ACCIDENT ANALYSIS OF SOUTHERN EXPRESSWAY

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Degree of Master of Engineering in Highway and Traffic Engineering

Department of Civil Engineering

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Dissertation submitted in partial fulfillment of the requirements for the degree of Master of Engineering in Highway and Traffic Engineering

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Declaration of the candidate & Supervisor

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Abstract

Southern Expressway, the first ever access controlled expressway in Sri Lanka, was opened for traffic to function in year 2011. Even though it has provided several safety precautions, about 2000 number of accidents have been reported during the last three and half years (2011-2013). Therefore, identifying reasons for the accidents and critical locations where majority of accidents have taken place are essential for introducing immediate safety improvements.

Main objectives of this research are to identify accident-prone locations, identify possible reasons for the accidents, and calculate the accident rate based on vehicle travel kilometre.

According to this research study, ten most critical accident-prone locations were identified in the Southern Expressway from Kottawa to Pinnaduwa section. Accident locations were grouped into nearest 100m distance and the ten most critical locations are 0+100 km, 5+800km, 5+900km, 8+000km, 22+100km, 27+800km, 55+300km, 58+800km, 64+800km, and 65+100km. Main causes of the accidents, as per the accident records, are the driving speed and poor road environment under rainy weather (slippery road condition). Driver fatigue also act as a key factor for some accidents. Accidents happened during night time are twice higher than that of day time. However, this trend was same in each of the section along the road.

Eventhough the highest accident rate of around 3.00 x 10^{-6}veh km was noted from Kottawa-Kahathuduwa section and Baddegama-Pinnaduwa section, accident rates in each section have reduced from year 2012 to 2013.When comparing Southern Expressway with Colombo-Wellawaya road (A2) road corridor from Moratuwa to Galle in year 2012, Southern Expressway shows higher accident rate (2.4 x 10^{-6} per vehicle kilometre travelled) than other corridors (1.86 x 10^{-6} per vehicle kilometre travelled). In addition, fatality rate in Southern Expressway has increased from 2012 to 2013, which is considerably a higher value than fatality rates of road accidents in most of the other countries. However fatality rate in southern expressway has a low value than relevant figures in A2 road and whole Sri Lanka.

Acknowledgement

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R. P. D. Chinthanie

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List of Abbreviations

EOMMD	- Expressway Operation Maintenance and Management Division
RDA	- Road Development Authority
LHS	- Left hand Side
RHS	- Right hand Side
GD	- Galle Direction
CD	- Colombo Direction
PRT	- Perception Reaction Time
IRTAD	- International Road Traffic and Accident Databases
VKT	- Vehicle Kilometres Travelled
A2	- Colombo - Galle - Hambanthota - Wellawaya road

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CHAPTER 1. INTRODUCTION

Economic development of any country directly relies on the efficiency of the transportation system. Since road transportation is the primary mode of transportation in Sri Lanka, it is vital that road network is adequately developed to promote efficient transport of people and goods.

On 27th November 2011, Sri Lanka initiated a giant step in road transportation, by introducing the first ever expressway experienced by the country. As in all expressways, Southern Expressway in Sri Lanka is designed to cater high mobility between southern province and the capital city, Colombo, with a safe environment.

1.1 Background

There are eight numbers of interchanges from Kottawa to Pinnaduwa section (96km) while Pinnaduwa to Godagama section, which started operation later, has three interchanges. Even though the design speed of the Expressway is 120km/h, allowable operation speed is 100km/h.

Following typical cross section (Figure 1.1) has been provided in Ssouthern Expressway with total of four lanes running two lanes in one direction.

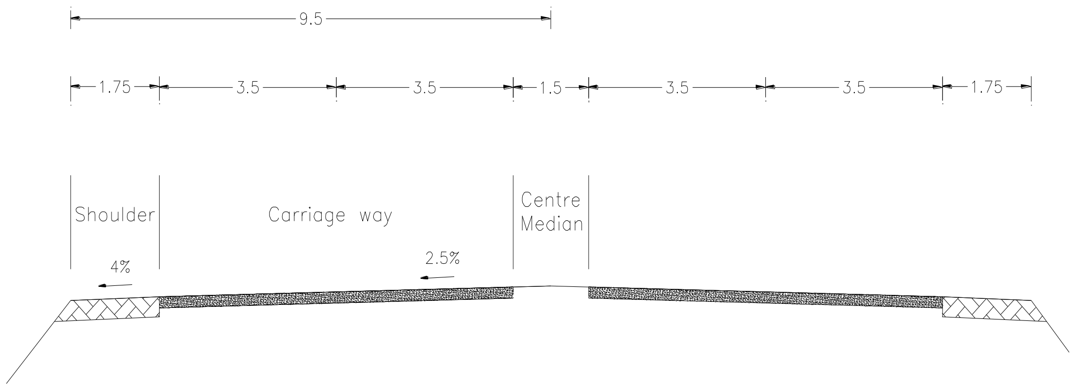


Figure 1.1: Typical Cross Section of Southern Expressway

Government of Sri Lanka expected to achieve several benefits from this Expressway other than the revenue generation and travel time reduction. Some of the direct benefits are:

1. Travelling in an uniform speed throughout the journey
2. Minimal congestion and obstruction to traffic in the expressway
3. Reduction of traffic congestion on Colombo - Matara Road
4. Reduction of fuel consumption and vehicle maintenance cost

Some of the indirect benefits are:

1. Attract private sector investors who consequently contribute to job market expansion
2. Expand tourism, presently confined to the coastal belt, along Colombo-Galle-Matara
3. Development of towns adjacent to 11 interchanges as Economic Centres
4. Value enhancement of land and property in the region

1.2 Problem Definition

Despite the benefits and privileges offered to the country, an unsafe road environment will have negative impacts to the economy as it leads physical losses. The losses become more severe, when those take place in the form of loss of human lives in fatal accidents.

Therefore, Road Development Authority (RDA) of Sri Lanka provided several safety precautions in Southern Expressway to assure a safe road environment to road user. Some such measures to prevent accidents and minimize the damages are:

1. Separate the opposite travelling directions by median fence
2. Guard fence at the edges of the shoulders at cut and fill sections
3. Speed limits
4. Lighting at interchanges and at the structures
5. Provision of road studs and reflectors at the center median and Guard fence
6. Provision of Road Markings and Signs along the roadway

7. Establishment of highway traffic patrol for enforcements of traffic rules and regulations

However, 956 numbers of accidents are reported in Southern Expressway in Kottawa to Pinnaduwa section during the 23-month period of November 2013 to November 2011. Out of those, nine accidents were fatal and twelve people died according to the data from Expressway Operation Maintenance and Management Division (EOMMD), RDA. Since large numbers of accidents have been taken placed within a short period of 2 years, a negative image has gradually developed in people's minds with respect to expressways of Sri Lanka. Therefore, it is vital to identify the accident-prone locations and the causes for the accidents to provide safety improvements and remedial measures immediately.

Accident rate is considered as a very good indicator for road safety. Since the traffic data of Southern Expressway is readily available at EOMMD, RDA, it was possible to conducted accident rate calculations based on the vehicle travel kilometres to conduct relative comparisons about safety level of the Southern Expressway.

1.3 Objectives

Objectives of this research study are:

1. Identify accident-prone locations of the Southern Expressway
2. Identify possible causes for the accidents in Southern Expressway
3. Estimate the accident rate based on vehicle travelled kilometers

1.4 Scope

Accidents occurred within 27th November 2011 to 31st October 2013 in the section between Kottawa to Pinnaduwa (96km long) were considered for this study. In addition, attempts were made to find the most severe accident-prone locations. This report presents the accident-prone locations in Southern Expressway according to accident records, and possible reasons for accidents.

1.5 Scope of the Report

The report consists of five chapters:

Chapter 1 provide the importance and the background of this research study comprising Introduction, Background, Problem definition, Objectives, and the Scope.
Chapter 2 present a summary of relevant literature based on international studies.
Chapter 3 explain the methodology followed to accomplish the research aim.
Chapter 4 present the Accident analysis through collected data.
Chapter 5 provide conclusions and recommendations of the study.

CHAPTER 2. LITERATURE REVIEW

Accident is an undesired or unintended happening. A road traffic accident may happen on a highway by collision with vehicles, persons, or with properties.

2.1 Accident factors

The factors contributing to road traffic accidents are commonly grouped into three categories as described below:

- Human Factors (Road Users)

Statistics reveal that road users who infringed the traffic law causes 60% - 62% of road accidents. For instance, it can be mentioned that driving speed exceeding the speed limit, careless driving, and being drunk while driving (Volvo Truck Research Team, 2013).

The driver is the main factor for the occurrence of an accident (Elvik, Vaa, Erke, & Sorensen, 2009). Previous studies indicate that many elements contribute to determine an unsafe and a distracted driving behavior related to driver's psycho-physical conditions, his mental workload, reduction of the attention threshold, and the increase of the perception-reaction time (PRT) (Rosolino et al., 2014).

Further, a study based on a dataset of 100 vehicles for a year revealed that distractions and inattention (e.g. fatigue) contribute to approximately 80% of crashes, and distraction contribute to around 65% of rear-end crashes (Rosolino et al., 2014).

- Road Environment

A proportion of road accidents are due to the environment, slippery roads, and incorrect road/bridge infrastructures, which are not yet included in the appropriate safety standards; i.e. potholes on the road might lead to a road accident. According to recent analysis, 30% of accidents are related to road characteristics, such as the pavement (in a percentage of 10%), geometry (10%), and other factors such as signals, guardrails, safety barriers, etc. (Rosolino et al., 2014).

- Vehicle Defects

Vehicles are also a cause to road accidents when their owners fail to properly maintain and regularly inspect the vehicle during operation. Therefore, road accidents occur due to reasons such as brake failure, tire blowout, power steering failure, and headlight failure. Only 10% of contributing factors are attributed to technical issues related to the vehicles according to the analysis (Rosolino et al., 2014).

A significant proportion of accidents are caused by a combination of the above all three categories.

2.2 Accident reporting

Reporting an accident at the correct time with all required information is an important task as those data reveal the causes for the accident and assist further activities. Once an accident occurs, it should immediately be reported before erasing the evidences. Accidents can be reported with several formats. Accident reporting mainly happens through the Police. In case the victim of the accident is injured or dead, it is reported to the hospital.

The driver of a vehicle must reports a traffic crash, if the incident happened on a road or any place commonly used by the public (e.g. car parks), if the incident resulted in a bodily harm to any person, if the total value of property damaged to all involved parties exceeds a certain value, or if the owner or representative of any damaged property is not present (Western Australia Police: http://www.police.wa.gov.au/).

Following information is required to report a traffic accident accurately:

- date of crash
- time of crash
- precise location of crash
- personal details (from driver's license)
- driver's license number and expiry details

- vehicle license plate and expiry details
- details of other involved drivers/passengers/owners/vehicles/witnesses
- details of injuries and other person's injuries
- crash features (traffic control, road features, road alignment, other conditions)
- total estimated cost of damage to all vehicles and property
- description of the manner in which the crash happened
- Optional - digital images of the crash incident

However, it is not reliable if the data only depends on the police. Results from many countries have shown wide variation between official (i.e. police) statistics and information from other sources. For example in the Philippines, only one out of five medically reported road deaths are included in police statistics.

Under reporting appears to be high in China, which already has the world's highest reported number of road deaths. Thus, the Beijing Research Institute of Traffic Engineering has estimated that the actual number of people killed in road accidents in 1994 was about 111,000, over 40% higher than the 78,000 officially reported by the police. Using results from several studies indicated that in developed countries, under reporting of fatalities was minimal (between 2-5%), whilst in developing countries, upper and lower adjustment factors were between 25-50% increase of those numbers reported by the police (Jacobs et al, 2000).

Deaths and severe injuries are more likely to be reported than minor injuries; drivers and passengers also have a greater likelihood of being recorded by traffic police than pedestrians, cyclists, and other non-motorized road users. There is also evidence that injuries occurring in the under-served urban communities and amongst children are less likely to be reported (Odero et al., 1997).

There should be a medical community, led by the World Health Organization to monitor road accident victims and include road accidents in national hospital surveillance systems. Accident databases in many developing countries should be improved through greater use of accident reporting and recording systems.

Therefore, using accident information from hospital data and sources like Insurance Companies can complement evidence obtained from police records.

2.3 Accident trends in developed countries

Considering the accident trends in developed countries, most countries could reduce fatalities with time by following several policies and actions.

In Britain, even though motor traffic levels have more than doubled since recording began in 1949, the relative risk of road deaths has fallen significantly (from 1949 to 2013). The fatality rate has halved in the past decade, from 10.6 fatalities per billion vehicle miles in 2004 to 5.6 fatalities per billion vehicle miles in 2013. In addition, the number of children killed in reported road accidents has fallen significantly since 1979. The 2013 level of 48 child fatalities is over 90% lower than the 1979 figure (Department for Road Fatalities, 2013).

Several reasons and improvements listed below have caused this trend:

- **Sustained periods of snow and ice** - comparable periods of bad weather were not observed from 2011
- **Technological** and **engineering** improvements to vehicles and highways
- **Improved education** and **training** is likely to have produced better and safer drivers
- **Improvements in trauma care** (and in England, particularly with the introduction of major trauma care centers) and **emergency services responses** are likely to have improved outcomes after an accident

If it is considered the road user made accidents due to Driver/Rider impaired by alcohol , Careless, reckless or in a hurry, Aggressive driving, Poor turn or maneuver, Loss of control , Exceeding speed limit ect. Fatalities have significantly reduced during past period up to 2013 (Department for Road Fatalities, 2013).

Member countries of the International Traffic Safety Data and Analysis Group (IRTAD) are Argentina, Austria, Belgium, Cambodia, Canada, Chile, Czech Republic, Denmark, Finland, Fence, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Jamaica, Japan, Korea, Lithuania, Luxembourg, Malaysia, Morocco, Netherlands, New Zealand, Nigeria, Norway, Poland, Portugal, Serbia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, and United States. As per the Road Safety Annual report 2015 of IRTAD, number of road fatalities declined by an overall 42% between 2000 and 2013 in the 32 countries. Greatest reductions were achieved in Spain with more than 70% and Portugal with almost 70%. Many other countries had achieved over 50% of reductions notably Denmark, France, Slovenia, and Lithuania. Most non-European IRTAD members achieved a lower than average reduction in the number of road fatalities (Figure 2.1 & Figure 2.2).

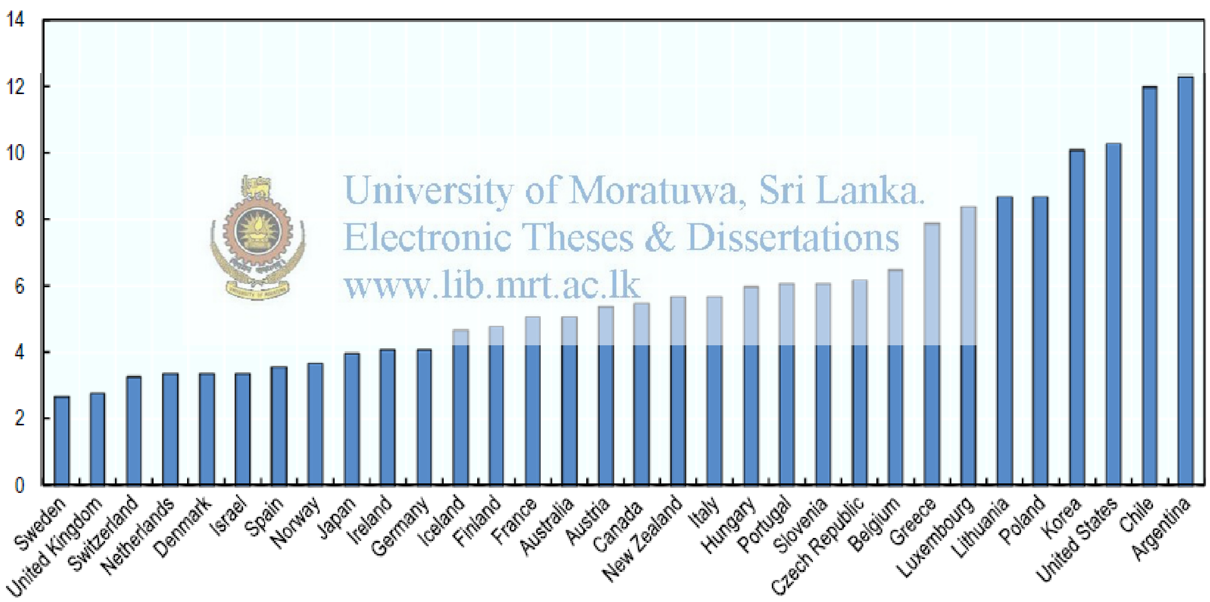


Figure 2.1 : Road fatalities per 100,000 Inhabitants in 2013 of IRTAD Countries

Source: (Road Safety Annual Report, IRTAD, 2015)

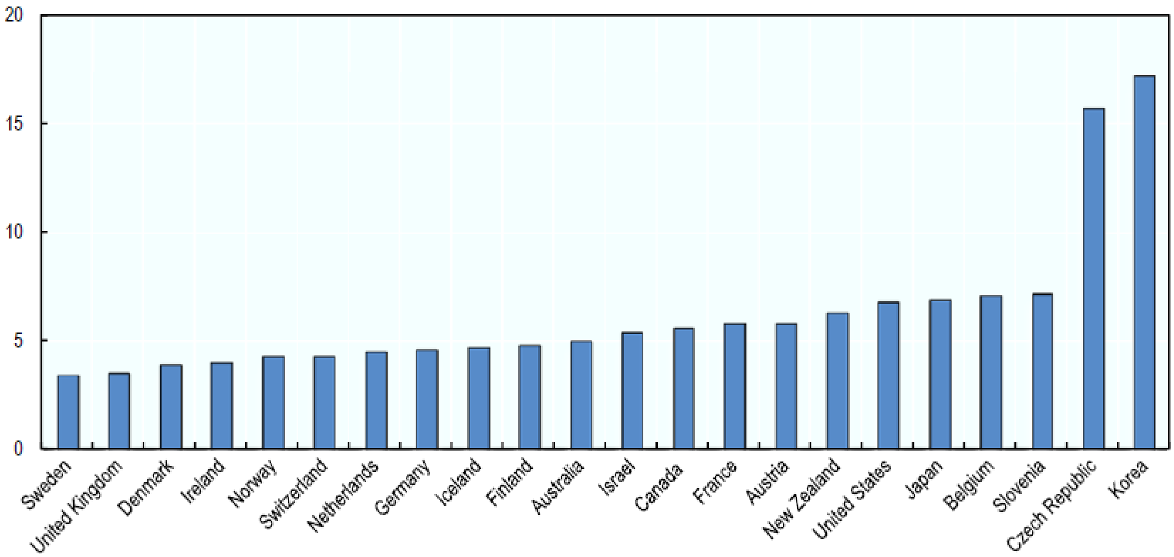


Figure 2.2: Road fatalities per billion veh. kilometers in 2013 of IRTAD countries

Source: (Road Safety Annual Report, IRTAD, 2015)

Main causes for this performance were the implementation of systematic road safety strategies and programs that tackle main risk factors for traffic crashes (speed, alcohol, non-compliance with traffic rules), advancing technical standards for road infrastructure and vehicles, improved emergency and heath care, and economic conditions (Road Safety Annual Report, IRTAD, 2015).

As per the IRTAD Road Safety Annual Report 2015, 90% of global casualties have reported from low- and middle-income countries.

2.4 Accident trends in developing countries

About 1.3 million persons die worldwide due to road accidents, and this is set to double by 2030 if this status continues. It is the developing countries that account for overwhelming part of the current fatalities, and forecasted accident fatalities. In particular, there are local and global initiatives to address the safety issues in developing countries. However, in developing countries there are emerging issues that may result in safety trend, which is different from industrialized countries (Mohamed et al., 2013).

Apart from the humanitarian aspect of reducing road deaths and injuries in developing countries, a strong case can be made for reducing road accident deaths on economic grounds alone, as they consume massive financial resources that the countries can ill afford to lose. Therefore, even within the boundaries of the transport and highway sector, hard decisions have to take on the resources that a country can devote to road safety (Jacobs, 2000).

Motor vehicle accidents are the leading cause of death in adolescents and young adults worldwide. Nearly three-quarter of road deaths occur in developing countries and men comprise a mean 80% of casualties (Odero et al., 1997).

There are wide variations in the characteristics of motor vehicle crashes between countries and regions of the developing world. Pedestrians are most vulnerable to injury and death. This may be due to many factors, including lack of pedestrian facilities in road design, poor knowledge and practice of road safety measures by the general population, uncourteous behavior of motorists, high-speed driving, and low levels of vehicle ownership. The high proportions of passenger fatalities appear to be associated with extensive use of public transport types and condition of such vehicles, and the driving skill of their operators (Odero et al, 1997).

2.5 Accidents in Expressways

Even though there are many expressways globally, it is vital to consider about a country similar to Sri Lankan context, as it will help to form an idea about the improvements and safety precautions need to apply for safer environment in this country. Under this topic, Expressways in our neighbour country India is considered, which has similarities to Sri Lanka with climate, traffic rules and regulations, types of vehicles used, and human thoughts.

- **Mumbai - Pune Expressway** in India is the first six-lane concrete, high speed, access controlled, tolled expressway. It spans a distance of 94.5km, connecting Mumbai-administrative capital of Maharashtra and Pune-financial capital of India. It was fully operationalzed in 2002 (https://en.wikipedia.org).

Speed and anti-crash barriers were the causes of most accidents in Pune expressway. A 60% of Expressway dividers had outdated anti-crash barriers.

- **Yamuna Expressway** is a six-lane (extendable to eight lanes) 165km long, controlled access expressway connecting Grater Noida with Agra (https://en.wikipedia.org). This road is prone to higher accident rates than others in India. Most of those are due to over-speed travelling and foggy environment. Severity of recent five major accidents are given below (Times of India, June 2015):
  - Five people dead – accident on 5 th June 2015
  - One person dead, seven people injured – accident on 8th March 2015
  - Two people dead, 25 injured, and 25 vehicles crashed with each other (25 car pile) – accident on 24 th December 2014 - in a cold and densely foggy morning
  - Two tourist buses were a part of the pile-up – accident on 26th November 2013 - result of low visibility, and collided with another vehicle
  - One dead and three injured – accident on 25 th August 2012

- Poor visibility due to fog led recent accidents on Greater **Noida Expressway** (State Road Development Co-operation Report, India, 2013).

2.6 Accident rate

Accident rate indicate the safety level of a certain road or the place, and it can be stated as population based rates or exposure based rate.

Population based rates are static in nature and not depend on the vehicle usage or total amount of travel. It is used in quantifying the overall risk to individuals on a comparative basis; for example, number of accidents per 100 populations, number of accidents per vehicle.

Road fatalities calculated for 100,000 inhabitants in 2013 of IRTAD countries are presented in Figure 2.1.

Exposure based rates reveal the accident rates based on vehicle miles/kilometers travel or vehicle hours travelled. It attempts to measure the amount of travel for exposure to risk.

For analyzing a road, exposure based rates are more accurate and important to get better image of the present situation than other method. Road fatalities calculated for billion vehicle kilometres in 2013 of IRTAD countries are presented in Figure 2.2.

To calculate accident rate based on the vehicle kilometres travelled (VKT), it need to find the VKT. The annual VKT estimation models based on traffic counts use the data collected on a sample of monitored road sections to estimate the VKT of the entire network. Traffic flow, usually represented by the Annual Average Daily Traffic (AADT), and length of the sampled road sections, are the main variables used. To calculate annual value, it is multiplied by the number of days in a year. In estimating VKT using traffic counts, it is customary to assume that a vehicle counted on a section of road travels the entire length of the section. Under this method, some vehicles travelling only a portion of the section will be counted while others will not, depending on whether they cross the counting location (Hossain and Gargett, 2011).

2.6.1 Accident rate in VKT for Sri Lanka

As per the study of “Estimation of Vehicle Kilometres travelled in Sri Lanka” by Darshika Jayasekera (Jayasekera, 2013), VKT for different types of vehicles in year 2012 is presented in Table 2.1.

Table 2.1: Vehicle Kilometre Travelled in 2012 in Sri Lanka

Vehicle type	Vehicle		VKT x 10^6
Diesel	Three wheelers		1,660
	Cars & S/Wagons		505
	Pick Ups	DP Vehicle	515
	SUV		466
	Passenger Van		1,550
	Goods Van		585
	Mini Bus	Bus	250
	Bus		647
	Light Truck	Truck	1,284
	Medium Truck		1,403
Total VKT for diesel vehicles			**8,865**
Petrol	Motor Cycles		15,410
	Three wheelers		8,103
	Cars & S/Wagons		3,911
	Jeep & Pajero	DP Vehicle	481
	Passenger Van		707
Total VKT for petrol vehicles			28,612
Total for Both type of vehicles			**37,477**

According to the accident statistics of Sri Lanka Police, road accidents in several severity levels in are given in Table 2.2.

Table 2.2: Road accidents summery based on severity in Sri Lanka (2009-2011)

Severity	2010	2011	2012	2013	2014
Fatal	2,570	2,491	2,203	2,189	1,914
Grievous	6,121	6,956	6,971	6,872	6,102
Non Grievous	12,540	13,176	14,200	13,526	11,079
Damaged only	16,378	17,562	17,542	15,293	12,426
Total no of accidents	**37,609**	**40,185**	**40,916**	**37,880**	**31,521**

Source: [Sri Lanka Police (http://www.police.lk)]

When total number of accidents are considered ,accidents seems to be increased drastically within 2011 and increased slightly up to 2012 while opposite trend has generated year 2013. In year 2014 number of accidents is considerably lower compared to year 2013. Similar trend can be observed with respect to crashes damage only type as well. However, when fatal crashes are considered, a reduction can be seen from 2010 to 2014.According to the above figures fatal accidents reported in Sri Lanka out of total road accidents is around 6% within past few years.

Accidents rate per VKT in 2012 can be estimated for each of the severity level based on the information provided in Table 2.1 and Table 2.2. Results are tabulated in Table 2.3 and according to that accident rate for the entire Sri Lanka for year 2012 is 1.092 x 10^{-6} per VKT.

Table 2.3: Accident Rate per VKT in Sri Lanka

Severity	**Accident rate per VKT x 10^{-6}**
Fatal	0.059
Grievous	0.186
Non Grievous	0.379
Damaged only	0.468
Total no of accidents	**1.092**

As per the table 2.3, fatality rate and grievous accident rate in Sri Lanka in year 2012 are 59 per billion VKT and 186 per billion VKT respectively. When comparing the fatality rate in IRTAD countries in year 2013 (figure 2.1) Sri Lankan situation is more sever.

2.6.2 Accident rate per VKT for A2 (Colombo – Galle – Hambanthota – Wellawaya) road section from Moratuwa to Galle

One objective of this research study is to estimate accident rate in Southern Expressway in Sri Lanka and to make comparisons of accident rates with similar road corridors in the country. In A2 road, corridor from Moratuwa to Galle (from Angulana to Magalle) has some similarities in traffic with Southern Expressway and both road corridors serve for traffic between Colombo and Galle.

According to the crash data collected from Sri Lanka Police Department, total number of accidents in A2 road corridor is tabulated in Table 2.4 with respect to their severities after sub dividing in to several sections (Audit on Southern Expressway Transportation Engineering Division, University of Moratuwa, 2014).

Table 2.4: Accidents data based on severity along A2 road in year 2012

Road section	**No of accidents (in year 2012)**				
	Fatal	**Grievous**	**Non Grievous**	**Damage only**	**Total**
Angulana- Panadura (10km - 25km)	12	76	91	205	384
Panadura- Payagala (25km - 50km)	21	87	163	139	410
Payagala – Benthota (50km - 63km)	11	28	85	37	161
Benthota –Hickkaduwa (63km -98km)	36	60	149	90	335
Hikkaduwa – Magalle (98 km -119km)	20	48	145	126	339
Total	**100**	**299**	**633**	**597**	**1629**

Source: (Audit on Southern Expressway, Transportation Engineering Division, University of Moratuwa)

Table 2.4 depict the distribution of accidents with several levels of severities alone the A2 road section and it can be clearly see that high percentage of total accidents are covered by damaged only type crashes while fatal accidents are around 5 -6 % of total. However in road section Benthota – Hikkaduwa, number of fatal accidents is considerably higher (10%).

According to the Traffic study [conducted by the ADB (Asian Development Bank) -funded Project Division of RDA in co-operation with Transportation Engineering Division, University of Moratuwa, traffic flow of several road stations in A2 road corridor selected is shown in Table 2.5.

Table 2.5 : Traffic flow in stations in Moratuwa – Galle road corridor in A2 road

Station	Average Hourly Traffic flow
Panadura	1530
Payagala	1216
Benthota	608
Hikkaduwa	711

Source: (Audit on Southern Expressway, Transportation Engineering Division, University of Moratuwa)

According to the data in Table 2.5, hourly traffic flow for the each of the road sections were calculated by considering the location of the station within the certain road sub sections. That aids to detect the Annual Average Daily Traffic (AADT) and consequently accident rate for each of the road section were calculated and tabulated in Table 2.6 and 2.7.

Table 2.6: VKT in considered sections in A2 road

Road section	Road length (km)	AADT	Annual Traffic Volume	VKT x 10^6
Angulana (Moratuwa) - Panadura	10	36,720	13,402,800	134.03
Panadura - Payagala	25	32,952	12,027,480	300.69
Payagala - Benthota	13	21,888	7,989,120	103.86
Benthota - Hikkaduwa	35	15,828	5,777,220	202.20
Hikkaduwa - Magalle	21	17,856	6,517,440	136.87
Angulana - Magalle (Galle) total road section	104	125,244	45,714,060	877.64

Table 2.7: Accident Rate per VKT in A2 road

Road section	Accident rate per VKT x 10^{-6}				
	Fatal	**Grievous**	**Non Grievous**	**Damage only**	**Total**
Angulana (Moratuwa) - Panadura	0.09	0.57	0.68	1.53	2.87
Panadura - Payagala	0.07	0.29	0.54	0.46	1.36
Payagala - Benthota	0.11	0.27	0.82	0.36	1.55
Benthota - Hikkaduwa	0.18	0.30	0.74	0.45	1.66
Hikkaduwa - Magalle	0.15	0.35	1.06	0.92	2.48
Whole section	**0.11**	**0.34**	**0.72**	**0.68**	**1.86**

Table 2.7 clearly shows that accident rate in Angulana – Panadura and Hikkaduwa – Magalle which are closer to the main town areas shows higher values than other while total toad section notifies 1.86 x 10^{-6}accidents per VKT .When we pay attention on fatal accident rate Benthota Hikkaduwa and Hikkaduwa Magalle road section have higher rates while whole road section shows fatality rate of 110 per billion VKT.

CHAPTER 3. METHODOLOGY

As the first step available literature were reviewed to identify possible reasons for the accidents occurring in Expressways in other countries, and to find geometrical requirement of roads to ensure more safety within the given speed limits.

Secondary, accident data relevant to the corresponding period was collected from EMMOD, RDA and Sri Lanka Police. Geometric drawings were collected to mark the accident-prone locations and to review the geometry of accident-prone areas. As one of the research objectives is to discover the accident rate, traffic data of above road section were collected from EMMOD, RDA.

Thereafter with the collected accident data, accident-prone locations were identified by marking each accident as a spot on the map. Each of the accidents were marked near to 100m road segments as the Author had data to that extent (as per the accident report form EOMMD, RDA). After that the accident prone locations were identified through the list of locations ranked by number of reported accidents (frequency). Ten locations were considered for further studies.

Next, the ten locations were studied geometrically, and environmentally. Then the police reports and the EOMMD accidents report were scrutinized to obtain some details of the causal reasons for accidents. By considering all these issues, few conclusions were made regarding the causes for the Southern Expressway accidents.

Accident rate based on vehicle travel kilometre was calculated from the collected traffic data and accident data from above mentioned two sources. Finally conclusion and some recommendations were made according to the results.

Figure 3.1 shows the flow chart of research methodology.

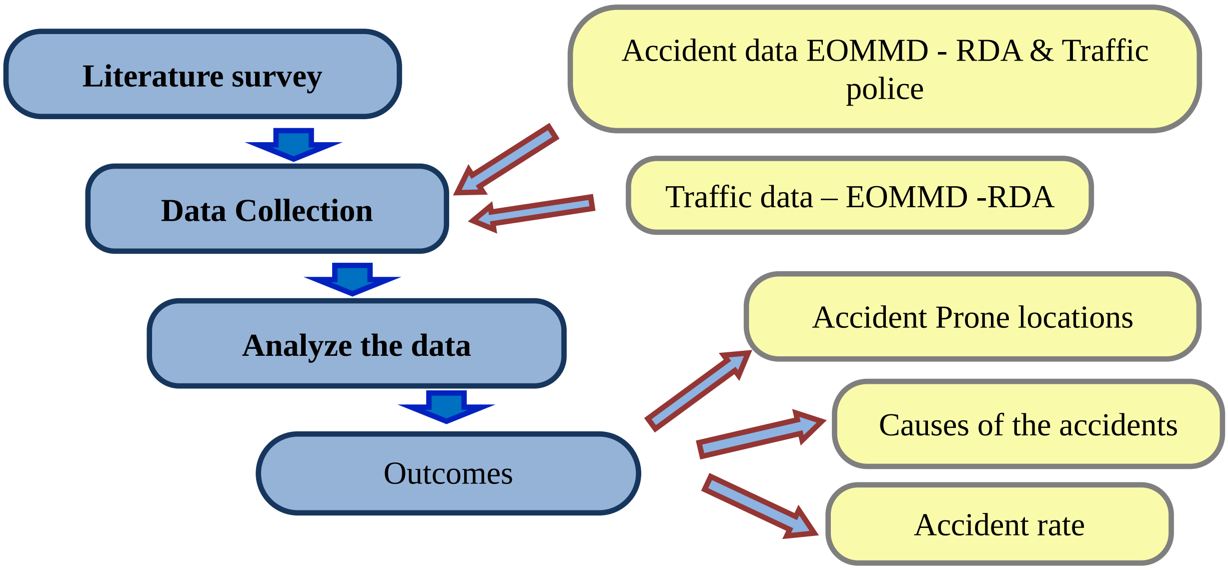


Figure 3.1: Flow Chart of the research methodology

CHAPTER 4. DATA ANALYSIS

4.1 Accident data

According to the accident data collected from EOMMD, RDA, and Sri Lanka Police, contributions of each of the above-mentioned factors for the accidents (in Kottawa – Pinnaduwa road section) are graphically presented in Figure 4.1 and Figure 4.2. As per these figures, contributions of Human errors and road environment are the significant reasons, similar to the literature. As the first experience of expressway at the first year of operation, it is acceptable that the higher contribution is from Human error (drivers). Later, contribution of each factor stabilized in to 14%, 35%, and 50% ranges.

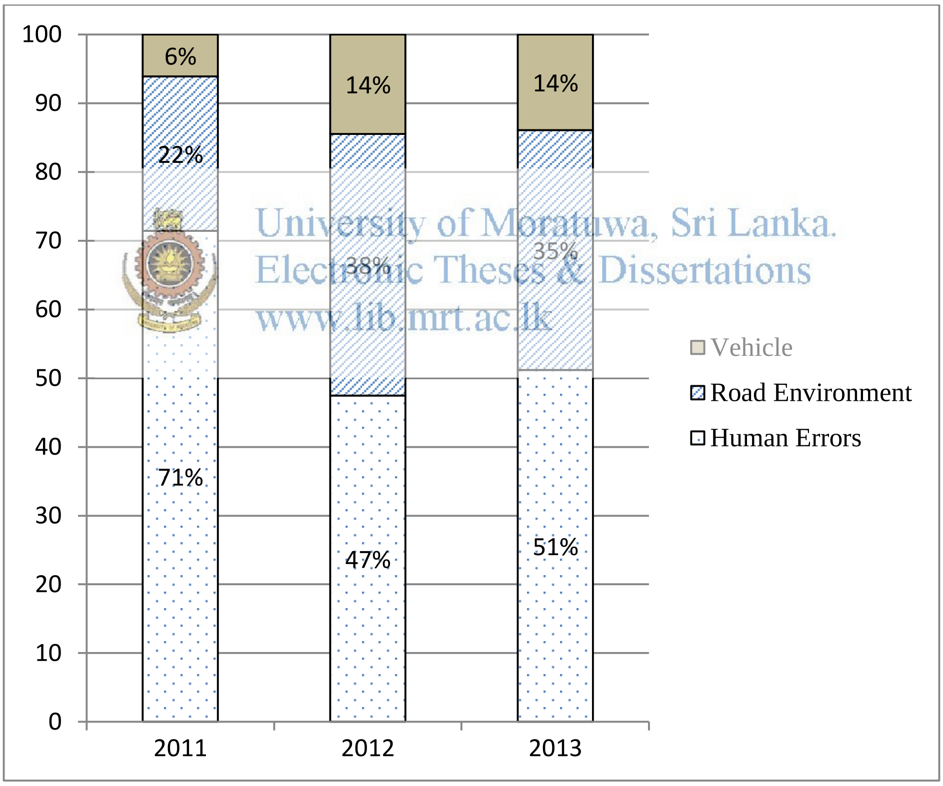


Figure 4.1: Contribution of main three factors for accidents as per the RDA data

Source: (Accident data – EMMOD, RDA, 2013)

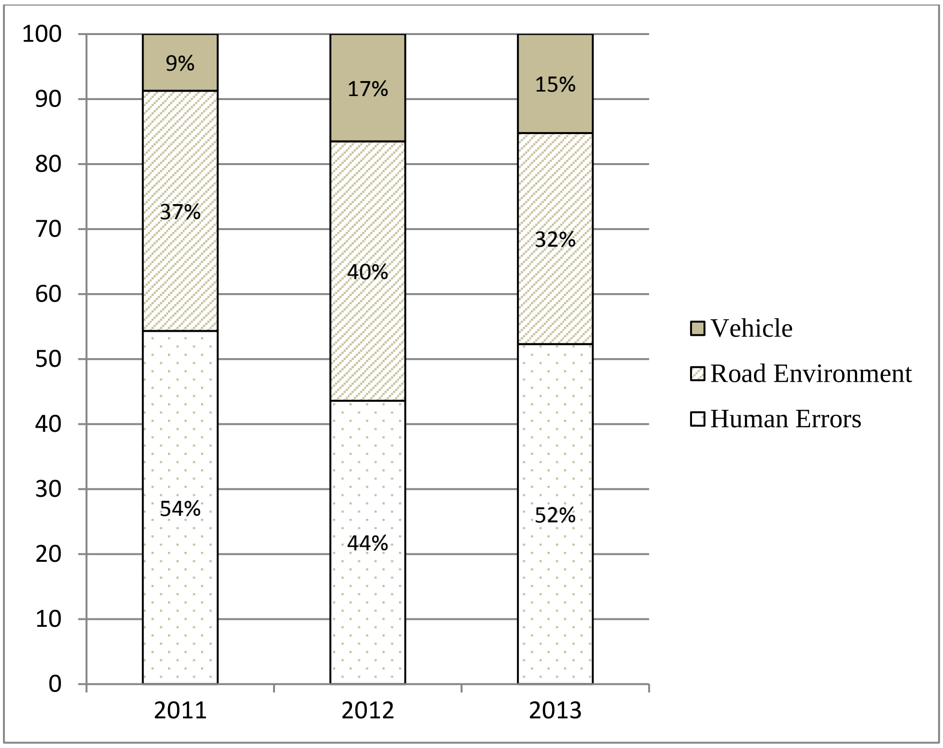


Figure 4.2: Contribution of main three factors for accidents as per the Police data

Source: (Accident data, Sri Lanka Police, 2013)

Above three factors contain sub causes as mentioned in figure 4.3. Contribution of each sub cause is presented in Table 4.1 and graphically demonstrated in detail in next pages.

- Speed
- Suddenly Stopping
- Incompetent Driving
- Overtaking
- Negligence
- Fatigue

} - Human factor

- Vehicle condition – (Technical Problems, Firing etc.) - Vehicle factor

- Road (Road Surface condition, Road Geometry etc.)
- Weather
- Animal factor
- Stone fallen

} Road environment

Figure 4.3: Sub division of main Accident causes

Figure 4.4 illustrates the number of accidents occurred due to each cause during the past period as per the reported data by RDA. Accordingly, even though initially the vehicle speed made considerable number of accidents, it reduced within seven months with the experience of road users on expressway. In addition, it signifies a correlation between vehicle condition and weather. Although number of accidents due to overtaking, drivers' negligence, and suddenly stopping have slightly reduced, accidents due to bad driving have increased irregularly with time. Effect of the road environment has not varied drastically with time and road environment was not a key factor compared with human factor. Details are tabulated in Table 4.1.

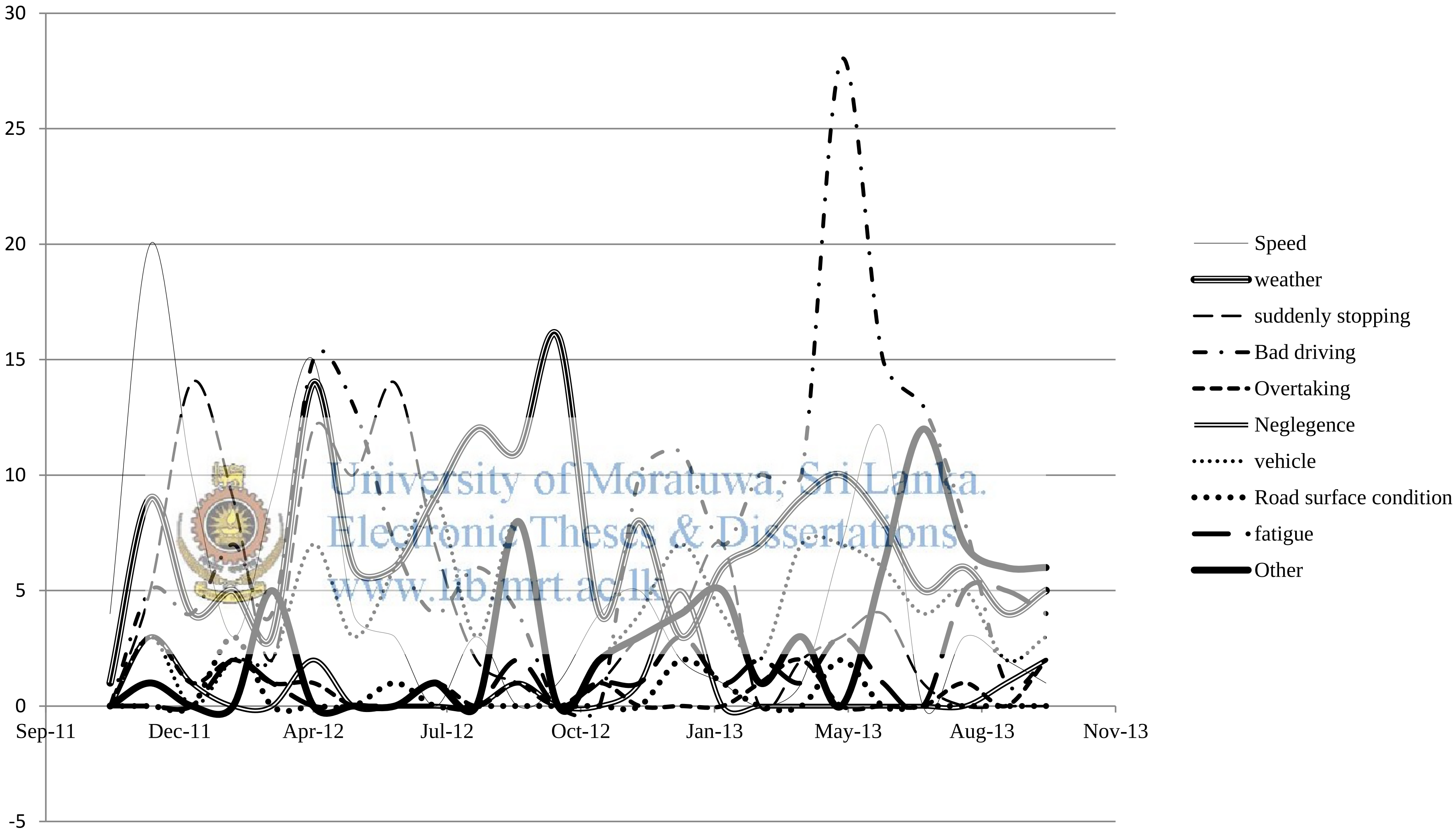


Figure 4.4: Causes for the accidents in Kottawa - Pinnaduwa section

Source: (EOMMD, RDA)

Table 4.1: Accidents due to different causes in Pinnaduwa – Kottawa section

Reasons for the Accidents	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13
Speed	4	20	10	3	9	15	4	3	0	3	0	1	4	5	2	1	0	1	7	12	0	3	2	1
Suddenly stopping	0	5	14	9	2	12	10	14	7	2	1	0	1	3	4	7	0	2	3	4	1	0	0	0
Bad driving	0	5	4	7	4	15	13	7	4	6	4	0	0	10	11	7	10	10	28	15	13	8	1	2
Overtaking	0	3	1	2	1	1	0	0	1	0	1	0	1	0	0	0	1	2	0	0	0	1	0	2
Negligence	0	3	1	0	0	2	0	0	0	0	1	0	0	1	5	0	0	0	0	0	0	0	1	2
Fatigue	0	0	0	2	1	0	0	0	0	0	2	0	1	1	3	1	2	1	3	1	0	5	5	4
Weather	1	9	4	5	3	14	6	6	9	12	11	16	4	8	3	6	7	9	10	8	5	6	4	5
Road surface	0	0	0	3	0	0	0	1	0	0	0	0	0	0	2	1	0	0	2	0	0	0	0	0
Vehicle defects	0	3	0	2	2	7	3	6	9	3	8	0	2	4	7	4	2	7	7	6	4	5	2	3
Other	0	1	0	0	5	0	0	0	1	0	8	0	2	3	4	5	1	3	0	6	12	7	6	6

Source: (EOMMD, RDA)

To analyse human factors, appropriate survey methodology has to be followed, as it is not suitable to rely on recorded data to obtain accurate results.

However, it is difficult to conduct such a survey within a short period and a data collection as such is presently unavailable. Hence, human factor was not considered and this research is focused only on the road environment, the second significant accident-causing factor, as it can attain accurate conclusions based on the available data and field observations.

To find the accident-prone locations and reasons for the accidents, below mentioned steps were followed:

1. Collection of Accident data from EOMMD, RDA, and Sri Lanka Police (Accident form of EOMMD of RDA; attached in Annex 1).
2. From the records, following details were extracted:
   - Accident location near to 100m
   - Accident occurred time
   - Weather condition
   - Surface condition of the road
   - Severity of the accident
3. Accident locations were marked in the map with severity.
4. High number of accident occurred locations were identified as 'prone locations' (Annex 2) and listed orderly.
5. From the identified locations, ten most vulnerable locations were selected.
6. Each of the identified prone location was analysed structurally, geometrically, and environmentally to identify reasons for the accidents at each spot.

Accident rates calculated by following methodology:

1. Collection of Annual Average Daily Traffic data from EOMMD, RDA
2. Calculation of Annual Traffic Volume using data from the previous step
3. Calculation of Vehicle travel km by multiplying Annual Traffic Volume and travel kilometres. Here, AADT for road segment within each of two

interchanges was multiplied by road length between that specific two interchanges, to have Accident rate for each of the sections separately.

4. Separately recording the accidents within each road segment.
5. Calculation of accident rate per vehicle travel kilometre, using following equation:

   Accident rate = Number of Accidents / Total Vehicle travel kilometre

4.2 Accident Prone Locations

Accident-prone locations identified by the methodology as described above are tabulated in Table 4.2.

Table 4.2 : Identified Accident Prone locations in Kottawa- Pinnaduwa section

Location (near to 0.1km)	Total No. of accidents occurred	No. of Accidents in Colombo Direction	No. of Accidents in Galle Direction
0+100 (RHS)	25	25	-
5+800 (RHS)	12	12	-
8+000 (RHS)	8	8	-
22+100 (RHS)	8	8	-
55+300 (LHS)	8	-	8
58+800 (LHS)	7	-	7
65+100 (LHS)	7	1	6
27+800 (RHS)	6	6	-
64+800 (RHS)	5	4	1
5+900 (RHS)	5	5	-

Source: (Accident data , EOMMD, RDA)

Table 4.2 clearly depicts that travelling direction of the vehicle faced the accidents at prone locations and accordingly, it was decided which side (RHS or LHS) road section are more critical and need further analysis. When accidents occurred at prone location in both directions, the side where majority of the accidents have taken place was considered.

At the (0+100)km location, all accidents have been reported before constructing the new interchange at Kottawa. Until completion, Kottawa interchange has provided temporary interchange with sudden turning geometry with directing vehicles by water barriers. Most of the accidents (23 accidents) happened in this location were due to crashing with water barriers or throw out from the road owing to sudden bend. After completion of the interchange, number of accidents occurred at this location reduced drastically and hence, the location (0+100)km can be neglected from the list of accident-prone areas.

4.3 Reasons for the Accidents

Accordingly to the all above facts, the only reason it could be considered for the accident is the road environment. To analyse this issue, each of the prone location was analysed in detail and data were summarized in Tables 4.3 and 4.4. For furnish the accurate decision, each of the locations were considered in environmentally as well as geometrically. In road environment, weather condition, road surface condition, and accident occurred time was considered as the important factors in an accident-prone location.

Table 4.3: Details of the accidents in identified prone locations

Chainage	Total No. of accidents	Weather			Surface Condition				Accident occurred Time		Lightning condition
		Rain	Clear	Cloudy	Slippery	Wet	Dry	Flooded with water	Night	Day	
5+800 / CD	12	12	0	0	10	0	0	2	3	9	With good street light in night
5+900 / CD	5	4	1	0	3	1	0	1	4	1	With good street light in night
8+000 / CD	8	8	0	0	7	0	0	1	1	7	No street light in night
22+100 / CD	8	6	2	0	6	1	1	0	2	6	No street light in night
27+800 / CD	6	6	0	0	6	0	0	0	1	5	No street light in night
55+300 / GD	8	7	1	0	7	0	0	1	0	8	
58+800 / GD	7	7	0	0	7	0	0	0	1	6	No street light in night
64+800 / CD	5	5	0	0	3	0	0	2	1	4	No street light in night
65+100 / GD	7	5	1	1	5	1	1	0	3	4	No street light in night

Table 4.4 : Geometrical details in identified prone locations

Chainage	Vertical Gradient	Horizontal Alignment	Cross fall	Super elevation provided or not
5+750 5+800 5+850 5+900 5+950	0.95% 0.70% 0.43% 0.10% -0.90%	Straight Straight Curve with R=2500 m	-2.500 -2.500 -2.500 -1.578 -0.189	Provided
7+950 8+000 8+050	2.00% 1.80% 1.53%	Curve with R=2500 m Curve with R=2500 m Straight	2.500 2.500 2.355	Provided
22+050 22+100 22+150	0.270% 0.273% 0.275%	Straight Straight Straight	-2.500 -2.500 -2.437	Started to provide
27+750 27+800 27+850	0.03% 0.03% 0.03%	Straight Straight Straight	-2.500	Not Provided
55+250 55+300 55+350	-0.34% -0.34% -0.34%	Straight Straight Straight	-0.298 1.369 2.480	Provided
58+750 58+800 58+850	-0.30% -0.30% -0.30%	Straight Straight Straight	-2.500	Not Provided
64+750 64+800 64+850	-0.15% -0.40% -0.50%	-Curve with R=1900 m	1.454 0.343 0.769	Provided
65+050 65+100 65+150	-0.51% -0.51% -0.51%	Straight Straight Curve with R=2100 m	3.200	Not Provided

In addition to the geometrical consideration with the drawings, side inspections produced more accurate details. Accordingly, some of the prone locations were observed to be in water stagnated situation or water flow across the road, during and after the rain, as tabulated in Table 4.5.

Table 4.5: Water remaining locations as per the site observations

Chainage	Condition	Remarks
5+800	-	
5+900	Water staging	LHS – Both lanes
8+000	Water staging	RHS – Both lanes
22+100	Water staging	RHS & LHS – Inner lanes at 22+200
27+800	Water staging	RHS & LHS – Inner lanes at 27+900
55+300	Water flow across the road	
58+800	Water flow across the road	At 58+700
64+800	Water flow across the road	At 64+900
65+100	-	

- **Accidents due to speed**

From year 2013, EMMOD, RDA has collected data on time of entering to the expressways of the vehicle that met with an accident (using the accident data for Kottawa – Pinnaduwa section). Since accident occurred time is readily available, it is possible to calculate the average speed of the vehicle. EOMMD, RDA only has the accident reported time to them and depending on the delay time between times of accident occurred and accident reported, the average speed of the vehicle would vary within a considerable range. Average speed of the vehicle faced with the accident was calculated by considering the accident reporting to EOMMD, RDA after 2 minutes, 5 minutes, and 10 minutes of the accident, as tabulated in Table 4.6.

However, as per the experience of the traffic Engineer and the accident data recording crew of the Southern Expressway, each accident was reported to EMMOD, RDA within five minutes of the accident. Based on that, it can consider the third column of Table 4.6 (Accident report after 5 minutes) as the average speed of the vehicle faced with the accident. Thereby, it is possible to identify whether the vehicle speed has a considerable influence on the accident.

Table 4.6: Average speed of the vehicles faced to accidents

Chainage	**Average Speed of the vehicle faced to accident (km/hr)**		
	Accident report after 2 min	**Accident report after 5 min**	**Accident report after 10 min**
5+800 - 5+900	117	132	174
8+000	78	89	120
22+100	65	83	109
27+800	96	100	106
55+300	81	89	105
58+800	76	80	102
64+800	81	109	115
65+100	80	106	118

- **Accident due to Fatigue**

  As per the records of EOMMD, RDA, data may have some correlation between cause of fatigue for accident and vehicle travelling distance. According to the 2013 accident data (for Kottawa – Pinnaduwa section) of EOMMD, RDA, number of accidents due to fatigue and the travelling distance can be tabulated as in Table 4.7.

Table 4.7: Accidents due to fatigue with travelling distance

Travel Distance (km)	**No. of Accidents**
0-20	6
20-40	7
40-60	11
60-80	7
80-95	9
Undefined	5
Total	**45**

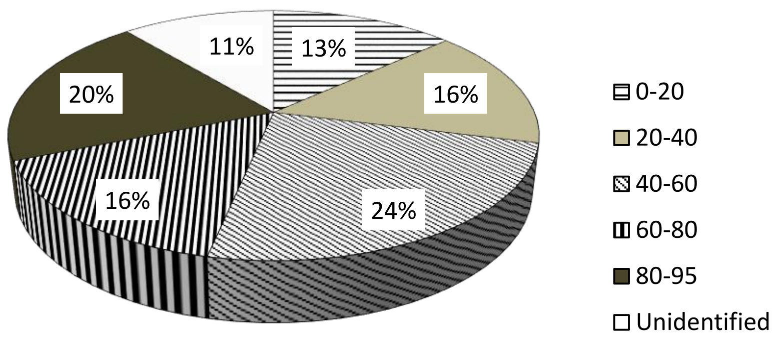


Figure 4.5: Contribution of travelling Distance to Fatigue Causing Accidents

Source: (Accident data of EOMMD, RDA, 2013)

Figure 4.5, which graphically displays the data in Table 4.7, clearly illustrate that, accidents were more when the travel distance is more (distance over 40km). Consequently, this demonstrates that drivers tend to fall asleep due to fatigue during driving long distances.

All facts relevant to each of the prone locations were analysed in logical manner, in compliance with the actual site conditions to identify possible reasons for the accident at those critical areas, which will represent the picture of whole expressway.

- **Accident occurred time**

In addition to the above issues, consequence of the accident occurring time (whether the accident happened during night time or day time) for happening an accident was considered. As per the EMMOD, RDA data, many accidents have taken place in night time and day time in year 2012 and 2013, as tabulated in Table 4.8. Accordingly, percentage of accidents occurring in day time has decreased from 75% to 65% while accidents in night time has increased from 26% (= 19% + 7%) to 35% (= 9%+26%). During the night time, majority of the accidents happened at locations without street light. However, there is no significant variation between situations with and without street light.

Table 4.8: Accidents in Day time and Night time (Kottawa to Pinnaduwa section)

	2012		**2013**		**Total**	
	No. of accidents	**%**	**No. of accidents**	**%**	**No. of accidents**	**%**
Day time	301	75%	361	65%	662	69%
Night time without street light	75	19%	50	9%	125	13%
Night time without street light	27	07%	143	26%	170	18%
Total	**403**		**553**		**956**	

According to Table 4.8, a significant number of accidents happened during night time. Number of accidents reported in each of the 5km road strips within past period (from November 2011 to October 2013) produced an idea about the most vulnerable accident locations during the night time compared to the day time. This information is presented graphically in Figure 4.5.

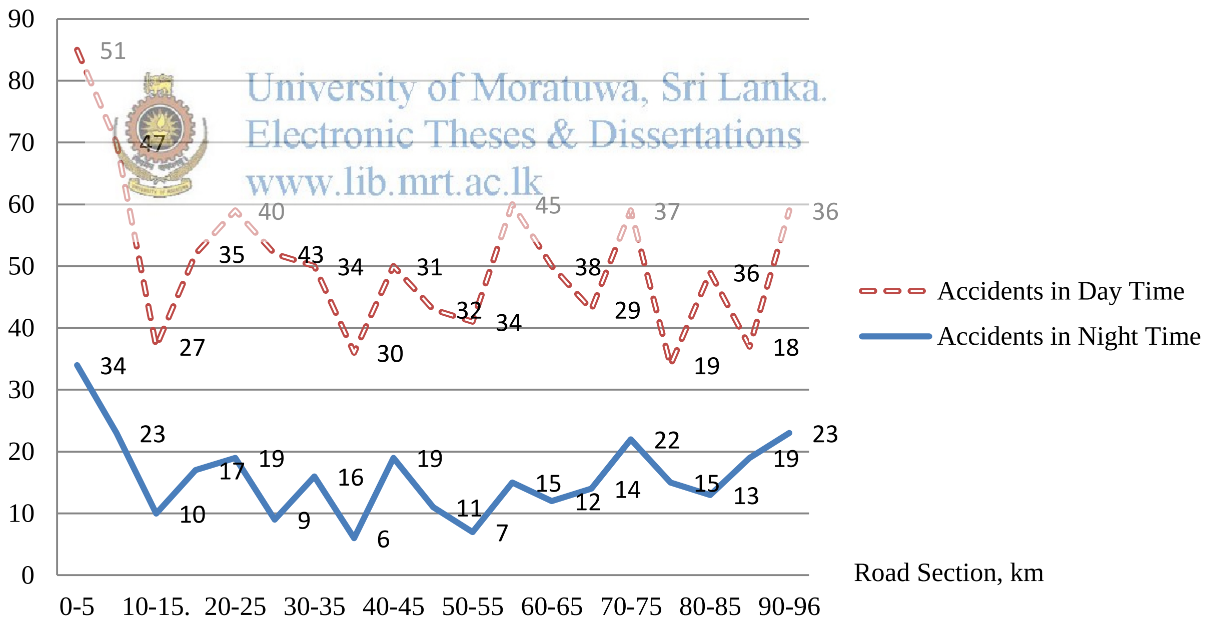


Figure 4.6: Accidents in Day Time and Night Time over 5km road sections
Source: (Accident data of EOMMD, RDA)

Figure 4.6 clearly illustrate that accidents in night time and day time vary in a similar pattern over each road section, though day time accidents is about double of the night time. However, since total traffic in day time is more than night time, percentage of accidents out of total traffic may not have a vast deviation. Therefore, it can be concluded that there is no influence of accident happening time for an accident on a particular road section.

4.4 Accident Rate

- Accident rate based on road length

Accident rates based on the road lengths were calculated. Number of accidents happened in each road sections were divided by the length of that road section.

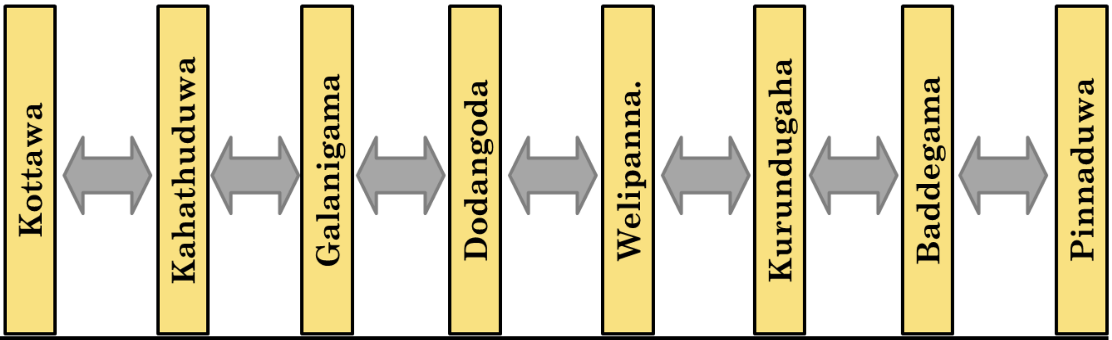
Table 4.9: Accident rate based on road length

Road Sections	No. of Accidents	No. of Accidents / km
Kottawa - Kahathuduwa (6km)	(119-23) = 96	16.0
Kahathuduwa - Galanigama (8km)	82	10.3
Galanigama - Dodangoda (20km)	194	9.7
Dodangoda - Welipanna (12km)	96	8.0
Welipanna - Kurudugaha (21km)	197	9.3
Kurudugaha - Baddegama (13km)	114	8.8
Baddegama - Pinnaduwa (16km)	155	9.7

Here, accidents occurred within Kottawa-Kahathuduwa section due to negligence of the temporary interchange for reasons given in section 4.2.

- Accident rate based on vehicle travel kilometres

Annual Average Daily Traffic (AADT) per each of the road section for year 2011-2012 and for year 2013 are demonstrated in Figure 4.7, Table 4.10, and Table 4.11.



Year	AADT						
2011 & 2012	6559	6979	6761	6008	5545	4877	4411
2013	8044	8553	7695	6682	6094	5282	4752

Figure 4.7: AADT for Kottawa – Pinnaduwa section in year 2011, 2012, 2013

Source: (Accident data of EOMMD, RDA)

Calculated accident rates per VKT for year 2011-2012 and for year 2013 are tabulated separately as in Tables 4.10 and 4.11.

Table 4.10: Accident rate per VKT for year 2011-2012

Road Section	Vehicle Travel km x 10^6	No. of Accidents	Accident rate Veh.km x 10^{-6}
Kottawa – Kahathuduwa	15.70	(73-23)=50	3.18
Kahathuduwa - Galanigama	22.28	49	2.20
Galanigama – Dodangoda	53.95	108	2.00
Dodangoda – Welipanna	28.77	52	1.81
Welipanna – Kurudugaha	46.46	114	2.45
Kurudugaha – Baddegama	25.30	66	2.61
Baddegama – Pinnaduwa	28.16	90	3.20
Total	**220.62**	**529**	**2.40**

Table 4.11: Accident rate per VKT for year 2013

Road Section	**Vehicle Travel km x 10^6**	**No. of Accidents**	**Accident rate Veh.km x 10^{-6}**
Kottawa - Kahathuduwa	14.72	46	3.12
Kahathuduwa - Galanigama	20.87	33	1.58
Galanigama - Dodangoda	46.94	86	1.83
Dodangoda - Welipanna	24.46	44	1.80
Welipanna - Kurudugaha	39.03	83	2.13
Kurudugaha - Baddegama	20.94	48	2.29
Baddegama - Pinnaduwa	23.19	65	2.80
Total road	**190.15**	**405**	**2.13**

According to the above data, Pinnaduwa–Baddegama and Kottawa–Kahathuduwa sections have the highest accident rates for year 2011-2012 and year 2013 respectively. However, accident rate for each road section has declined from year 2011-2012 to 2013. For the entire road, accident rate has reduced from 2.40 x 10^{-6} to 2.13 x 10^{-6} from 2012 to 2013 period.

According to literature, road accident rate in A2 road corridor in year 2012 was 1.86 x 10^{-6} per VKT and hence, Southern Expressway shows a higher accident rate (2.40 x 10^{-6}) within the considered period than similar road sections in Sri Lanka.

Details of the fatal accidents in each of the road section are tabulated in Table 4.12.

Table 4.12: Fatal Accidents in Each road section in Southern Expressway

Road Section	No. of Fatal Accidents	
	2012	**2013**
Kottawa - Kahathuduwa	-	-
Kahathuduwa - Galanigama	-	-
Galanigama - Dodangoda	3	2
Dodangoda - Welipanna	-	-
Welipanna - Kurudugaha	1	1
Kurudugaha - Baddegama	-	1
Baddegama - Pinnaduwa	-	1
Total	**4**	**5**

In years 2012 and 2013, the percentages of fatal accidents out of the total accidents are 0.75% and 1.23% respectively. Following calculation demonstrate the more elaborative picture on whole expressway total fatal accident rate per vehicle kilometre travelled (for the total road).

For year 2012, Fatal Accident Rate per vehicle kilometre Travelled

$$= \frac{\text{Number of fatal accidents}}{\text{Total vehicle kilometre travelled (as per Table 4.10)}}$$

$$= \frac{4}{(220.62 \times 10^6)}$$

= 18 per billion Veh km

For year 2013, Fatal Accident Rate per vehicle kilometre Travelled

$$= \frac{\text{Number of fatal accidents}}{\text{Total vehicle kilometre travelled (as per Table 4.11)}}$$

$$= \frac{5}{(190.15 \times 10^6)}$$

= 26 per billion Veh km

This illustrates that risk of fatal accidents have increased from year 2012 to 2013.

However fatal accident rate in A2 road corridor is considerably higher (Table 4.7) than values for southern expressway.

Vehicle kilometre travelled per month in year 2012 was 18.4 (= 220.62veh km / 12 months) while in 2013, it was 19.0 (= 190.15veh km / 10 months).

Total percentage of vehicle kilometre travelled in the Southern Expressway, out of the total country value could be obtained for year 2012 referring the values in Table 2.1 and Table 4.10 as 0.60 % (= 220.62 x 10^6 / 37477 x 10^6 x 100).

CHAPTER 5. CONCLUSION

5.1 Discussion

Accident Prone locations were identified for closer 100m distance. Each accident-prone area was considered in detail to find the reasons for accidents in those locations respectively.

- 5+800km
    - This location is in the Kahathuduwa interchange. Here, adequate amount of streetlight is provided, even during night time. According to Table 4.3, there are 12 number of accidents occurred at 5+800km, out of which, majority happened in day time. Therefore, it is concluded that lighting was not a causal reason for the accidents of this location.

    - According to Table 4.3, all accidents at 5+800km happened during rainy weather condition, and out of that, 10 accidents occurred with slippery road surface while two accidents when the road was flooded with water. Therefore, there is a high possibility of having a problem in road surface or the cross fall.

    The cross fall of (6+038 to 5+868)km region from Table 5.1 denotes it has less cross fall due to super elevation provided. This has led to create a water stagnation condition at that location. Thus, actual site condition under rainy situation was investigated for further clarification. According to the Table 4.5 it was not observed a stagnated water flow across the road at the rainy weather at this location. Eventhough there is a less cross fall region excellence in the construction (perfectly maintain the cross fall variation) has prevented the water stagnation.Therefore, water stagnation due to less cross fall is not an issue for the accidents.

    Subsequently, road surface condition is required to check with standard roughness values.

- According to Table 4.4, vertical gradient is around 1% and horizontal alignment not been critical.
- When considering the speed data according to Table 4.6, average speed of the vehicles encounter with accidents is 132km/hr. Allowable speed limit for Southern Expressway is 80-100 km/hr while design speed is 120 km/hr. Therefore, speed of the vehicles may be a reason for the accidents at this spot.

Table 5.1: Variation of cross fall around 5+800-5+900km

Actual Chainage	Cross Fall
5.798	2.500
5.808	2.500
5.818	2.500
5.828	2.500
5.838	2.500
5.848	2.500
5.858	2.500
5.868	2.412
5.878	2.134
5.888	1.856
5.898	1.578
5.908	1.300
5.918	1.023
5.928	0.745
5.938	0.467
5.948	0.189
5.958	0.088
5.968	0.366
5.978	0.644
5.988	0.922
5.998	1.199
6.008	1.477
6.018	1.755
6.028	2.033
6.038	2.311
6.048	2.500
6.058	2.500

- 5+900km
  - This location is also in Kahathuduwa interchange and good street lightings are provided during night time. According to Table 4.3, majority of accidents occurred during night time. However, visibility could not be the reason behind the accidents at night time.
  - According to Table 4.3, four accidents out of a total of five happened during rainy weather, while one occurred at clear weather. Further, all the accidents happened during wet, slippery, or flooded with water condition. Hence, it is obvious that reasons based on road surface or the cross falls lead to accidents in this part of the road section.

    Cross fall provided due to super elevation is less than 2.5% from the region around 5+900km (Table 5.1), as described previously. There is a possibility of water stagnating at this location as per the geometric drawings and details in Table 4.4 as well as the appearance. Therefore, water remaining on the surface at rainy weather may be a reason for the accidents in this road segment. As per Table 4.3, majority of accidents have taken place at a slippery surface condition.
  - Considering the vertical and horizontal alignment, vertical gradient and curve radius are within the limit (Table 4.4)
  - Considering the speed data as per Table 4.6, average speed of the vehicles faced with accidents are 132km/hr. Since allowable speed limits are 80-100km/hr, speed could be considered as one reason for the accidents.

- 8+000km
  - According to Table 4.3, majority of accidents occurred in day time. Only one accident happened in night time.
  - All accidents at 8+000km (7+950 – 8+050) km have taken place in rainy weather condition with slippery road surface or flooded with water condition. According to Table 5.2, variation of cross fall (less than 2.5%) due to super elevation has led to form a water-flooded condition.

As per the site condition, water remained on the surface at rainy weather was observed. It is considered as one of the reasons for accidents at this location.

Further, Surface roughness is checked to obtain an accurate decision regarding the surface condition.

Table 5.2: Variation of cross fall around 8+000km

Actual Chainage	Cross Fall
8.036	2.500
8.046	2.500
8.056	2.355
8.066	2.077
8.076	1.800
8.086	1.522
8.096	1.244
8.106	0.966
8.116	0.688
8.126	0.411
8.136	0.133
8.146	0.145
8.156	0.423
8.166	0.700
8.176	0.978
8.186	1.256
8.196	1.534
8.206	1.812
8.216	2.089
8.226	2.367
8.236	2.500
8.246	2.500
0.186	2.500

- Vertical gradient around 2% and curve radius R=2500m are not problematic conditions.

- Average speed of the vehicles faced to accidents at the 8+000km location is 89km/hr. As it is not beyond the speed limit, speed is not a criterion for the accidents.

Likewise, each prone location can be analyzed in detail and possible reasons for the accidents at those road segments can be identified in a logical manner, in compliance with the actual site condition.

Considering the next six numbers of prone locations as per Table 4.3, majority of the accidents always occurred during rainy weather condition and in slippery road surface. According to the recorded data of 55+300km and 64+800km, some accidents happened at the condition of flooded with water.

As for the road geometry (Table 4.4), vertical gradient and the horizontal curve radius are within the required limits for all six prone areas. According to Table 4.4, cross fall at the above-mentioned two locations, 55+300km and 64+800km, are less than the minimum required value to drain out water from the road surface as those are in super elevation development region. Water stagnating might be a possibility in those locations as recorded in the collected data. However Table 4.5 point out that, there is a water flow across the road at those locations in rainy time.

According to Table 4.3, even though none of those prone areas have provided with street lighting except at 65+100km, majority of the accidents occurred at day time. At 65+100km, nearly half of the accidents occurred during night time. Hence, lighting may be a possible reason for the accidents at 65+100km. According to Table 4.6, vehicle speed may be a possible reason for the accidents at 64+800km and 65+100km.

Likewise, all decisions were taken based on the available data and site observations and then summarized to evaluate the possible reasons for the accidents in each prone location in Table 5.3. Here it was considered that slippery surface condition is one of the possible reasons, depending only on the recorded data. In order to confirm, it needs to check the surface roughness at prone locations. When considering column wise in summary Table 5.3, prone locations at 5+900km, at 64+800km, and at 65+100km are highlighted among all as several possible reasons could be identified for the accidents than other locations. For 5+800km, 8+000km, and 55+300km locations, three reasons for the accidents could be identified. Hence, it is mandatory to take immediate action to neutralize even one reason of those locations.

Table 5.3: Summary of the causes for accidents in prone locations

Accident Causes	Prone Location								
	5+800 km	5+900 km	8+000 km	22+100 km	27+800 km	55+300 km	58+800 km	64+800 km	65+100 km
Speed	V	V						V	V
Water Stagnation		V	V			V		V	
Slippery Surface	V	V	V	V	V	V	V	V	V
Lighting problems									V
Weather	V	V	V	V	V	V	V	V	V

Calculated accident rates per vehicle travel kilometres in Table 4.10 and Table 4.11 indicates that accident rate in Southern Expressway is reducing from 2012 to 2013 while values are considerably high.

When comparing the accident rate in VKT in similar road corridor (A2) in Table 2.5 with Southern Expressway, figures of expressway shows higher values. However, accident rate calculated for A2 road section totally depend on the accidents reported in the Police. As described in section 3.2 of this report, there may be a vast variation between number of reported accidents and the total number of accidents occurred. Hence, there may be a problem in accuracy of the number of reported accidents for A2 road and the entire country, while Southern Expressway accident records (number of accidents) are more reliable. Therefore, accident rate per VKT in island wise and A2 road corridor may be closer to the expressway value.

Fatality rate per VKT for year 2012 and 2013 has increased from 18 accidents per billion VKT to 26 accidents per billion VKT. When compared with Road Fatalities in IRTAD countries (consisting of developing and developed countries) in Figure 2.2, values in Southern Expressway depict massive deviation. Majority of them have fatality rates around five per billion vehicle kilometres while all the 32 countries have fatality rates less than 17 per billion vehicle kilometres. However fatality rate per A2 road corridor (110 accidents per VKT) is considerably higher than the southern expressway.

5.2 Summary

Content of this research intends to identify the accident-prone locations in Southern Expressway (from Kottawa to Pinnaduwa section) and possible reasons for the accidents. The findings are based on the detailed study of the accidents at those prone locations since a considerable number of accidents happened in Southern Expressway within a short period of time. In addition, since all the traffic data are recorded, calculations were made to find the accident rate based on the vehicle travel kilometres, which is one of the most accurate methods of accident rate calculation.

If accidents frequently occur at one particular road segment, it denotes a possible problem in that specific location. The most frequent accident locations could be identified as prone locations and analysing those locations may identify the possible reasons for accidents. Table 5.3 revealed that most accidents occur at situations under rainy weather; for example, conditions such as water stagnation on road surface and slippery road surface after or during the rainy weather. Water stagnation mostly happen at the super elevation development region where there is no adequate cross fall to drain out water from the surface. However excellence in construction can be avoid this issue by carrying out more accurate work without a little variation in finish levels at the construction stage. In addition, as speed of the majority of vehicles faced with accidents are faster than 100km/hr upper limit, it may be one possible reason for the accidents.

Considering the effect of fatigue to the accidents, according to the outcomes of this analysis, it is a clear possibility for an accident due to heavy sleepiness of the driver, if the travel distance is above 40km.

The analysis also indicated that, number of accidents at each road section during day time is more than the number of accidents at night time.

Accident rate in Southern Expressway in year 2013 is less than previous year 2011 - 2012. However, Kottawa– Kahathuduwa and Baddegama–Pinnaduwa road segments, which were at the edges, indicate higher accident rates than the others, with figures around 3.00 x 10^{-6}veh km. When compared with the similar road section in A2 road in Sri Lanka, accidents rate per VKT in Southern Expressway (2.40 x 10^{-6}) is higher than the A2 road section accident rate (1.86 x 10^{-6}).

Even though Fatality rate per VKT in Southern Expressway is considerably higher (18 accidents per billion VKT in year 2012 and 26 accidents per billion VKT in year 2013) when compared with the international condition (in IRTAD countries, less than 17 billion VKT), that figures are much low compared with A2 road (110 accidents per billion VKT) and whole country (59 accidents per billion VKT).

5.3 Recommendations

Under this research, the accidents in Southern Expressway from Kottawa to Pinnaduwa section were analysed within the duration of 27th November 2011 to 31st October 2013, to find the accident prone locations and reasons for the accidents, based on the road condition.

Accordingly, nine prone locations were identified where a significant number of accidents happened, in rainy weather.

Therefore, it can recommend that those identified locations have higher possibility for accidents to happen under rainy weather. Thus, road users and the road maintenance unit should pay attention on that warning.

Water stagnating locations need corrections or need to provide solutions to drain out water from the surface. In addition, speed of the vehicle should be maintained within the allowable limit to have a safe journey in the expressway. Since this study only considered the reasons for accidents contributed by road environment, it may not be the exact reasons; however, paying attention on these findings can reduce the possibility of accidents.

The analysis revealed that while travelling long distance, especially distances over 40km, there is a high possibility for the driver to feel drowsiness and thus, to meet with accidents. Therefore, road user should be aware on this situation.

Accident rate in Southern Expressway is higher than the similar road corridor, A2 value while fatality rate has low value than same road. However fatality rates in southern expressway, A2 road and whole country are heavily deviates with the international figures leading towards an unsafe trend. Therefore, it is essential to take immediate action to implement a safety improvement program.

Appropriate safety improvement method for each of location can be identified in future through continuation of this research study.

References

Volvo's Accident Research Team (2013). Why do traffic accidents happen? *Europian Accident Research and Safety Report,* 10-12.

Ung Chun Hour, H. E. (2007). *Country Report on Road safety in Colombia.* Royal Government of Colombia.

Kabbach Jr., F. I, Suzuki, C. Y., & Trentin, L. C. (2011). *Case-Studies of Influence in Rainfall Intensity on Safety conditions.* 12th International Conference on Urban Drainage, Porto Alegre / Brazil.

Whitelegg, J. (1932). *Road Safety: Defeat, complicity and the Bankruptcy of Science.* Department of Geography, University of Lancaster, Bailrig, Lancaster, England.

Road Development Authority (1998). *Geometric Design Standards of Roads.* Road Development Authority, Sri Lanka.

Elvik, R., Vaa, T., Erke, A., & Sorensen, M. (2009). *The handbook of road safety measures* (2nd ed.). Emerald Group Publishing Limited, ISBN: 978-1-84855-250-0.

Rosolino, V., Teresa, I., Vittorio, A., Carmine, F. D., Antonio, T., Daniele, R., & Claudio, Z. (2014). *Road safety performance assessment: a new road network Risk Index for info mobility.* Department of Civil Engineering, University of Calabria, Arcavacata Campus, Cosenza, Italy.

Odero, W. G. P. & Zwi, A. (1997). *Road traffic injuries in developing countries: a Comprehensive review of epidemiological studies.* Tropical Medicine and International Health.

Esmael, M. O., Sasaki, K., & Nishii, K. (2013). *Road Traffic Accident Trend in Developing Countries - The Policy Implications.* Eastern Asia Society for Transportation Studies.

Department of Transport (2014). *Reported Road Causalities in Grade Britain: Main Results, 2013.*

International Traffic Safety Data and Analysis Group (2015). *Road Safety Annual Report 2015.* International Transport Forum, 2015.

Hossain, A., & Gargett, D. (2011). *Road vehicle-kilometres travelled estimated from state/territory fuel sales*. Bureau of Infrastructure, Transport and Regional Economics, Department of Infrastructure and Transport, GPO Box 501, Canberra ACT 2601, Australia.

Jayasekera, D. A. S. (2013). *Estimation of Vehicle Kilometers Travelled in Sri Lanka*. Dissertation for the degree of Master of Engineering in Highway & Traffic Engineering, Department of Civil Engineering, University of Moratuwa, Sri Lanka.

Transportation Engineering Division (2014). *Audit on Southern Expressway*. Department of Civil Engineering, University of Moratuwa.

Mohamed Omer Esmael, Kuniaki Sasaki, Kazuo Nishii.. *Road Traffic Accident Trend in Developing Countries- The Policy Implications*, Proceedings of the Eastern Asia Society for Transportation Studies

International Traffic Safety data and Analysis Group (2015 *). Road Safety Annual Report Summery*, International Transport Forum, 2 rue André Pascal, 75775 Paris Cedex 16,France.

Planning division. *"Monthly accident data in Southern Expressway*" Road Development Authority.

Traffic Division.*"Annual Report of road Traffic Accidents* ", Sri Lanka Police Department (2011, 2012, 2013)

Jacobs,G.D.,& Amy Aeron-Thomas(2000). *A review of global road accident fatalities*.Today pp(4-5).Retrieved from https://www.google.lk

Yamuna Expressway, Pune Expressway. Retrieved from https://en.wikipedia.org

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Annexes

Annex 1: Accident Recording Form of EOMMD - RDA

Southern Expressway

Road Accident Report

1. Exact Location:

Two nearest functional km or km post upward and downward of accident location with side (L or R)

Upward km post

Downward km post

2. Day, date, and Time

Day	d	d	m	m	y	y	y	y	h	h	m	m

3. Road Surface condition:

Dry	Wet	Flooded with water	Slippery

4. Weather:

Clear	Cloudy	Rain	Fog/Mist	Other

5. Light Condition:

Daylight	Dusk, Dawn
Night, No street lighting	Night, improper street lighting
Night, good street lighting	

1. Number of vehicles Involved:

2. Category of vehicle/s involved, speed, vehicle number, and year of manufacture:

Vehicle involved	Speed	Vehicle Number	Year of manufacture

8. Reason/s for the accidents:

Speed	Merging
Negligence	Sudden Stopping
Bad Driving	Vehicle
Alcohol	Road (Signboard, marking, visibility etc.)
Fatigue	Weather
Overtaking	Mobile Phone

9. Severity

Fatal	Grievous	Non -grievous	Property Damaged only

10. Crash patterns / Collision diagram: (Please draw below)

11. Brief description of the accident: Explain the collision and subsequent of the collisions if any)

12. Number of persons Killed:

13. Number of persons injured:

14. Severity of the damage to the vehicle:

15. Fixed objects or road furniture damaged and severity:

Crash barrier in the middle	Low/Medium/High
Crash barrier on embankment slopes	Low/Medium/High
New jersey Barrier	Low/Medium/High
Light poles	Low/Medium/High
Road studs	Low/Medium/High
Bridges	Low/Medium/High
Culverts	Low/Medium/High
Sign board	Low/Medium/High
Other	Low/Medium/High
	Low/Medium/High

16. Remarks if any:

Annex 2: Accident Prone Locations