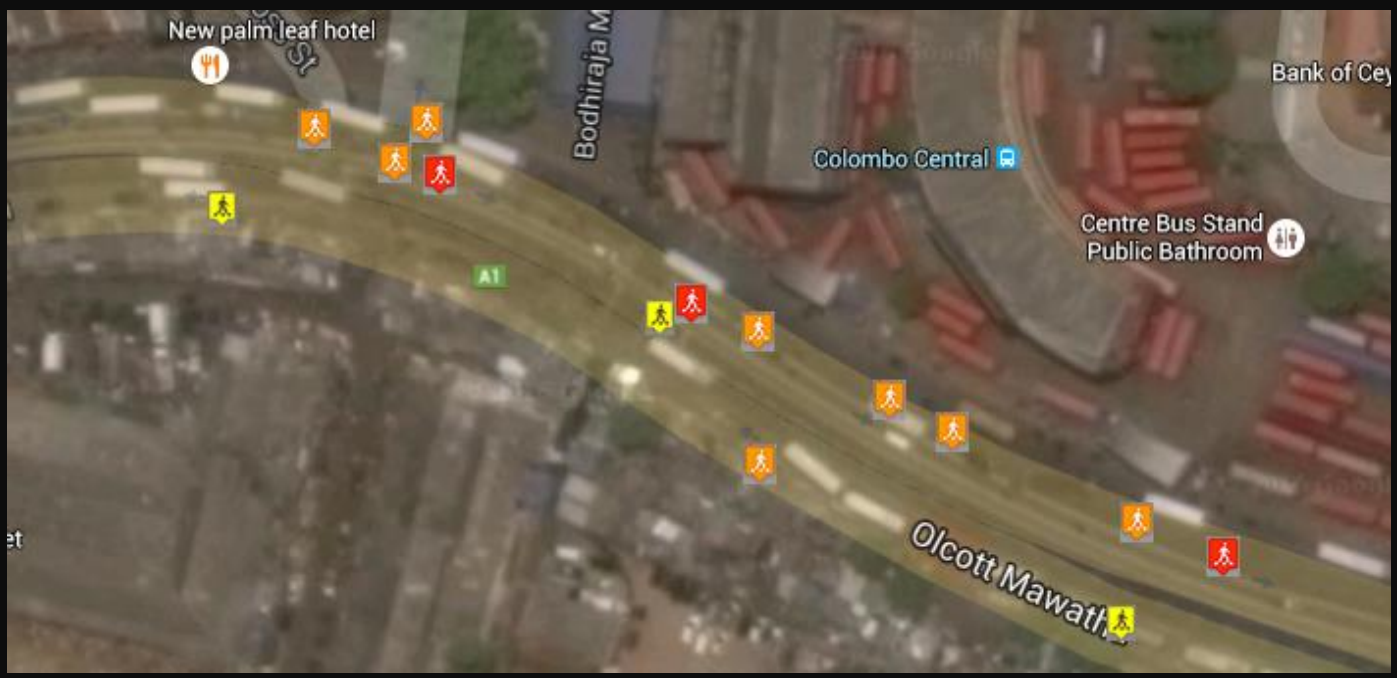



An example for ramp for the entering to sidewalk

An example for painted curb

# Location 1-Point 2

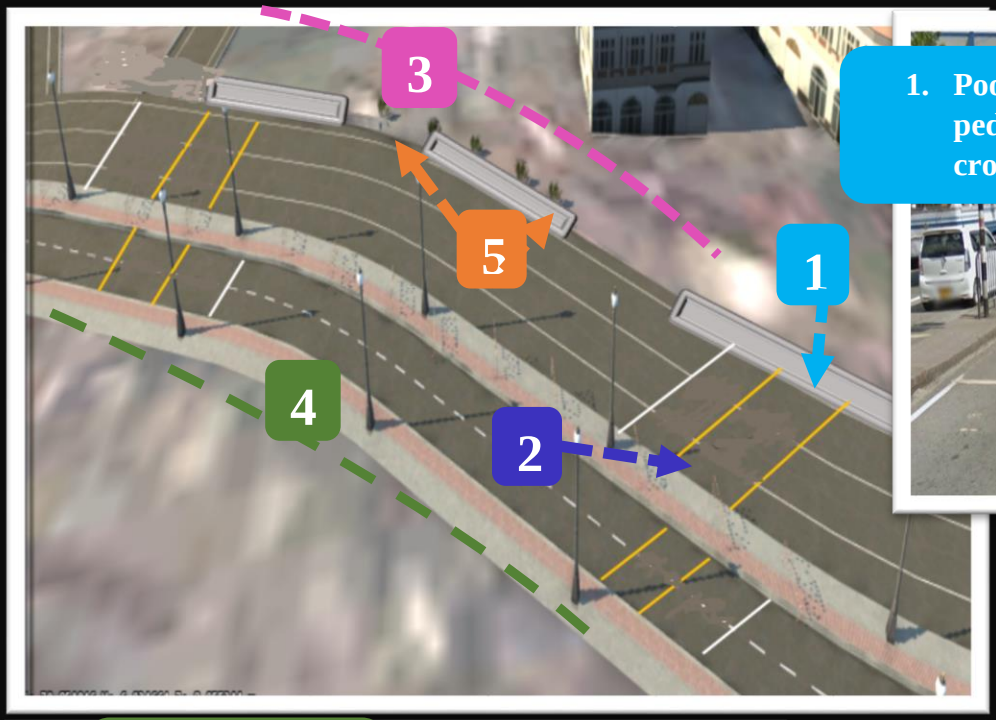
## Bodhiraja Mawata, Colombo, Western Province


Collision Map in Bodhiraja Mawatha

# Existing - Situation

## Bodhiraja, Colombo, Western Province





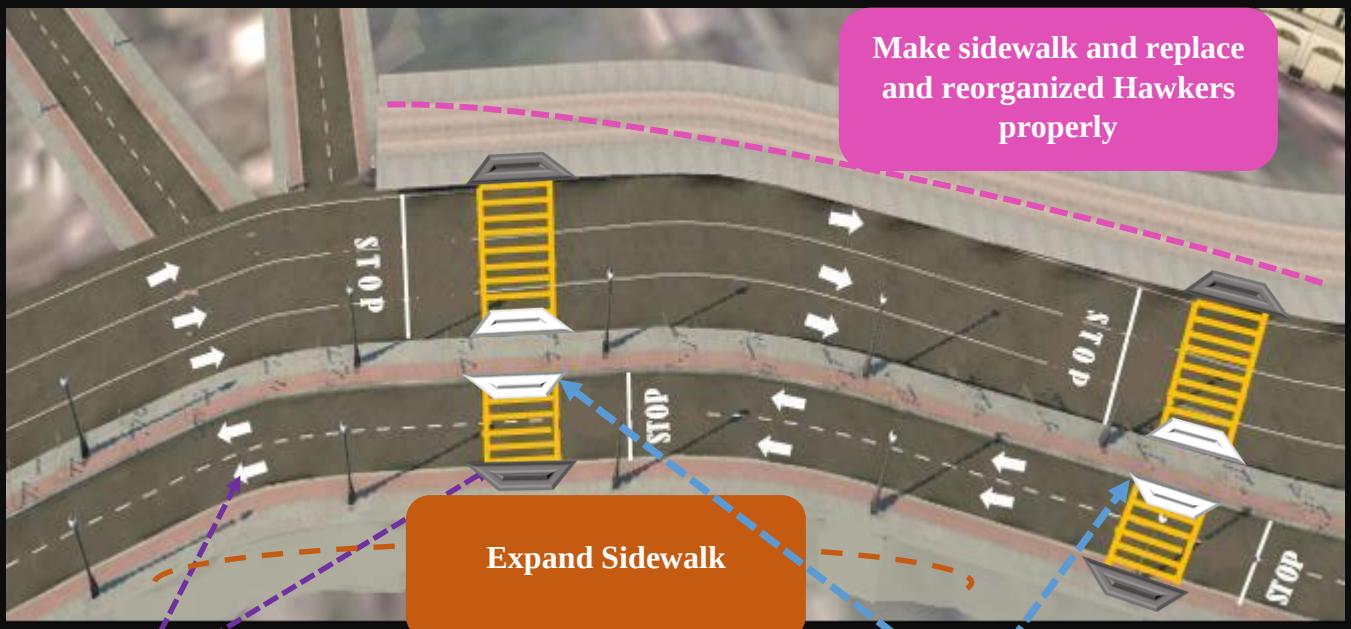


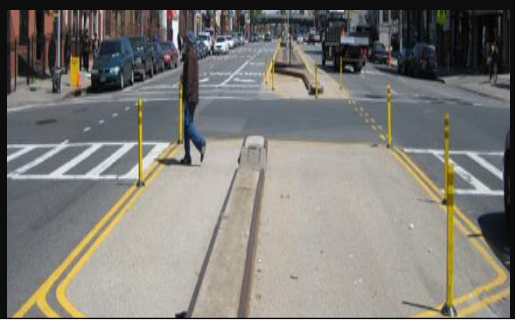

# Proposal

## Bodhiraja Mawatha, Colombo, Western Province

Organized Hawkers in Mumbai

Organized Hawkers in New York



Expanded median with painted curb-4th Avenue, Atlantic

# Location 1- Point 3

## Bastian Mawata, Colombo, Western Province



Collision Map in Bastian Mawatha

# Existing - Situation

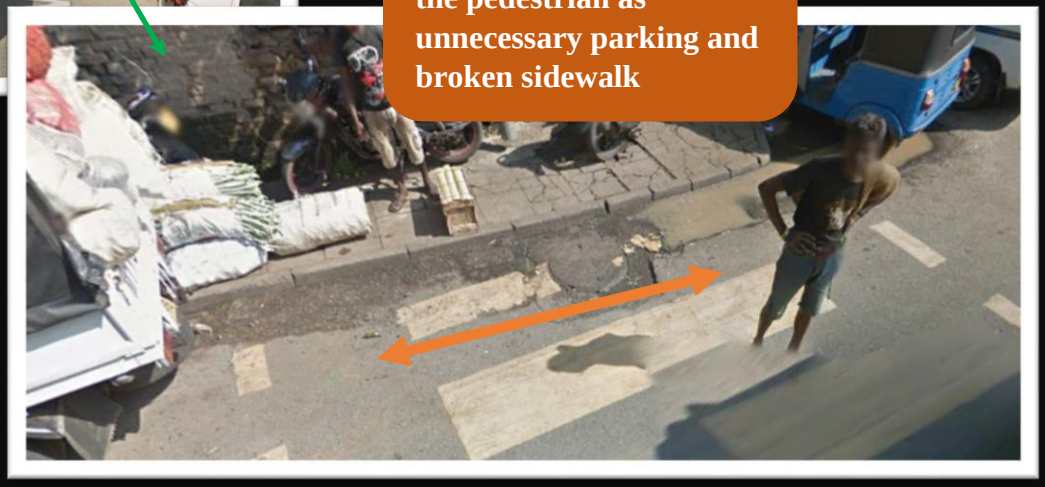
## Bastian Mawatha, Colombo, Western Province


**2. No sidewalk and inappropriate parking**



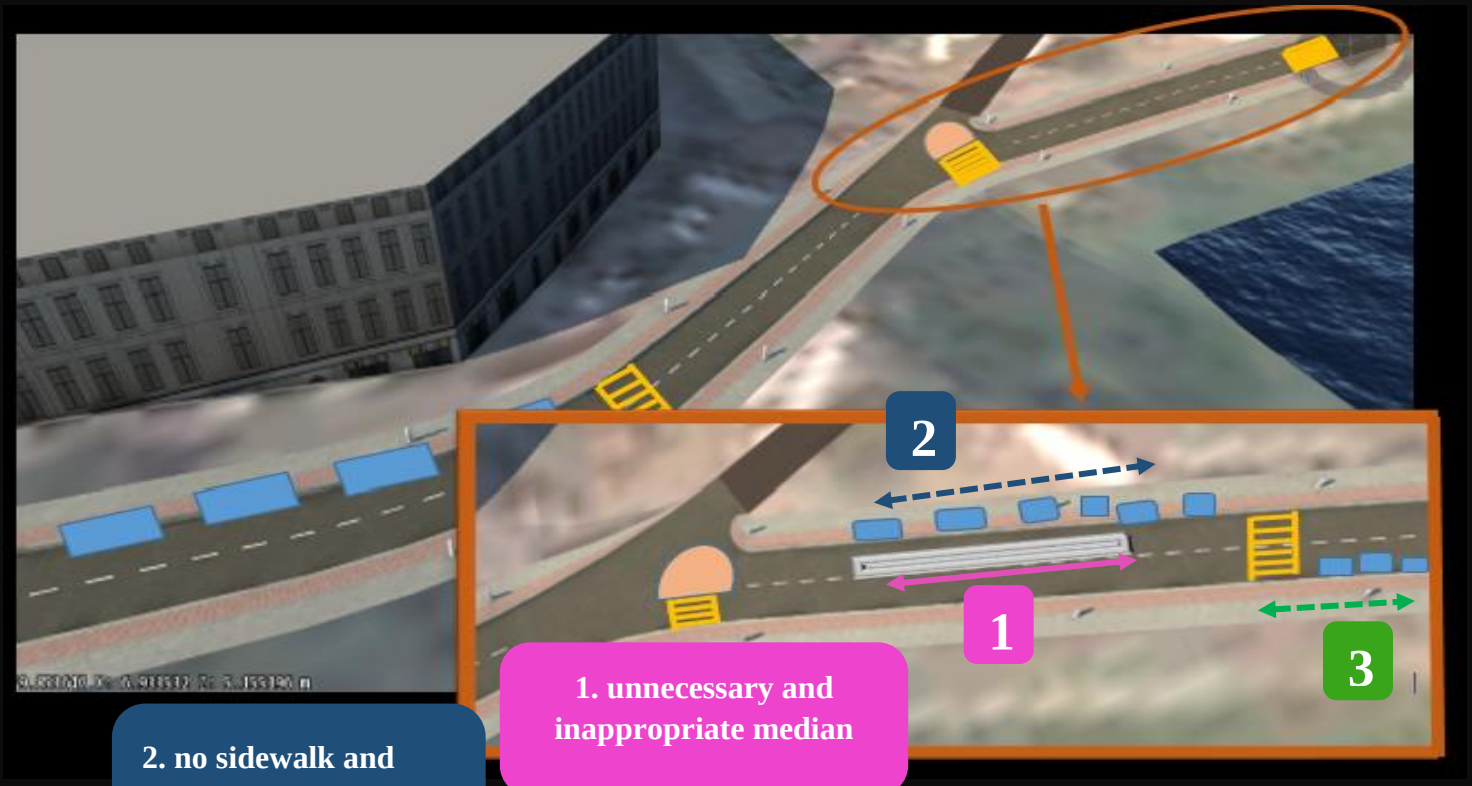
**1. Pedestrian cannot use this sidewalk as vehicle parking**

**3. No place to wait for the pedestrian as unnecessary parking and broken sidewalk**



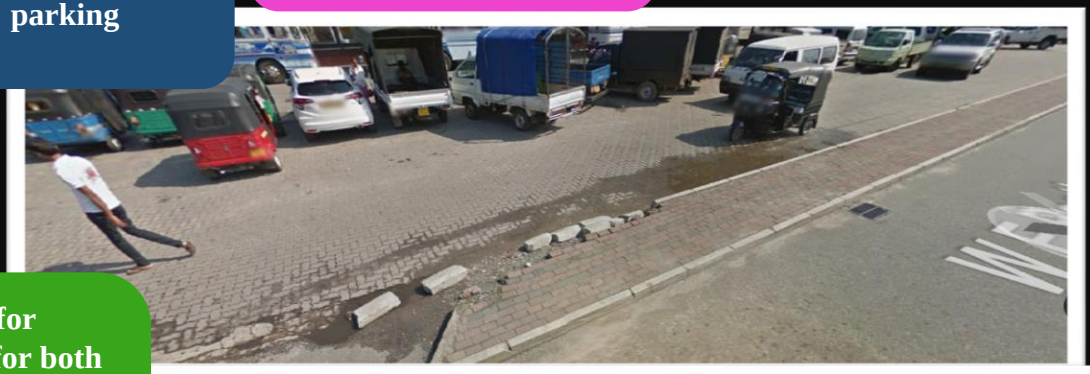
# Existing - Situation

## Bastian Mawatha, Colombo, Western Province




**1. unnecessary and inappropriate median**

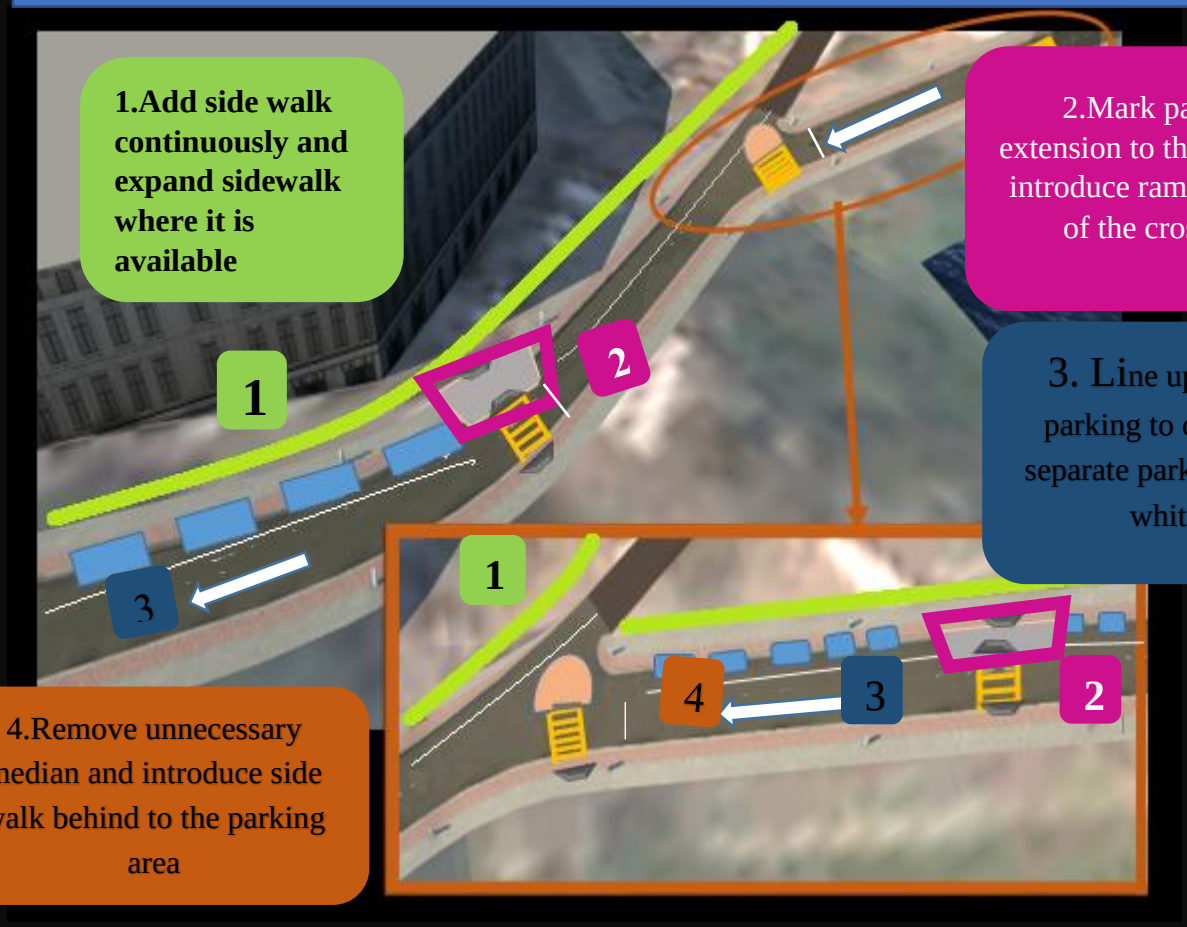
**2. no sidewalk and careless parking**



**3. No proper ramps for pedestrian crossing for both side and inappropriate parking both side and reduce the space for road**

# Proposal

## Bastian Mawatha, Colombo, Western Province




Existing situation in Bastian Road: unnecessary median and improper parking and no sidewalk

Example for the propose situation (Jerome Avenue New York): Line up vehicle parking and expanded sidewalk with painted curb extension

# Location 2- Dematagoda Junction

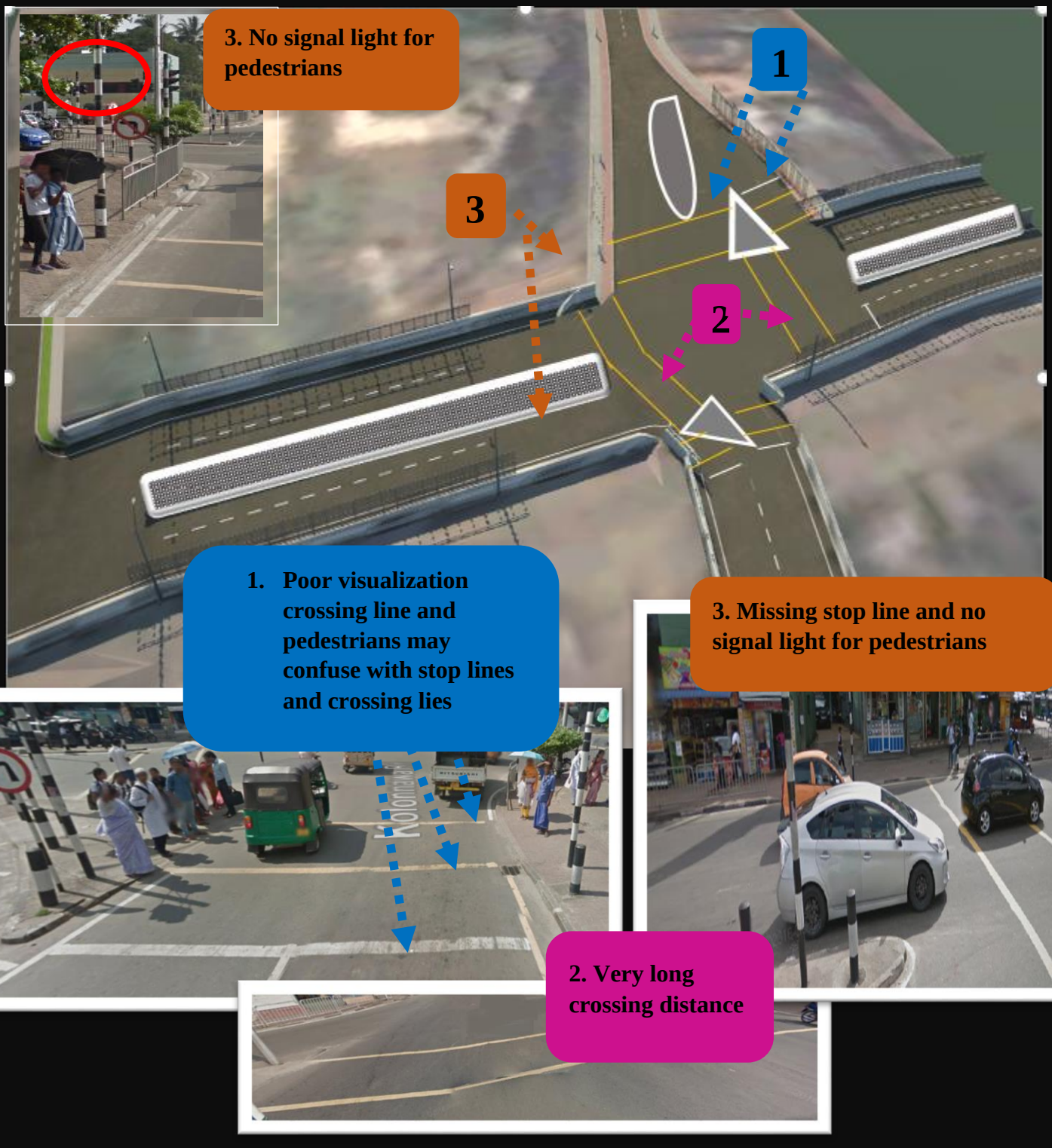
## Colombo, Western Province



Collision Map in Dematagoda Junction

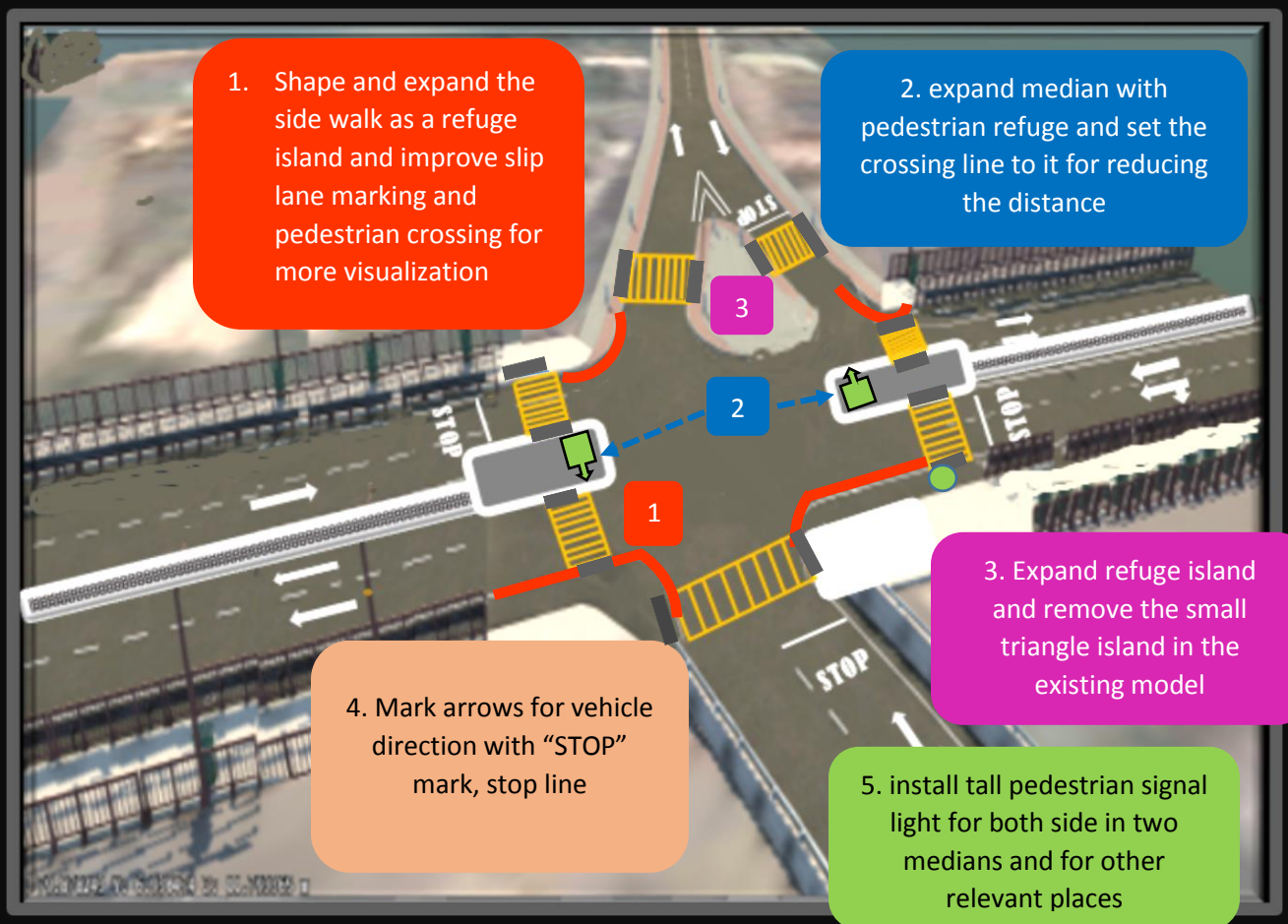
# Existing Situation-

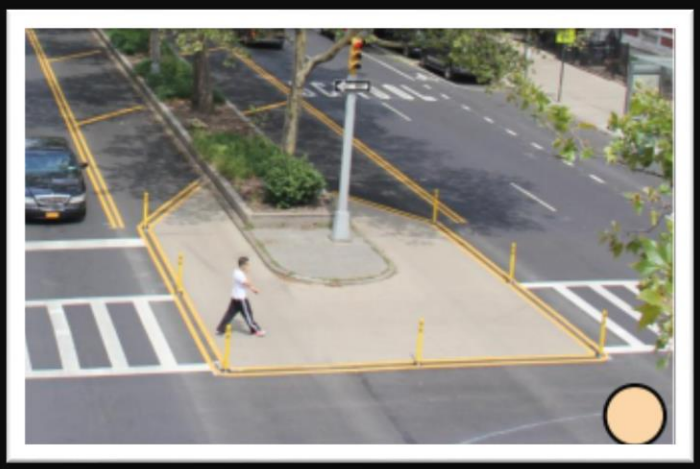
## Dematagoda Junction, Colombo, Western Province



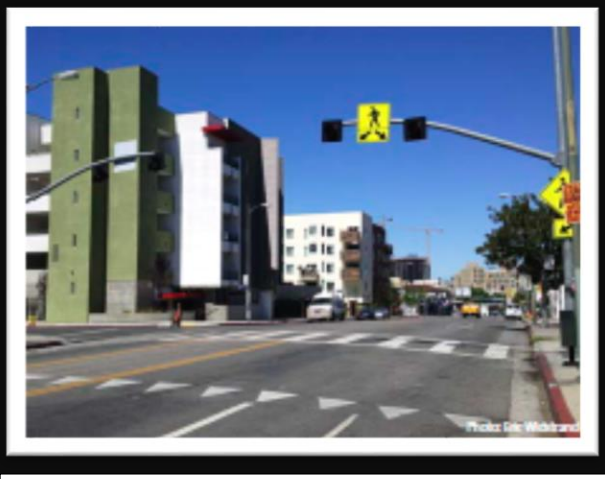
# Proposal

## Dematagoda Junction, Colombo, Western Province



An example for concrete median extension and refuge island.
*141st street New York*



An well suited tall signal light for pedestrian crossing specially for large inter sections
*Virginia – Lawyers Road*

# Location 3- Borella Junction

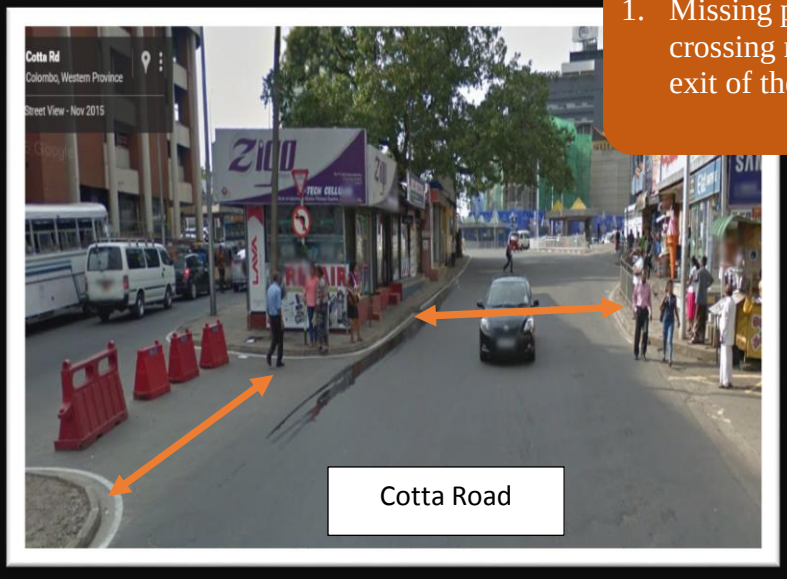
## Colombo, Western Province

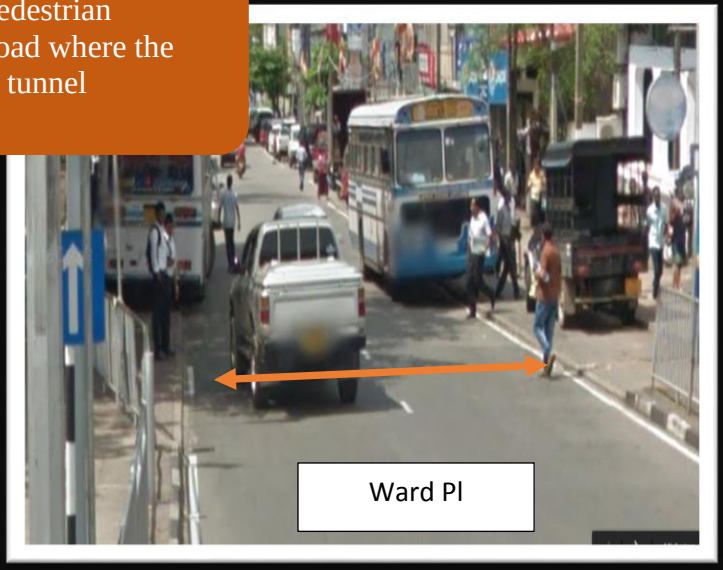

Collision Map in Borella Junction

# Existing Situation

## Borella Junction Junction, Colombo, Western Province

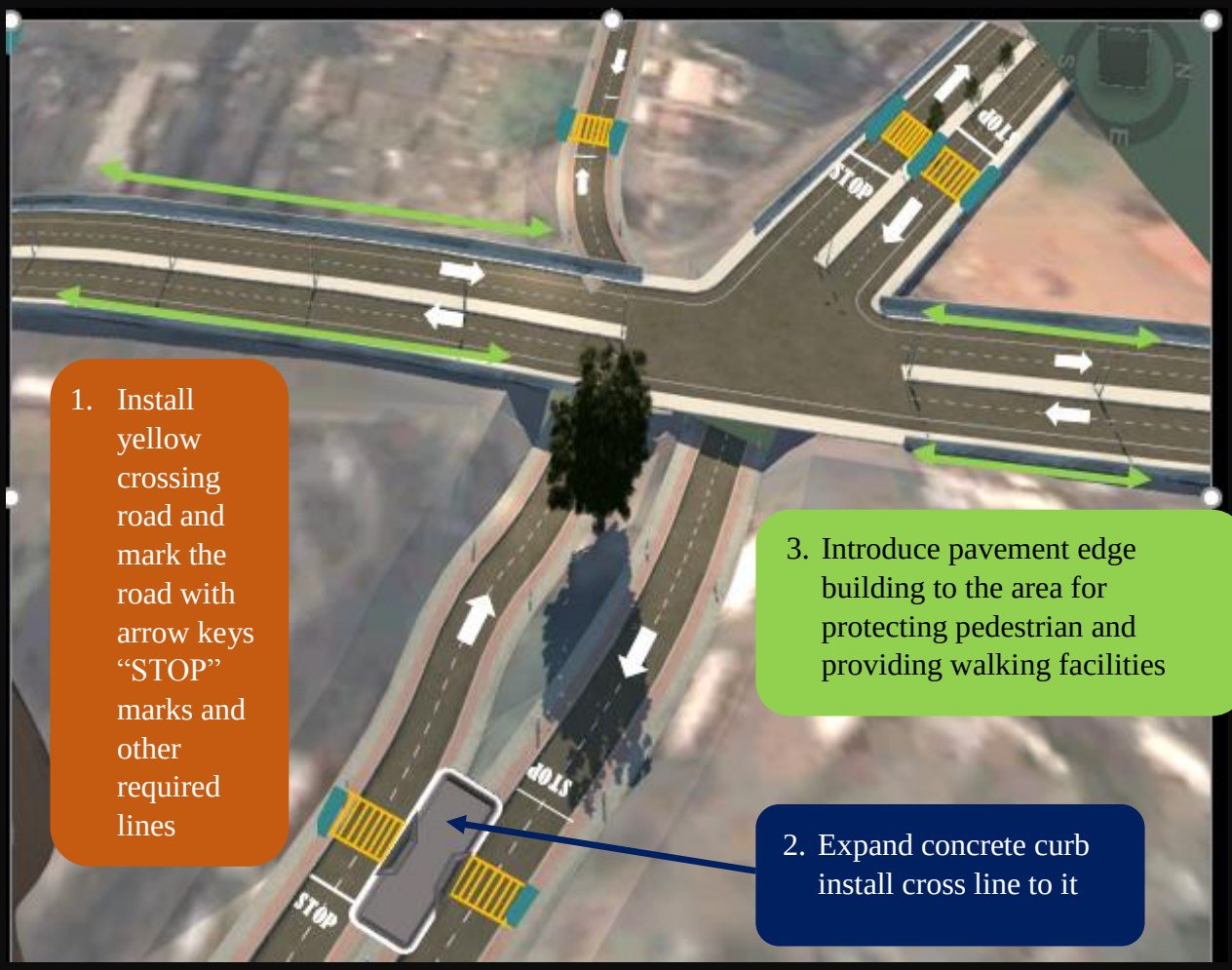

1. Missing pedestrian crossing road where the exit of the tunnel



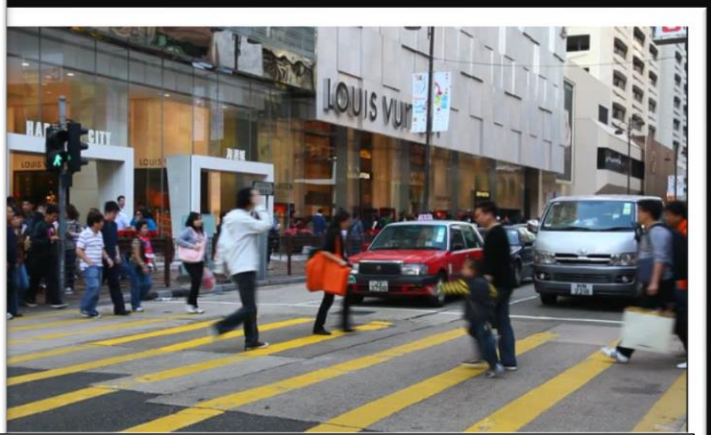



# Proposal

## Borella Junction Junction, Colombo, Western Province




Example for Pavement edge building
*Street Design Guidelines © UTTIPEC, DDA 2009*



Example for pedestrian crossing in front of a tunnel exit
*Hong Kong, China*

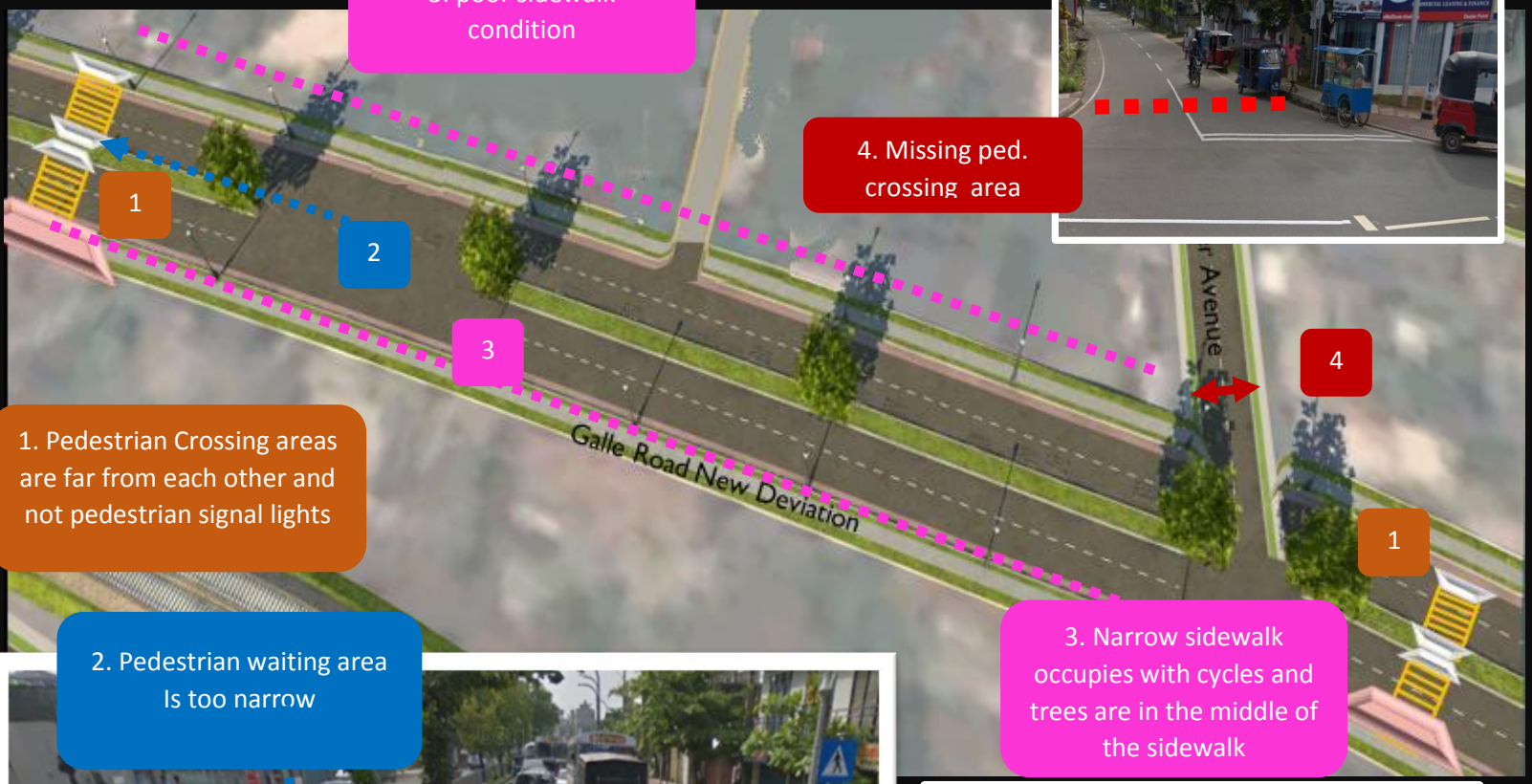
# Location 4- Fraser Avenue, Galle Road

## Colombo, Western Province


Collision Map in Fraser Avanue

# Existing Situation

## Fraser Avenue, Galle Road, Colombo, Western Province



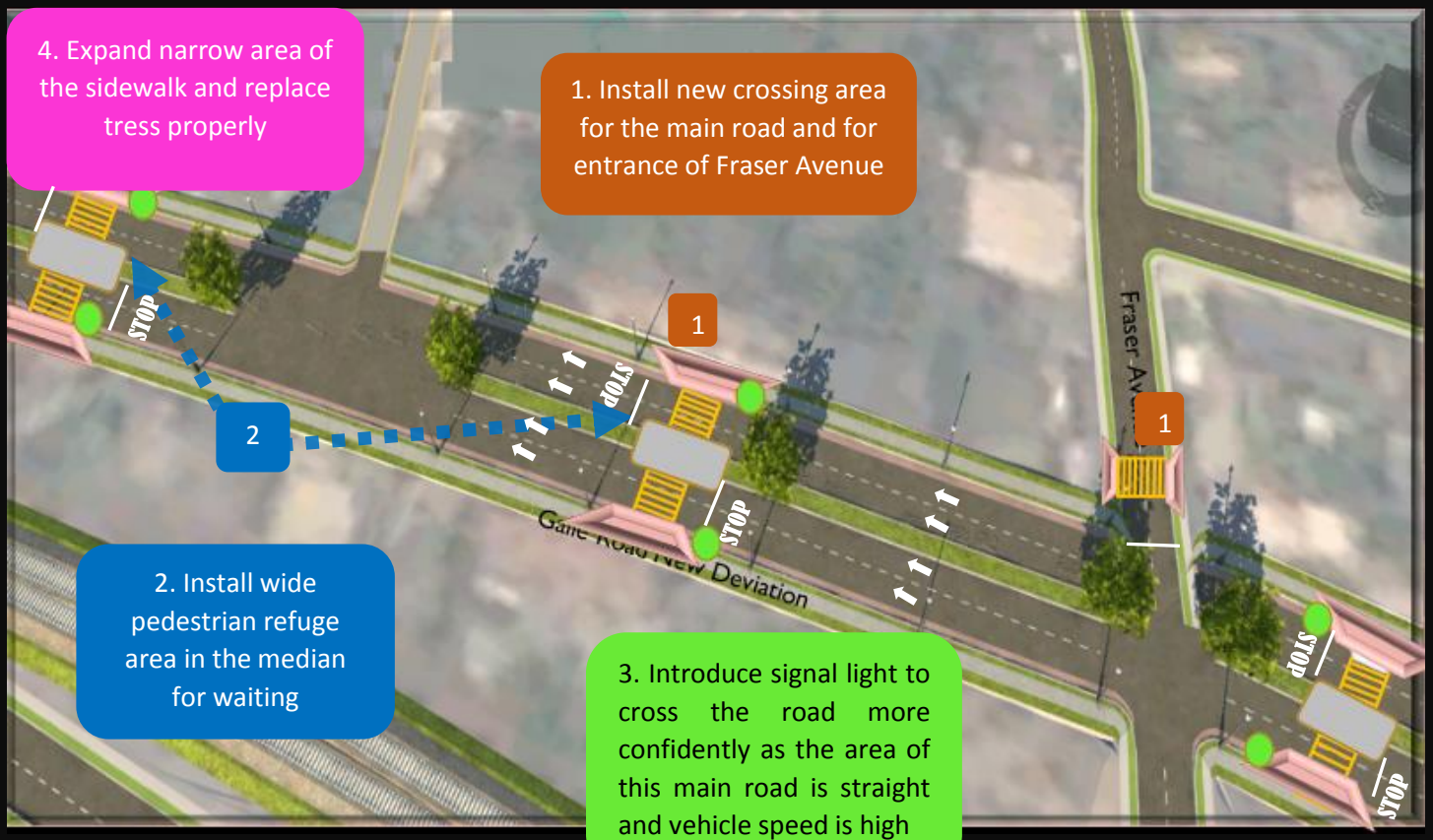






# Proposal

## Fraser Avenue, Galle Road, Colombo, Western Province




2. Newly constructed ped. Refuge area of the median in the same road but in different area

*Katubedda, Moratuwa, Sri Lanka*

# Location 5- Library road

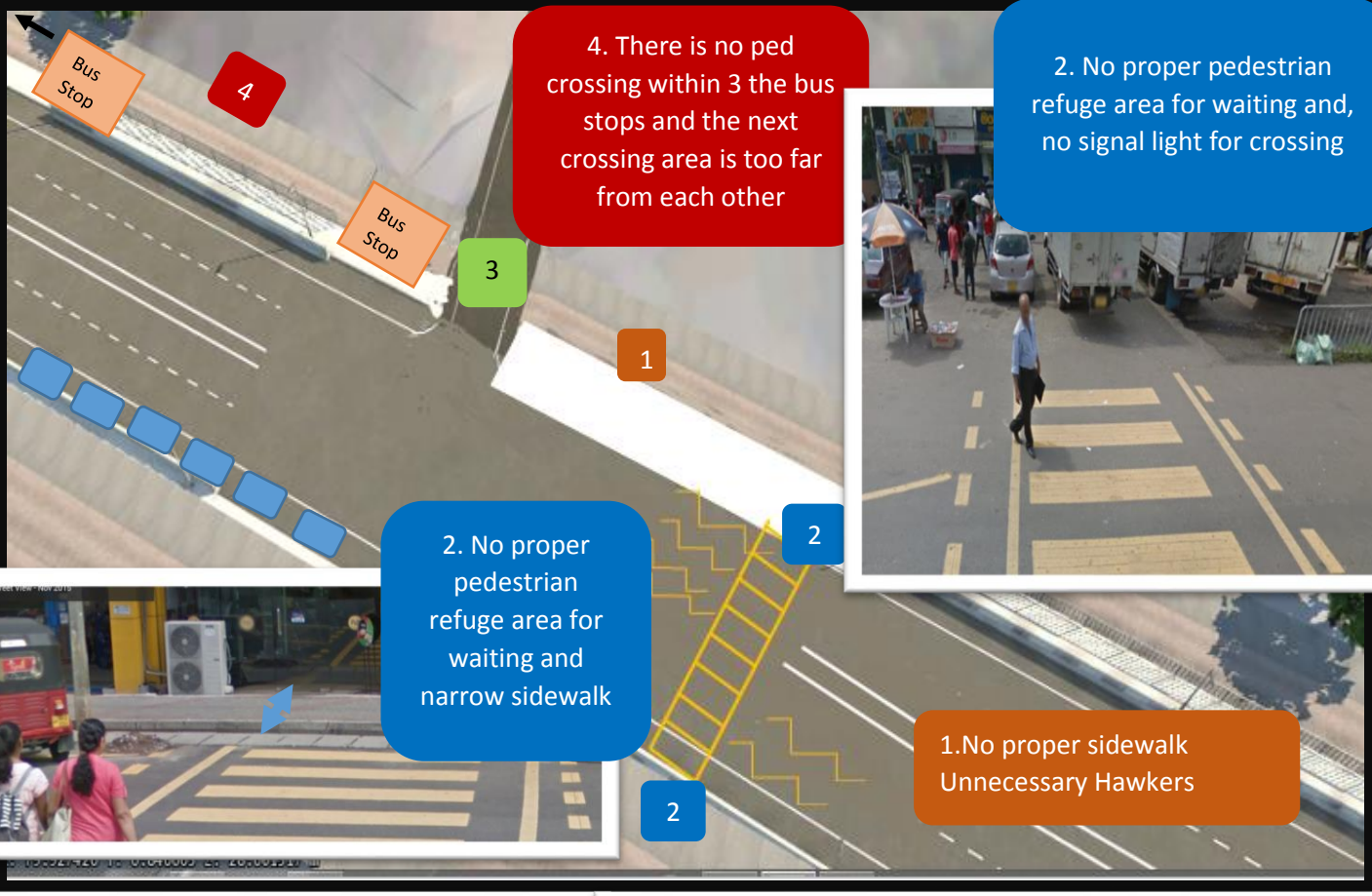
## High level road, Colombo, Western Province



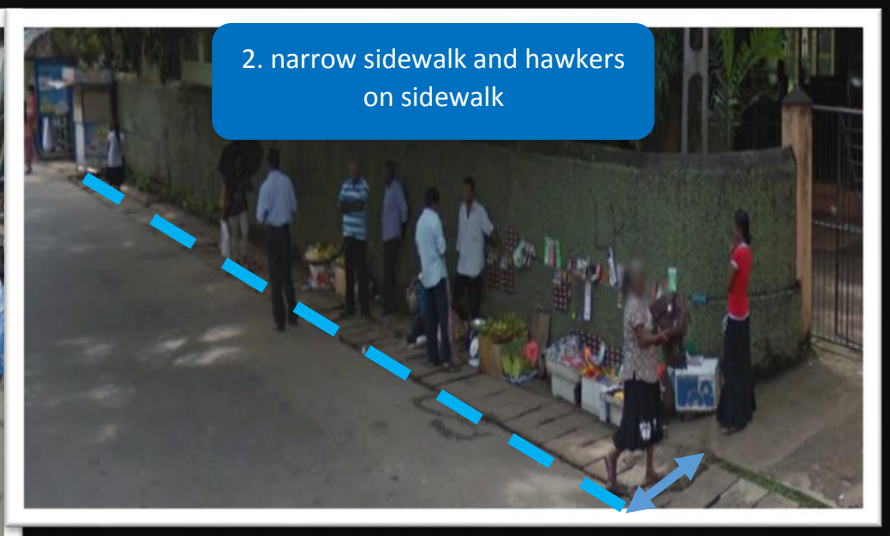
Collision Map in Library Road

# Existing Situation

## Library road, High level road, Colombo, Western Province

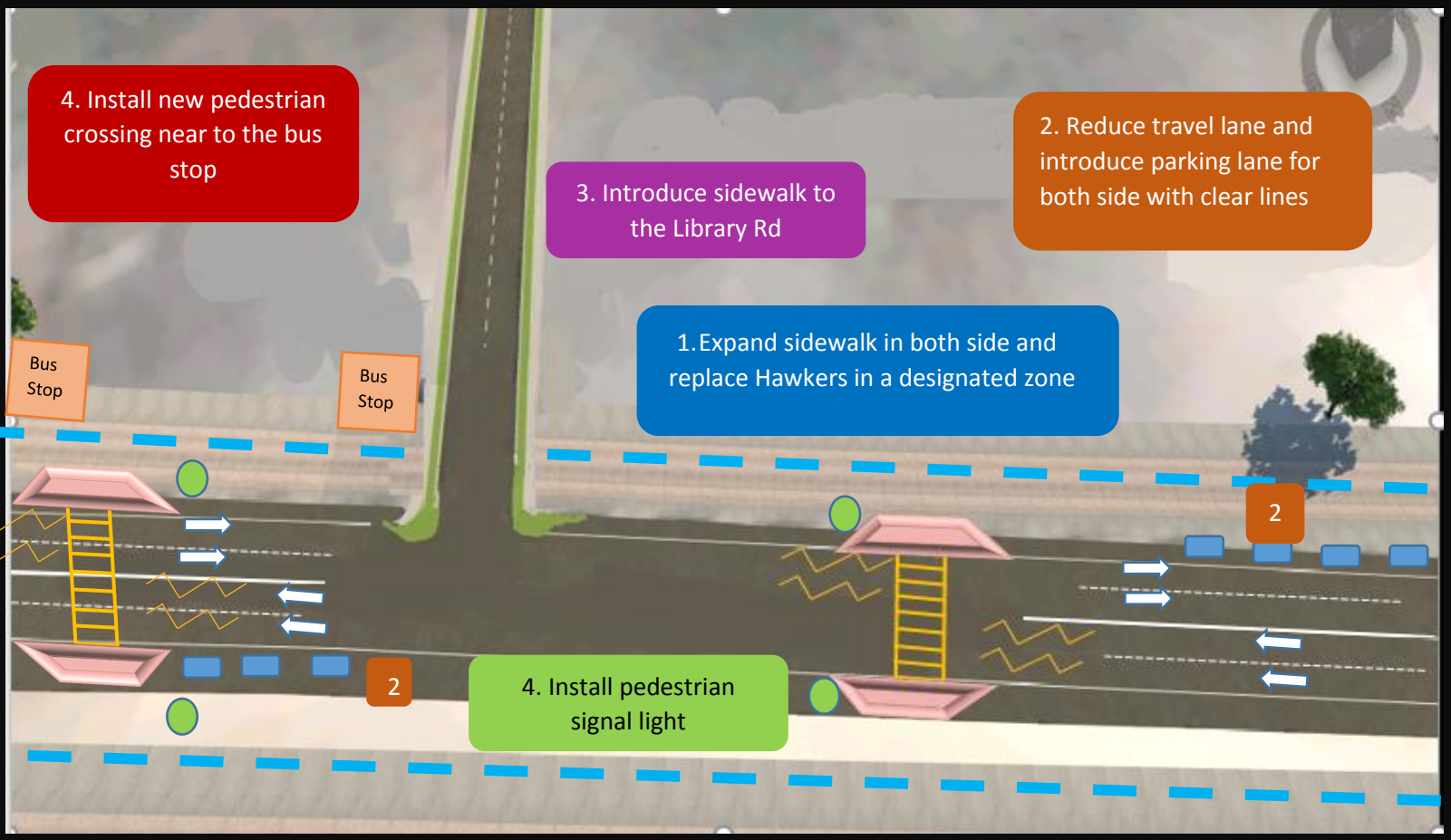






# Proposal

## Library road, High level road, Colombo, Western Province



# Location 6- Nugegoda

## Nugegoda, High level road, Colombo, Western Province

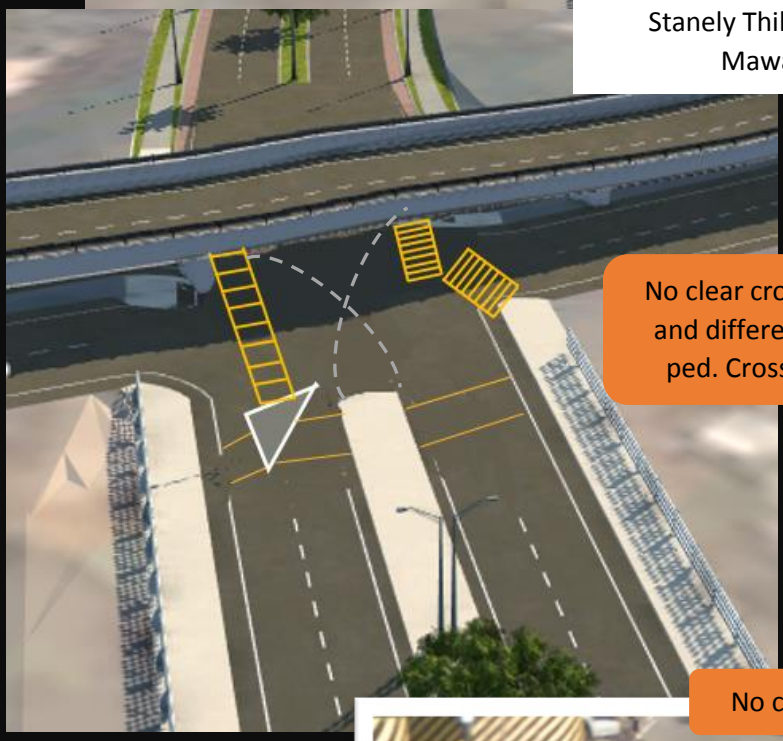


Collision Map in Nugegoda

# Existing Situation

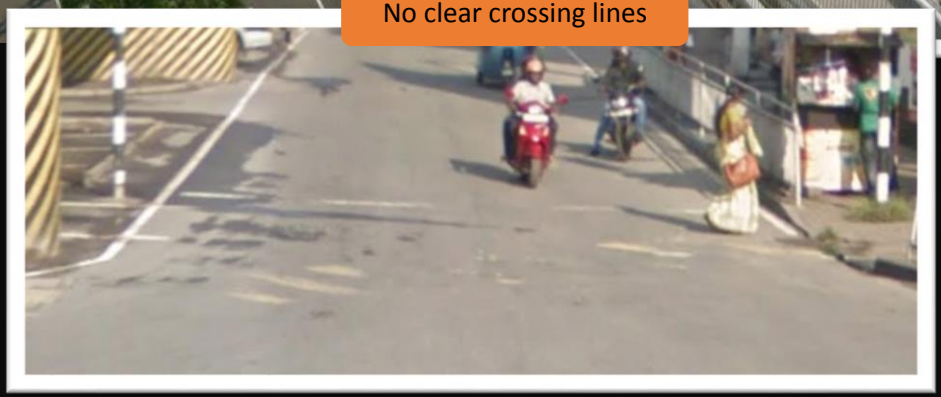
## Nugegoda, High level road, Colombo, Western Province


Stanely Thilakarathne Mawatha

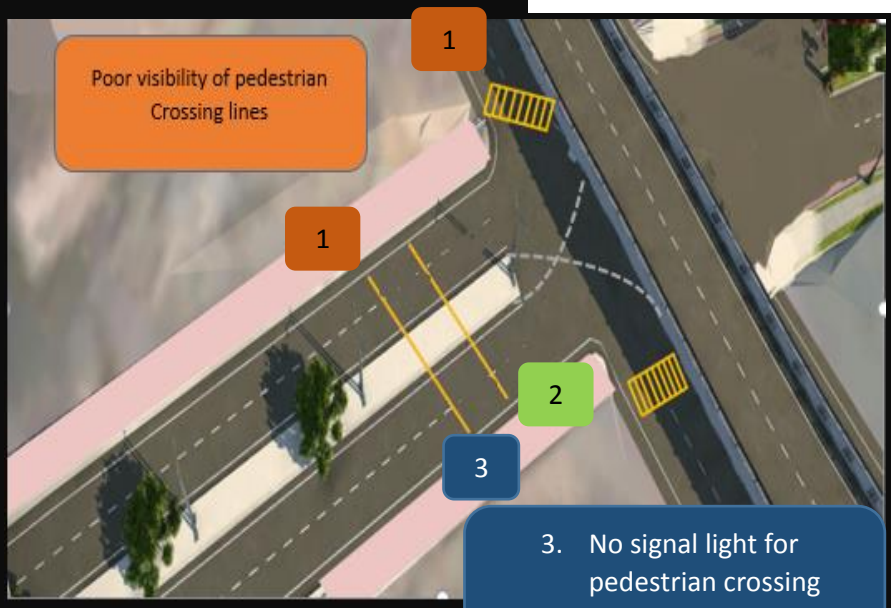


No clear crossing lines and different kind of ped. Crossing lines

No clear crossing lines

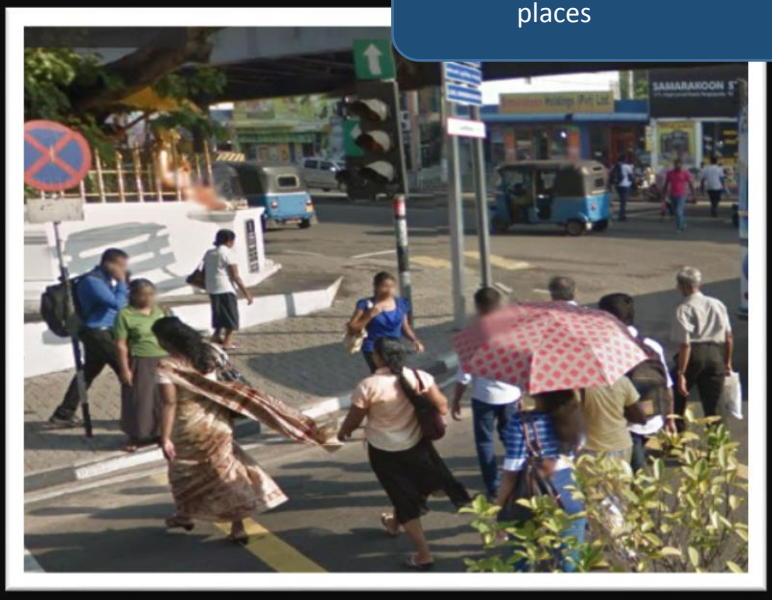


S Des Jayasinghe Mawatha




2. concrete ramp are not at the curbs of pedestrian crossing places

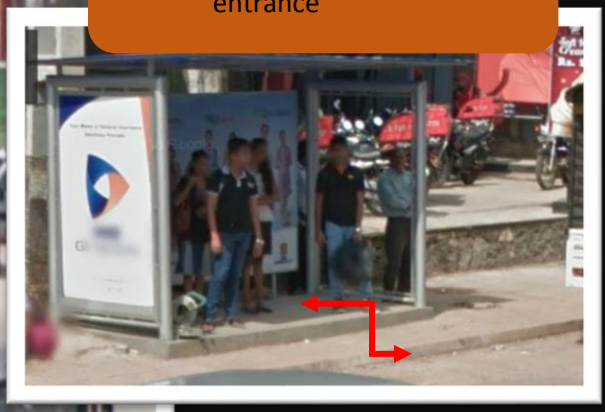
3. No signal light for pedestrian crossing places



1. Poor visibility of pedestrian crossing places

High Level Road, At end of the bridge





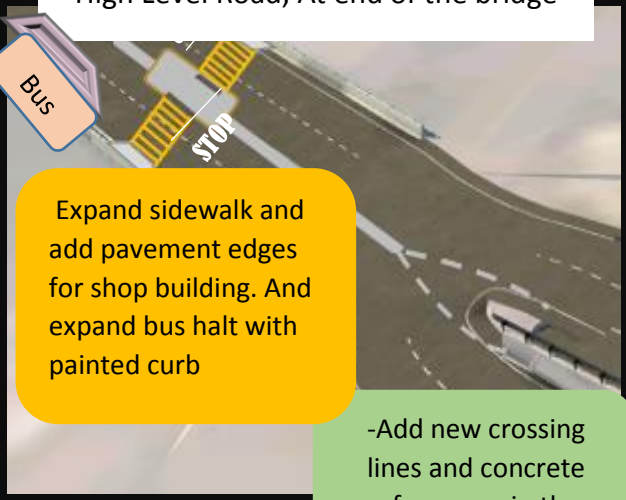

# Proposal

## Nugegoda, High level road, Colombo, Western Province

Stanely Thilakarathne Mawatha


Clearly mark the crossing lines and other marks . Install the concrete ramps

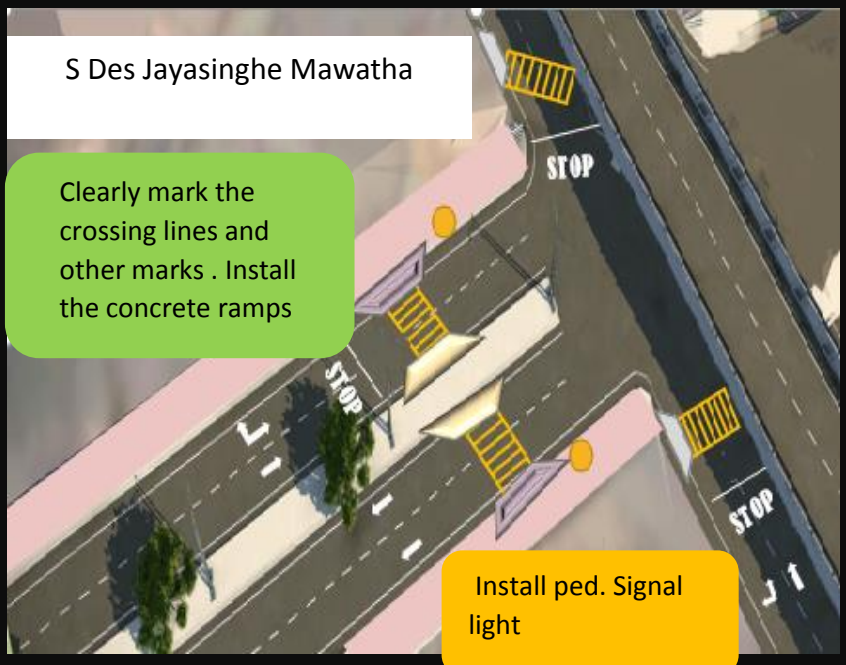
High Level Road, At end of the bridge




Expand sidewalk and add pavement edges for shop building. And expand bus halt with painted curb

-Add new crossing lines and concrete refuge area in the median.

S Des Jayasinghe Mawatha




Clearly mark the crossing lines and other marks . Install the concrete ramps

Install ped. Signal light

## 5.4 Significant of the Research

The main contribution goes to the selected field through this study. This research is categorized as a field study. The selected field is the Colombo Metropolitan Area in the western province of Sri Lanka. As mentioned in the section of Motivation, this area is a critical area with the aspect of transportation sector. The experts in the field of transportation sector have identified the importance of increasing public transport mode share and reducing private vehicle usage in the area to reduce the traffic congestion [13]. On the other hand, western province nearly 50% of national GDP is contributed [82] and 1.5% of country GDP was losing due to traffic congestion [11]. Hence identification of the opportunities to find the ways for reduction of traffic congestion through encouraging traveler for public transportation is very important. Not only that, high rate of accidents and lack of safety on roads, specially for pedestrians are the other critical reasons to select this field. Researches related to the development of transportation sector in the field of CMA is very low. Specially this study related to the mode choice behavior in the field of CMA is unique as it could not be found from the past research studies from the field.

In the section of mode choice analysis in this study has an originality even it has been used well known statistical approaches, as most of the studies focus for one particular trip purpose or one category of subject participant. For instance, as mentioned in Chapter 2, some studies focused only for workers, university student etc. and/ or only for the purpose of shopping or schooling etc. However, this study focuses all regular trips for all members who were more than 15 years old of a household in the study area. From the section of safety and accident analysis, the way of approaching to the location safety issues and solution to improve the pedestrian facilities is unique in this study.

## 5.5 Limitations of the Study

There are several limitations can be identified of this study.

- The analyzed data in the section of mode choice behavior analysis was collected from the pre-formatted questionnaire. Even the sample population is in the required level according to the Solvise' formula, the residence response rate is limited. Thus the decisions are based on the limited range of responses.

- The analyzed data are based on different assumptions according to the selected statistical tools.
- In the same section with the access mode analysis considers only the access mode choice behavior but not considers about the egress mode choice behavior.
- Even this study can conclude with a solution by proposing and designing road to improve the safety facilities, it cannot be implemented to check the benefits and accuracy within the time duration of this study period.
- Relatively high installation cost for the proposed solution and difficulties with the rules and policy of the government bodies and decision makers are the other limitations.

## 5.6 Chapter Summary

This chapter conveys and explains profoundly the results which are received from the previous two chapters. Afterwards it denotes a specific solution with as a proposal for the improvement of safety facilities for the pedestrians by considering founded results. The limitations and the strength and major contribution from the research domain have been discussed at the end of this chapter.

The first part discusses about the factors influencing to mode choice behavior of the residence. According to that section, peoples who have low income level, likely to use the public transport. Most people use public transport for long distance trips and young people greatly use public transport. it may for the purpose of education as they do not have any vehicle ownership. When selecting public transport people much think about the time reliability than the comfort and safety as they do not have trustworthiness about the time reliability of the public transport. Most private vehicles use for a short distance trip at the peak hour by the residence in the study area. The study area is an economically activated area and always fill with vehicles and peoples. If the residence is also driving private vehicles to the city, the traffic congestion will be increased terribly. Thus encouraging people for the public transport is vital. According to that, further analysis the public transport users with Logistic Regression Analysis to find a probability tendency model with most significant variables. Number of earning members in the household, Vehicle ownership, Gender, Age, Education, Occupation, Trip Distance, Trip Time, Total Cost and Safety were the significant factors that mostly affected to the mode choice of public transport. Further, by using the designed model, the peoples can be assessed whether he/she tend to use public transport or not. In addition

to that, how access mode choice behavior is affected to the decision of public mode choice was assessed using SEM approach. According to the developed model, access mode choice is affected to the mode choice of public mode choice and thus developing access mode choice facilities may influence to encourage people for the public transport.

The other main part of this chapter discusses about the safety and the road accident in the western province of Sri Lanka. Pedestrian accident of the study area is focused for further analysis as pedestrian accidents are greatly occurring and public transport share can be increased when pedestrian safety facilities are increasing. When analyzing crash data, a model was calibrated with focusing the accident severity. From that model, it was identified that the pedestrian location is a significant point for the accident severity. Thus the pedestrian accident was mapped with GIS software and run the hot spots analysis to find the locations for high rate of pedestrian accidents. Then there are nine critical points have been identified in the western province. As a further analysis, those locations were investigated with crash characteristics in order to find the safety issues on road. As a proposal, the locations were newly designed with new solutions with a road designing software. Finally, this chapter presents about the strength and research contribution to the research domain and limitation of the study.

# CHAPTER 6

# Conclusions and Recommendations

## 6.1 Conclusions

Traffic congestion is a main burden case associated with increasing the risk of road accidents and greater use of private vehicle in the urban area. Public transport service is a remarkable solution to reduce the traffic congestion in the urban area. Hence encouraging traveler for the public transport is vital and an essential requirement for the economic development while mitigating traffic congestion.

The traffic growth rate per annum in Sri Lanka is measured with private bus and train transport growth rate were 5% and 0% respectively. But private transport growth rate was 60% [91] in 2012. This awful situation was motivated to select the Colombo Metropolitan Area (CMA) in the western province of Sri Lanka as the study area. Because, most economic activities (around 50% of GDP) are coming from this region and trip demand and private vehicle usage of this region are increasing rapidly. It has been estimated that growth rate of trips by car accounts six times while public transport growth rate accounts only 1.5 times during the period of 2013-2035 [11]. Hence development of the public transport of this study area is an essential requirement. According to the previous studies, over 50% of residence in the Colombo area are unhappy about public transport and its operating system [10]. Thus encouraging people for the public transport is required to the development of public transport. Hence the objectives of this study lead to identify the most inducing factors to optimize the public transport with the aspects of mode choice behavior and safety facilities. Then the study was starting from the identification of feasible field for the data collection and then identified the factors influencing to mode choice behavior for private and public modes, assessed the relationship between access mode choice and public mode choice and evaluated the road accidents in the study area and evaluated the road accidents and measure the severity impacts to the public transport.

CMA in the western province of Sri Lanka includes three main districts including the capital city of Sri Lanka and its includes 20 DSDs. Urban structure, transport network, traffic congestions, population distribution and even strategic transportation programs are highly varied since these 20 DSDs are in three different districts including capital of Sri Lanka. Hence, with the intension of collecting more accuracy data sample, a feasible field needed to be found from the selected area. Accordingly, 11 DSDs were recommend from a specific analysis method for the further analysis. The one of the main objectives was to identify the most influencing factors for the mode choice development of the public transport and private transport. For that, a pre-formatted questionnaire was designed and delivered to the 11 DSDs for the data collection. After attainment of statistically significant number of sample population from the residence subjects, the next objective of inducing factors for mode choice behavior was running by using descriptive statistic and factor analysis.

According to the factor analysis and descriptive analysis, peoples who have low income level likely to use the public transport. Most people use public transport for long distance trips and young people greatly use public transport. it may for the purpose of education as they do not have any vehicle ownership. When selecting public transport, people much think about the time reliability than the comfort and safety as they do not have trustworthiness about the time reliability of the public transport. Most private vehicles use for a short distance trip at the peak hour by the residence in the study area. If the residence is also driving private vehicles to the city, the traffic congestion will be highly increased as this economic activated area always fills with peoples and vehicles. Thus it is substantiating that the importance of improving the public transport. Logistic Regression was used to find a probabilistic model with most significant factors for selecting public transport. Accordingly, it is emphasized and proved that the earning capacity, vehicle ownership, gender, age, education, occupation, trip characteristics and safety are highly affected to the public transport mode choice and the formatted model can be predicted the travel behavior of wide variety of people and their mode choice as a probability with these significant factors. The model accuracy is 78.4%.

The other objective is to find the relationship of the access mode with public mode choice behavior. As a model calibration with most inducing factors, this study attempts to formulate a model with running SEM modeling method, beyond the conventional modeling approaches. The developed

model shows that the access mode choice is affected to the public mode choice. First select the public mode and then select the access mode for the journey. Hence improving access mode facilities is one critical point to increase the attractiveness of the traveler for the public transport.

The last objective is to evaluate the road accident and measure the severity impacts to the public transport. When considering about the transportation sector, road safety is an important factor as the rapid increment of road accident in the world is demanding urgent attention. In Sri Lanka, there was a significant number of road accidents occurred particularly around 59% were accounting from the Western Province (WP) of the country. On the other hand, the 29% of fatal accidents from the category of Pedestrians, but including non-fatal accident, the pedestrian accidents come to the highest place of road accidents in Sri Lanka [82]. This high rate of pedestrian accidents implies that the traveler hesitates to access the public transport as this unsafe situation and most of pedestrians are the public transport users. Thus the improvement of pedestrian safety facilities leads to great access of public travel modes. The previous sections of factor identification also illustrate that the peoples think about the safety but they did not have trustworthiness about the public transport with the aspect of safety. Even the public transport had low safety, peoples used the public transport due to the low income levels. On the other hand, private vehicle users choose their own vehicle because of the high safe than the public transport. Hence, analysis of road accident and pedestrian crashes is important to find the critical places and issues. Accordingly, past five years (2010-2014) of accident data in the western province of Sri Lanka was collected from the Traffic Police Division in the western province. More than 99,500 accident data was available and it would be a strength of the analysis to be more accuracy. From the descriptive analysis of the data, it has identified that the pedestrian and Motor cycle accidents are very high when comparing with other modes in the selected area. Moreover, SEM method was use to find the most influencing measures for the severity of the accident. Road locations, weather, lighting condition, urban/rural area, age and gender of the casualty directly influence to the severity of the accidents. Accordingly, under the road location, pedestrian road location is highly significant for the severity of the accidents. As the majority of pedestrians are the public transport users and improving pedestrian facilities is vital for the improvement of public transport. Pedestrian accidents were evaluated within the five years of period by using Hot Spots analysis with Arc GIS package to find high rate of pedestrian accident locations. According to that analysis, there are

nine pedestrian accident prone locations have been identified for the improvement of safety facilities. Thus the all defined objectives are achieved as a fulfillment of the research work and the findings of this study will be aided for the decision makers and road design engineers to improve the public transport sector in Sri Lanka. As a further analysis, the high rate of accident locations were investigated with crash characteristics in order to find the safety issues on road. As a proposal, the locations were newly designed with new solutions with a road designing software.

## 6.2 Recommendations

- Related with the characteristic of journey, travel time, travel distance and the travel cost are associated with probability to choose mode for the regular activities. Thus it is important to make some policies related with these factors. The policy makers must intervene in providing sufficient public bus services to operate and increasing frequency of buses for root with a fixed time table to provide an efficient service to the public while saving their time. On the other hand, the road passenger loading rules must be properly provided particularly for long distance trips.

- Based on the factor of safety, it is important to build a communication strategy to aware people about the traffic rules and regulations while improving the road discipline of passenger and motorists to reduce the road accident. And also the city traffic regulations should be properly managed to minimized purposeful violation of traffic regulation.

- Vehicle ownership is another factor that mostly influence to the mode choice for the people. Increasing vehicle ownership in Sri Lanka is also a huge problem in the transportation sector. It is impossible to make policies to control purchasing a vehicle for the purpose of private usage. Introducing some strategies like high tax rate for purchasing vehicles and so on etc. it can be reduced the effect from private vehicle on road and traffic congestions.

- The passenger can be encouraged to move to rail from road is a decent strategy to change the people behavior on motorization. Introducing easy access way for the rail way station, elevator facilities and new ticketing system are the ideal solutions.

- The current road design is very deprived particularly for the pedestrians. For example, Sidewalks, waiting refuges, concrete curb are not in a proper way. Recommended solutions were represented for the high accident prone locations in the Colombo area which this study was found. As a proposal, the solutions have been designed with a road design software (Infrawork 360) in Chapter 5.

## 6.3 Future Work

The future work will be based on the specific proposed solution which this study mentioned in Chapter 5, for the road design of the selected locations in this study. The solutions are given to increase the pedestrian facilities on road with the intention of encouraging people for the public transport. If the pedestrian facilities are in a good condition, then the traveler tends to access the public transport without hesitating. It is a way of increasing public mode share. The next step of this study will be to assess that solution with expert's ideas. Thus in order to get that ideas for validating this solution, the proposal should be sent to the experts with a pre-formatted questionnaire. The questionnaire should be created in different formats by considering different respond categories such as road design engineers, government responsible bodies and policy makers etc. Thereafter, analyzing their ideas, the proposed solutions would be changed or proceed for the success under the government approval.

# Reference


[1]. Sigrún Birna Sigurðardóttir, Drivers of sustainable future mobility: Understanding young people's travel trends and the mediating factors of individual mobility intentions, PhD thesis, Department of Psychology University of Copenhagen, pp 1-2, 2013.

[2]. World Economic Forum, Sustainable Transportation Ecosystem, Industry Agenda, pp 4, 2012.

[3]. John Dulac, Global transport outlook to 2050, Energy Technology Policy Division International Energy Agency, 2012.

[4]. Walker J, Li J. Latent lifestyle preferences and household location decisions. Journal of 2 Geographical Systems, pp 77-101, vol 9(1), 2007

[5]. The World Bank, Urban Transport, The link access on 2016/7/27, http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTTRANSPORT/EXTURBANTRANSPORT/0,,menuPK:341455~pagePK:149018~piPK:149093~theSitePK:341449,00.html

[6]. World Health Organization, Global Status Report on Road Safety, Department of Violence & Injury Prevention & Disability (VIP), Switzerland, 2009.

[7]. World bank and World Health Organization, World Report on Road Traffic Injury Prevention: Summary, Geneva, 2004.

[8]. Amal S. Kumarage, Impacts of transportation infrastructure and services on urban poverty and land development in Colombo, Sri Lanka, Journal of Global Urban Development, Vol 3(1), 2007.

[9]. Amal, S. Kumarage.. Criterion for a fares policy and fares index for bus transport in Sri Lanka, International Journal of Regulation and Governance, 2(1): 53-73, 2002.

[10]. Sevanatha, Urban Resource Center. Sri Lanka country report- Partnership to improve access and quality of public transport – case study Colombo, Sri Lanka. WEDC, Loughborough University, UK, 2002.

[11]. Amal K.; Massive Rs 32 billion Loss due to Traffic Congestion: An article on Business Times, 2011.http://www.sundaytimes.lk/110313/BusinessTimes/bt03.html

[12]. Japan International Cooperation Agency – JICA, Ministry of Transport, Sri Lanka, CoMTrans Urban Transport Master Plan, Final Report - Japan International Copperation Agency. Japan. 2014

[13]. Amal K.; Pressing Need to Move Away from Private Car Mentality, A 21st Century transport system for Sri Lanka: An article on Business Lk, 2014. Accessed on 27/7/2016. http://blog.ciltsl.com/wp-content/uploads/2014/09/Business-LK-Sept-2014.pdf

[14]. R.A.M. Madhuwanthi, Ashu Marasignhe, R.P.C. Janaka Rajapakse and Asanka D. Dharmawansa, Shusaku Nomura, Factors Influencing to Travel Behavior on Mode Choice of Transport. International Journal of Japan Society of Kansei Engineering (JSKE), vol. 14(5), May, 2015

[15]. R.A.M. Madhuwanthi, Ashu Marasignhe, Shusaku Nomura, Appraising the strongly associated impacts to choose the mode of public transport: a case study of Colombo metropolitan area in Sri Lanka. International Journal for Traffic and Transport Engineering (IJTTE), vol. 6(1), 2016.

[16]. Tri Basuki, Safety and Security Improvement in Public Transport based on Public Reception in Developing Countries. TATSS Research, Vol 30(1), pp 86-100, 2006.

[17]. Economic Development Research Group Boston, Massachusetts, Assessing the Social and Economic Effects of Transportation Projects, Final Report, 2001.

[18]. Marilla D. Svinicki, A Guidebook On Conceptual Frameworks for Research in Engineering Education, Rigorous Research in Engineering Education, NSF DUE-0341127, DUE-0817461, 2010.

[19]. Shan Jiang, Joseph Ferreira, Jr, Marta C Gonzales, Analyzing Household Lifestyles, Mobility and Activity Profiles: A Case Study of Singapore, Transportation Research Board 92nd Annual Meeting, Washington D.C, 2013.

[20]. Feifei He, Xuedong Yan, Yang Liu and Lu Ma, A Traffic Congestion Assessment Method for Urban Road Networks Based on Speed Performance Index, GITSS2015, vol 137, pp 425 – 433, 2016.

[21]. Omer Khan, Modelling Passenger Mode Choice Behavior using Computer Aided Stated Preference Data, Doctoral Thesis, Urban Development, Queensland university of technology, pp 11-33, 2007.

[22]. Hongzhi G., Shan H. and Hai Yan; Study on Traffic Access Mode Choice of Urban Railway System in Beijing, International journal of Researcher, vol. 1(5), pp 52-57. ISSN: 1553-9865, 2009.

[23]. Fengming S., Jan-Dirk S. and Michael G.H.B.; Mode Choice of Older People Before and After Shopping, Journal of Transport and Land Use, vol. 2 (1), pp 29–46, 2009.

[24]. Ali A. M. and Alaa, A.S.; Factors that affect transport mode preference for graduate students in the national university of Malaysia by Logit Method, Journal of Engineering Science and Technology, vol. 8(3), pp 351 – 363, 2013.

[25]. Asa B., John G. and James S.; Modeling Access Mode Choice for Inter-Suburban Commuter Rail, Journal of Public Transportation, Vol. 14(4), pp 23-42, 2011.

[26]. Frank S. Koppelman and Chandra Bhat, A Self Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models, U.S. Department of Transportation Federal Transit Administration, 2006.

[27]. Moshe Ben-Akiva and Michel Bierlaire, Discrete Choice Methods and their Applications to Short Term Travel Decisions, Handbook of Transportation Science.

[28]. Ben-Akiva, M. and Lerman, S. R, Discrete Choice Analysis: Theory and Application to Travel Demand, The MIT Press, Massachusetts, USA, 1985.

[29]. Minal and Ch. Ravi Sekhar, Mode Choice Analysis: The Data, The Models and Future ahead, International Journal for Traffic and Transport Engineering, Vol 4(3), pp 269 – 285, 2014.

[30]. Joe Castiglione, Mark Bradley, and John Gliebe; Activity-Based Travel Demand Models: A Primer, Resource Systems Group, Inc. White River Junction, Vermont, 2015.

[31]. Eriksson L.; Pro-environmental Behavior: The Importance of Attitudinal Factors, Habits, and Transport Policy Measures, Department of Psychology, Umea University, Sweden, pp 7-8, 2008.

[32]. Rajalakshmi P.; Mode Choice Modelling based on Work Trips – Artificial Neural Network Model, International Journal of Innovative Research in Science, Engineering and Technology, pp 360-369, 2013.

[33]. Minal1 and Ch. Ravi Sekhar; Mode Choice Analysis: the Data, the Models and Future Ahead, International Journal for Traffic and Transport Engineering, 4(3), pp 269 – 285, 2014.

[34]. Mintesnot G. and Shin-ei T.; The Effect of Travelers' Level of Satisfaction on Transport Mode Choice: An Input for Policy Analysis, World Conference on Transport Research, California, 2007.

[35]. Steiner, R.; Trip Generation and Parking Requirements in Traditional Shopping Districts, Journal of the Transportation Research Board, vol. 1617, pp 28-37.1998.

[36]. Drennen E.; Economic Effects of Traffic Calming on Urban Small Businesses, Department of Public Administration, San Francisco State University, 2003.

[37]. New York City DOT; Measuring the Streets: New Metrics for 21st Century Streets, preliminary Report, 2012.

[38]. Chang-jun Cai, En-jian Yao,Sha-sha Liu, Yong-sheng Zhang, and Jun Liu; Holiday Destination Choice Behavior Analysis Based on AFC Data of Urban Rail Transit, Research Article on Discrete Dynamics in Nature and Society, Hindawi Publishing Corporation, Article ID 136010, 2015.

[39]. Amal S. Kumarage; Sri lanka transport sector Policy Note, Final Report, pp17-18, 2012.

[40]. Haghshenas, H., & Vaziri, M., Urban sustainable transportation indicators for global comparison. Ecological Indicators, Vol 15, pp 115-121, 2012.

[41]. Dimitrios Papaioannoua, and Luis Miguel Martinezb, The role of accessibility and connectivity in mode choice. A structural equation modeling approach, 18th Euro Working Group on Transportation, Transportation Research Procedia, Netherland, vol 10, pp 831 – 839, 2015.

[42]. Transport Research Board, Airport Ground Access Mode Choice Models, ACRP synthesis 5, Airport Cooperative Research Program, 2008.

[43]. Rong-Chang J., David A., and Tzu-Lan H.; Airport ground access mode choice behavior after the introduction of a new mode: A case study of Taoyuan International Airport in Taiwan, International journal of Transportation Research Part E: Logistics and Transportation Review, vol 47(3), pp 371-381, 2011.

[44]. Lothar Bondzio, Study of Airport Choice and Airport Access Mode Choice in Southern Germany, Ruhr-University, Bochum, Germany, 1996.

[45]. Mahdi Yazdanpanah and Mansour Hsdji Hosseinlou, The influence of personality traits on airport public transport access mode choice: A hybrid latent class choice modeling approach, Journal of Air Transport Management, vol 55, pp 147-163,2016.

[46]. Vladmit Yangirov, analyzing Airport and acess Mode Choice Behavior, Kyushu region case study, Department of Urban Engineering, University of Tokyo, 37-136166.

[47]. Asa Bergman, John Gliebe, James Strathman, Modeling Access Mode Choice for Inter-Suburban Commuter Rail, Journal of Public Transportation, Vol. 14(4),pp 23-42, 2011.

[48]. Umberto Crisalli & Francesca Gangemi, The access/egress mode choice to railway terminals, Journal of Transactions on the Built Environment, vol 30, pp 43-53, 1997.

[49]. Franklin Bel T. lsip, Encouraging the use of Slovin's Formula in computing sample sizes in DMS survey related projects, Position paper.

[50]. Charles M. Friel; Notes on Factor Analysis, Criminal Justice Center, Sam Houston State University. Texas, US.

[51]. Rasario, M. 2011. Managing urban mobility system. Emerald Group Publishing Limited, UK. 260 p.

[52]. William, Z.; Wen Long, Y. 2001. Alternative solutions for urban traffic congestion, In Proceedings of the 3rd Eastern Asia Society for Transportation Studies, 327-342.

[53]. Zhan, G. 2008. Transfers and path choice in urban public transport systems, Thesis- Doctor of Philosophy, Department of Urban and Regional Planning, Massachusetts Institute of Technology.

[54]. Niels, V.O. 2011. Service Reliability and Urban Public Transport Design, Thesis- TRAIL Thesis Series , TRAIL Research School, Netherland.

[55]. Debbie, J.; Mark P.; Bryan, M. 2006. Secondary analysis of existing data on disabled people's use and experiences of public transport in Great Britain, Research Report, University of Leeds.

[56]. Ortuzar, J.D. ; Willumsen, L.G. 1994. Modeling Transport,. John Wiley & Sons ltd. USA. 207 p.

[57]. Eluru, N, Chakour, V., & El-Geneidy A., Travel Mode Choice and Transit Route Choice Behavior in Montreal: Insights from McGill University Members Commute Patterns. Public Transport: Planning and Operations, Vol 4(2), pp 129–149, 2012.

[58]. Vo Van Can , Modelling tourism demand, travel mode choice and destination loyalty , A dissertation for the degree of Philosophiae Doctor, Tromso university business school, 2013.

[59]. Schiebel, Omrani and Gerber, Border effects on the travel mode choice of resident and cross-border workers in Luxembourg, European Journal of Transport and Infrastructure Research, Vol 15(4), pp.570-596, 2015.

[60]. Charles, E. 2014. Maximum likelihood, logistic regression, and stochastic gradient training. Available from internet: < http://cseweb.ucsd.edu/~elkan/250B/logreg.pdf>

[61]. Subbarao, S.S.V.; Krishna, R.K.V. 2013. Analysis of Household activity and travel behavior: A case of Mumbai Metropolitan Region, International Journal of Emerging Technology and Advanced Engineering. 3(1).

[62]. Richard, W.2015. Logistic Regression, Part III: Hypothesis Testing, Comparisons to OLS. Available from internet: < https://www3.nd.edu/~rwilliam/stats2/l83.pdf>

[63]. Lothar Bondzio; Study of Airport Choice and Airport Access Mode Choice in Southern Germany, Airport planning issues, proceeding of seminar K., Research and computation European Transport forum, Brunel University, England, Vol pp409,1996.

[64]. Rongrong Y., Hai Y., Wen X. and Tao L.; The Study of Pedestrian Accessibility to Rail Transit Stations Based on KLP Model ,13th COTA International Conference of Transportation Professionals (CICTP 2013), China, Elsevier Ltd., pp714-722, 2013.

[65]. Amal K.; Pressing Need to Move Away from Private Car Mentality, A 21st Century transport system for Sri Lanka: An article on Business Lk, 2014. http://blog.ciltsl.com/wp-content/uploads/2014/09/Business-LK-Sept-2014.pdf

[66]. Amal K.; Confronts Ever-increasing Vehicle Congestion Head-on: An article on LMD, the Voice of Business, 2015.http://lmd.lk/transport-network/

[67]. IBM Corporation; IBM SPSS Amos, Test Relationships in Attitudinal and Behavioral Models, IBM Corporation, United States of America, pp 1-7, 2013.

[68]. Bruce.H.P, Adrian. T., Alexander V.E.; Structural Equation Modeling, 2nd edition, Cambridge University Press, , pp 3-11, 2003.

[69]. Barbara M. Byrne; Structural Equation Modeling with AMOS, Basic Concepts, Applications, and Programming, 2nd edition, Taylor and Francis Group, LLC, pp3-40, 2010.

[70]. Marcoulides, G. A., Hersberger, S. L.; Multivariate Statistical Methods. Mahwah, NJ-Lawrence Erlbaum Associates, 1997.

[71]. UCDHSC Center for Nursing Research, Structural Equation Modeling with AMOS 5.0, 2006. http://www.ucdenver.edu/academics/colleges/nursing/Documents/PDF/HowToUseAMOS5.pdf

[72]. World Health Organization, Global Status Report on Road Safety, Department of Violence & Injury Prevention & Disability (VIP), Switzerland, 2009.

[73]. World bank and World Health Organization, World Report on Road Traffic Injury Prevention: Summary, Geneva, 2004.

[74]. Tiwari, G., Safety aspects of public transport vehicles. Journal of Traffic Medicine Vol 22(4), pp 153-160. 1994.

[75]. P. S. Kharola, Geetam Tiwari, and Dinesh Mohan, Traffic Safety and City Public Transport System: Case Study of Bengaluru, India, Journal of Traffic Safety and City Public Transport System, Vol. 13 (4), pp 63-91, 2010.

[76]. Lidia• P.• Kostyniuk, Pupil Fatalities on Public Transit Buses: A Comparison with School Buses, Journal of Public Transportation, Vol 6(3), pp 43-63, 2003.

[77]. Donald Katz and Laurie A. Garrow, The Impact of Bus Door Crowding on Operations and Safety, Journal of Public Transportation, Vol 15(2), pp 71-93, 2012.

[78]. D. A. C. Maunder and T. Pearce, Public transport safety in Nepal and Zimbabwe, Highways and Transportation, Vol 46(10), pp 36-3 7, 1999.

[79]. NZ Transport Agency, Pedestrian planning and design guide, New Zealand, 2009.

[80]. US Department of Transportation, Pedestrian Safety Guide for Transit Agencies, Report no FHWA-SA-07-017, 2008.

[81]. WHO, FIA Foundation, Global Road Safety Partnership, The World Bank, A road safety manual for decision-makers and practitioners, ISBN 978 92 4 150535 2, page 9, 2013

[82]. AS Kumarage, SM Wikramasinghe, MDRP Jayarathne, Report on Analysis of Road Accident in Sri Lanka, Supreme Group of Companies, ISBN 955-9027-14-X.,2003.

[83]. World Health Organization, Report on Road Safety in the South East Asia Region, 2015.

[84]. Samath D Dharmaratne , Achala Upendra Jayatilleke & Achini C Jayatilleke, Road traffic crashes, injury and fatality trends in Sri Lanka: 1938–2013, Bulletin of the World Health Organization, Vol 93, pp 589-664, 2015

[85]. International Traffic Safety Data and Analysis Group, Annual Report of Road Safety in 2105, OECD Publishing, Paris. ISBN 978-92-8210786-7 (PDF), 2015.

[86]. Department of Census and Statistics, Sri Lanka. Accessed on 27-9-2016, http://www.statistics.gov.lk/Abstract2015/CHAP7/7.4_7.5_7.6.pdf

[87]. Deepthi Jayan.K, B.Ganeshkumar , Identification of Accident Hot Spots: A GIS Based Implementation for Kannur District, Kerala, International Journal of Geomatics and Geosciences , pp 51-59, Volume 1, No 1, 2010, ISSN 0976 – 4380

[88]. Sunday Times. 2001. The article- Killer Roads. Available from internet: <http://www.sundaytimes.lk/040606/plus/1.html>

[89]. World Bank & WHO, World Report on Road Traffic Injury Prevention, 2006.

[90]. Md Aftabuzzaman, Graham Currie, Majid Sarvi, Evaluating the Congestion Relief Impacts of Public Transport in Monetary Terms, Journal of Public Transportation, Vol. 13, No. 1, 2010.

[91]. Aamal S. Kumarage, Sri Lanka Transport Sector Policy Note, Final Report, 2012.

[92]. Nicholas M. Giner, Parrish S. Henderson. Finding Hot Spots using ArcGIS, Online: Minimizing the Subjectivity of Visual Analysis, Fed GIS conference, Washington, DC, Feb, 2016.

# Appendix I

# Author Publications Related to the Research

**Journal Publications**

- R.A.M. Madhuwanthi, Shusaku Nomura, Approach of Structural Equation Modeling for Evaluating Access Mode Choice, A case of Colombo Metropolitan Area in Sri Lanka. International Journal of Affective Engineering, Vol 15 (3), July, 2016

- R.A.M. Madhuwanthi, Ashu Marasignhe, Shusaku Nomura, Appraising the strongly associated impacts to choose the mode of public transport: a case study of Colombo metropolitan area in Sri Lanka. International Journal for Traffic and Transport Engineering (IJTTE), Vol. 6(1), March, 2016.

- .R.A.M. Madhuwanthi, Ashu Marasignhe, R.P.C. Janaka Rajapakse and Asanka D. Dharmawansa, Shusaku Nomura, Factors Influencing to Travel Behavior on Mode Choice of Transport. International Journal of Affective Engineering, Special Issue on ISASE (2015), Vol. 15(2), June, 2016.

**International Conference Publication**

- R.A.M. Madhuwanthi, Ashu Marasignhe, R.P.C. Janaka Rajapakse and Asanka D. Dharmawansa, A Recommendation Mechanism for the Adaptation of the Activity Based Travel Demand Model. International Symposium on Affective Science and Engineering, Vol 1, ISBN: 978-4-9905104-2-8, March, 2015.

- R.A.M. Madhuwanthi, Duminda Bandara, Amila Jayasinghe, A.D. Dharmawansa and Shusaku Nomura, Modeling of Road Accident Severity with Most Affected Accident Occurring Circumstances, 5th International GIGAKU conference, Oct, 2016.

# Appendix II

- This appendix includes the pre-formatted questionnaire which was delivered to the residence in Colombo Metropolitan Area in Sri Lanka.

## Mode Choice-Travel Survey Questionnaire

### Household Information

1 **Your current address:** No123/1, Parakandeniya, Imbulgoda

2 **What is monthly family income in Rupees?**

- ☐ No Income
- ☐ 15,000-30,000
- ☐ 75,000-100,000
- ☐ Below 5,000
- ☑ 30,000-50,000
- ☐ More than 100,000
- ☐ 5,000-15,000
- ☐ 50,000-75,000

3 **How many earning members are there in your household?** 2

4 **What is the type of your residence?**

- ☑ Own House
- ☐ Rented House
- ☐ Government quarters
- ☐ Apartment
- ☐ Employer Provided
- ☐ Other

5 **How many vehicles are there in your household?**

| | |
|---|---|
| None | ☐ |
| Foot Cycle | 1 |
| Motor Cycle | 1 |
| Three Wheeler | |
| Car/Van | |
| Other | |

6 **Please fill the following table for your all family members and select the suitable category from the given list for each members. Please follow your family members as A, B, C, D and so on including you and please follow the same letter for same member for all the given tables.**
*** Please follow the example**

| Member | Gender | Age Group (Years) | Education | Occupation |
|---|---|---|---|---|
| ex. | Female | 26-35 | Graduate | Government Employee |
| A | Male | 46-55 | Diploma | Government Employee |
| B | | | | |
| C | | | | |
| D | | | | |
| E | | | | |
| F | | | | |

7 **Please fill this table only for the all-family members who are more than 15 years old and for those who are traveling for their regular matters.**

* Please follow the example

| Member | Purpose of your regular trip | Average travel distance | Main mode for traveling | Average travel time from home to distance | Daily traveling expenses | Are you a travel pass holder? | Are you a Vehicle License holder? | Which days of the week do you travel for your regular trip? Please put a x mark in the relevant cell. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
| ex. | Work | 2-6 km | Motor Cycle | 30 min to 1 hr | Rs 150-300 | No pass | Yes | x | x | x | x | x | | |
| A | | | | | | | | | | | | | | |
| B | | | | | | | | | | | | | | |
| C | | | | | | | | | | | | | | |
| D | | | | | | | | | | | | | | |
| E | | | | | | | | | | | | | | |
| F | | | | | | | | | | | | | | |
| G | | | | | | | | | | | | | | |
| H | | | | | | | | | | | | | | |
| I | | | | | | | | | | | | | | |
| J | | | | | | | | | | | | | | |
| K | | | | | | | | | | | | | | |

8 **In this section we'd like to know how you normally travel to your regular journey. This section is the key to our survey. We understand that it can be difficult to describe how you travel each day because it can change a lot. However, could you try and describe each step of your normal journey?**

**For example, if you walk 10 minutes to the bus stop, wait about 5 minutes, and then take the bus for 20 minutes to arrive on your son's school, wait about 5 minutes, then take the bus 10 minutes to arrive on your office. Then you have 5 steps and you would enter:**

Step 1: Walk - 10 minutes

Step 2: Wait - 5 minutes

Step 3: Bus - 20 minutes

Step 4: Wait - 5 minutes

Step 5: Bus - 10 minutes

* Please follow the example

| Member | Step 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 | Step 8 | Step 9 |
|---|---|---|---|---|---|---|---|---|---|
| ex. | Walk - 10 minutes | Wait - 5 minutes | Bus - 20 minutes | 5 minutes | Bus - 10 minutes | | | | |
| A | | | | | | | | | |
| B | | | | | | | | | |
| C | | | | | | | | | |
| D | | | | | | | | | |
| E | | | | | | | | | |
| F | | | | | | | | | |
| G | | | | | | | | | |
| H | | | | | | | | | |

## Public Transport Users

9 **If you travel mainly by using public transport, please rank the following in the order of their importance to you on your journey with public mode.**

1: Not Important 2: Barely Important 3: Important, 4: Very Important, 5: Most Important

* Please follow the example

| Member | Total Cost | Vehicle travel time | Access time from home | Waiting time on bus top/ station | Time reliability | Comfort | Safety |
|---|---|---|---|---|---|---|---|
| ex. | 5 | 5 | 3 | 4 | 4 | 3 | 5 |
| A | | | | | | | |
| B | | | | | | | |
| C | | | | | | | |
| D | | | | | | | |
| E | | | | | | | |
| F | | | | | | | |
| G | | | | | | | |
| H | | | | | | | |
| I | | | | | | | |
| J | | | | | | | |

10 **Please fill the following table when you use the above -mentioned public mode.**

* Please follow the example

| Member | How much time do you have to wait at the station/ bus stop before boarding the bus/ train? | How much time does it take you to reach your office/institute building from the bus stop/ station? |
|---|---|---|
| ex. | Less than 2 min | 2-5 min |
| A | | |
| B | | |
| C | | |
| D | | |
| E | | |
| F | | |
| G | | |
| H | | |
| I | | |
| J | | |

## Private Vehicle Users

11 **If you travel mainly by using personal vehicle,please rank each of the following aspect in or**

1: Not Important 2: Barely Important 3: Important, 4: Very Important, 5: Most Important

* Please follow the example

| Member | Total Cost | Vehicle travel time | Access time from home/ office | Privacy during traveling | Parking | Comfort | Safety |
|---|---|---|---|---|---|---|---|
| ex | 5 | 5 | 3 | 4 | 5 | 4 | 3 |
| A | | | | | | | |
| B | | | | | | | |
| C | | | | | | | |
| D | | | | | | | |
| E | | | | | | | |
| F | | | | | | | |
| G | | | | | | | |
| H | | | | | | | |
| I | | | | | | | |
| J | | | | | | | |

12 **Please rank each of the following change (in order of its importance) following which you are willing to switch to public transpor**

1: Not Important 2: Barely Important 3: Important, 4: Very Important, 5: Most Important

* Please follow the example

| Member | Reduced waiting time on station/bus stops | Reduced in vehicle time | Subsidized cost | Reduced access time (from home and from work) | Increased comfort | Increased security | Increased time reliability |
|---|---|---|---|---|---|---|---|
| ex | 5 | 5 | 5 | 5 | 4 | 4 | 5 |
| A | | | | | | | |
| B | | | | | | | |
| C | | | | | | | |
| D | | | | | | | |
| E | | | | | | | |
| F | | | | | | | |
| G | | | | | | | |
| H | | | | | | | |
| I | | | | | | | |
| J | | | | | | | |

13 **Please fill the following table when you use the above -mentioned private vehicle**

* Please follow the example

| Member | How much time does it take you to access your vehicle from your home/ office? | How much time does it take you to park your vehicle and reach your office/institute building from the parking? | What are the weaknesses of the public transport in according to you? |
|---|---|---|---|
| ex. | 2-5 min | 2-5 min | Time consuming |
| A | | | |
| B | | | |
| C | | | |
| D | | | |
| E | | | |
| F | | | |
| G | | | |
| H | | | |
| I | | | |
| J | | | |

The End, Please Save and Send me back

**Thank you for your time!**

# Appendix III

Sample results for the Hotspots Analysis. The decision making is based on the Z score and P value.

| OBJECTID * | Shape * | SOURCE_ID | ICOUNT | GiZScore Fixed 15000 | GiPValue Fixed 15000 |
|---|---|---|---|---|---|
| 1 | Point Z | 1 | 1 | 0.293364 | 0.769244 |
| 2 | Point Z | 2 | 2 | -2.449239 | 0.014316 |
| 3 | Point Z | 3 | 2 | -2.31426 | 0.020653 |
| 4 | Point Z | 4 | 1 | -2.309635 | 0.020908 |
| 5 | Point Z | 5 | 2 | -2.34945 | 0.018801 |
| 6 | Point Z | 6 | 1 | -2.305121 | 0.02116 |
| 7 | Point Z | 7 | 4 | -2.384242 | 0.017114 |
| 8 | Point Z | 8 | 1 | -2.394621 | 0.016638 |
| 9 | Point Z | 9 | 2 | -2.384242 | 0.017114 |
| 10 | Point Z | 10 | 1 | -2.364548 | 0.018052 |
| 11 | Point Z | 11 | 4 | -2.31614 | 0.020551 |
| 12 | Point Z | 12 | 3 | -2.31614 | 0.020551 |
| 13 | Point Z | 13 | 2 | -2.359936 | 0.018278 |
| 14 | Point Z | 14 | 4 | -2.340252 | 0.019271 |
| 15 | Point Z | 15 | 1 | -2.35543 | 0.018501 |
| 16 | Point Z | 16 | 1 | -2.35543 | 0.018501 |
| 17 | Point Z | 17 | 2 | -2.311871 | 0.020785 |
| 18 | Point Z | 18 | 1 | -2.35543 | 0.018501 |
| 19 | Point Z | 19 | 2 | -2.35543 | 0.018501 |
| 20 | Point Z | 20 | 2 | -2.31614 | 0.020551 |
| 21 | Point Z | 21 | 1 | -2.394496 | 0.016643 |
| 22 | Point Z | 22 | 1 | -2.220254 | 0.026402 |
| 23 | Point Z | 23 | 1 | -2.201022 | 0.027734 |
| 24 | Point Z | 24 | 1 | -2.246179 | 0.024693 |
| 25 | Point Z | 25 | 1 | -2.557553 | 0.010541 |
| 26 | Point Z | 26 | 4 | -2.524551 | 0.011585 |
| 27 | Point Z | 27 | 1 | -2.379901 | 0.017317 |
| 28 | Point Z | 28 | 1 | -2.486361 | 0.012906 |
| 29 | Point Z | 29 | 1 | -2.486361 | 0.012906 |
| 30 | Point Z | 30 | 2 | -2.467188 | 0.013618 |
| 31 | Point Z | 31 | 1 | -2.637893 | 0.008342 |
| 32 | Point Z | 32 | 1 | -2.428682 | 0.015154 |
| 33 | Point Z | 33 | 1 | -2.447961 | 0.014367 |
| 34 | Point Z | 34 | 1 | -2.701706 | 0.006898 |

| | | | | | |
|---|---|---|---|---|---|
| 35 | Point Z | 35 | 1 | -2.50695 | 0.012178 |
| 36 | Point Z | 36 | 1 | -2.686358 | 0.007224 |
| 37 | Point Z | 37 | 1 | -2.81149 | 0.004931 |
| 38 | Point Z | 38 | 1 | -2.463633 | 0.013754 |
| 39 | Point Z | 39 | 1 | -2.842093 | 0.004482 |
| 40 | Point Z | 40 | 1 | -2.359936 | 0.018278 |
| 41 | Point Z | 41 | 1 | -2.95534 | 0.003123 |
| 42 | Point Z | 42 | 1 | -2.496164 | 0.012554 |
| 43 | Point Z | 43 | 1 | -2.543568 | 0.010973 |
| 44 | Point Z | 44 | 1 | -2.600314 | 0.009314 |
| 45 | Point Z | 45 | 1 | -2.62189 | 0.008744 |
| 46 | Point Z | 46 | 1 | -2.658421 | 0.007851 |
| 47 | Point Z | 47 | 1 | -2.730946 | 0.006315 |
| 48 | Point Z | 48 | 1 | -2.712881 | 0.00667 |
| 49 | Point Z | 49 | 1 | -1.761713 | 0.078118 |
| 50 | Point Z | 50 | 1 | -1.648416 | 0.099267 |
| 51 | Point Z | 51 | 1 | -1.683194 | 0.092338 |
| 52 | Point Z | 52 | 1 | -1.724217 | 0.084669 |
| 53 | Point Z | 53 | 1 | -1.701982 | 0.088759 |
| 54 | Point Z | 54 | 1 | -1.785062 | 0.074251 |
| 55 | Point Z | 55 | 1 | -1.822437 | 0.068389 |
| 56 | Point Z | 56 | 1 | -1.821394 | 0.068547 |
| 57 | Point Z | 57 | 1 | -1.879575 | 0.060166 |
| 58 | Point Z | 58 | 1 | -1.860576 | 0.062804 |
| 59 | Point Z | 59 | 1 | -1.823523 | 0.068224 |
| 60 | Point Z | 60 | 1 | -1.86179 | 0.062633 |
| 61 | Point Z | 61 | 2 | -1.758081 | 0.078734 |
| 62 | Point Z | 62 | 1 | -1.815219 | 0.06949 |
| 63 | Point Z | 63 | 1 | -1.89141 | 0.05857 |
| 64 | Point Z | 64 | 1 | -1.911095 | 0.055992 |
| 65 | Point Z | 65 | 1 | -1.892491 | 0.058426 |
| 66 | Point Z | 66 | 3 | -1.873843 | 0.060952 |
| 67 | Point Z | 67 | 1 | -1.855151 | 0.063575 |
| 68 | Point Z | 68 | 1 | -1.836415 | 0.066296 |
| 69 | Point Z | 69 | 1 | -2.123967 | 0.033673 |
| 70 | Point Z | 70 | 1 | -2.224912 | 0.026087 |
| 71 | Point Z | 71 | 1 | -2.224912 | 0.026087 |
| 72 | Point Z | 72 | 1 | -2.609635 | 0.009064 |
| 73 | Point Z | 73 | 1 | -2.721119 | 0.006506 |
| 74 | Point Z | 74 | 1 | -2.668494 | 0.007619 |
| 75 | Point Z | 75 | 1 | -1.608005 | 0.107834 |

The detail table for the section of world Comparison of road fatality accidents in the Chapter 4, Figure 4.8. Fatality rate per 100,000 Population in each Country in 2013 versus the Average Percentage Change in Road Traffic Fatalities in the Year of 2012-2013 [85], [86].

| **Country** | **Country-Label** | **Road Fatality per 100.000 inhabitance (2013)** | **Fatality changers % (2012-2013)** |
|---|---|---|---|
| Argentina | Arg | 12.30 | 2.7 |
| Australia | Aus | 5.10 | -8.7 |
| Austria | Aut | 5.40 | -14.3 |
| Belgium | Bel | 6.50 | -6 |
| Canada | Can | 5.50 | -7.4 |
| Chile | Ch | 12.00 | 6.6 |
| Czech Republic | Cze | 6.20 | -11.9 |
| Denmark | Den | 3.40 | 14.4 |
| Finland | Fin | 4.80 | 1.2 |
| France | Fra | 5.10 | -10.5 |
| Germany | Ger | 4.10 | -7.3 |
| Greece | Gre | 7.90 | -11 |
| Hungary | Hun | 6.00 | -2.3 |
| Iceland | Ice | 4.70 | 6 |
| Ireland | Ire | 4.10 | 16 |
| Isreal | Isr | 3.40 | 5.3 |
| Italy | Ita | 5.70 | -9.8 |
| Japan | Jap | 4.00 | -1.6 |
| Korea | Kor | 10.10 | -5.6 |
| Lithuania | Lith | 8.70 | -14.3 |
| Luxembourg | Lux | 8.40 | 32.4 |
| Netherland | Net | 3.40 | -12.3 |
| New Zealand | New | 5.70 | -17.5 |
| Norway | Nor | 3.70 | 29 |
| Poland | Pol | 8.70 | -6 |
| Portugal | Por | 6.10 | -11.3 |
| Slovenia | Slo | 6.10 | -8.8 |
| Spain | Spa | 3.60 | -11.7 |
| Sri Lanka | Sri | 17.40 | -3.3 |
| Switzerland | Swi | 3.30 | -20.6 |
| United Kingdom | UK | 2.80 | -1.8 |
| United States | US | 10.30 | -3.1 |
| | **Average** | **6.3** | **-2.9** |