CHAPTER 01 -INTRODUCTION

1.1 General Background

Southern Expressway is the first access control expressway in Sri Lanka. The route from Kottawa to Matara was initially opened to the public from Kottawa – Pinnaduwa in 2011 November, while the extended section from Pinnaduwa - Godagamawas was opened to the public on March 2014.

Maintenance management and operations of the expressway are currently being carried out by the Expressway Operation Maintenance and Management Division under the Road Development Authority.

- Total length - 124.8Km
- Design Speed - 120Kmph
- Operating speed - 100Kmph
- Four lane capacity (Both direction)

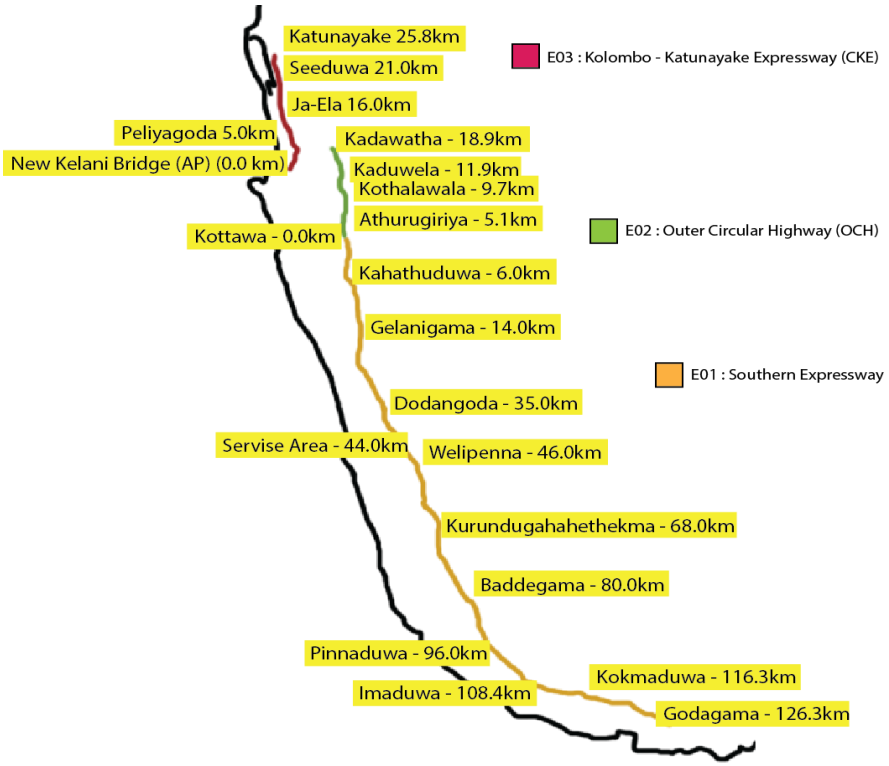

Figure 1.1: Expressway Map

Southern expressway will extended again from Godagama up to Mattala and Hambanthota with purpose of linking airport and harbor respectively. More than 200km will expect to travel through the southern expressway and following benefits will generate.

- Travel time reduction
- Investments on private sector business will be expanded
- Tourism development
- Gall road (A2) traffic congestion can be minimized
- Land value enhancement
- Generates revenue for the government
- Industries development
- Nearby town development

1.2 Problem Identification and research background

From the beginning of the operation, on the 27th November 2011, from Kottawa to Pinnaduwa, and on the 15th March 2014, from Pinnaduwa to Matara, until the end of April 2016, 2,275 accidents were reported in the Southern expressway, out of which 14 were classified as fatal. The statistics do not speak in favour of the existence of the expressway.

At present, several safety precautions and services have been ensured by the Road Development Authority, to assure a safe road environment to expressway users:

- Guard rail safety barrier at the center median, embankment filling and rock cutting area
- Traffic sign boards indicating the speed limits of expressway and ramp locations
- Variable Message Sign boards throughout the expressway
- Reflector tab at the center median and road edge guard rail
- Road markings and signs
- Police enforcement
- Expressway patrolling process by RDA units and Police units
- Fire and rescue operation by the Special Task Force
- Emergency services (Through 1969)
- Street Lights at the intersections, structures and isolated locations

Though this may be the case, the rate in which accidents occur has not reduced, and keep occurring in the same frequency, leading to economic and property loses, also most devastatingly -loss in human lives.

Therefore,

- Accidents on the Southern Expressway should be critically analyzed as the initial step.
- From the outcomes of analysis, mitigation measures and safety improvements should be decided and implemented for the expressway network.

1.3 Objectives

Following considerations are the objectives of this study.

- Analysis of accidents on the carriageway and an ‘in depth analysis of accidents for a selected period.
- Investigation of the accident trend between interchanges based on the accident rate.
- Comparison of accidents with other expressways.
- Proposing mitigation measures and improving the accident data collection process of RDA.

1.4 Scope

Accidents on the carriageway between Kottawa and Godagama had been taken in to consideration from the period starting from 27th November 2011 to the end of April 2016. Attempts were made to find out the accident-prone areas, accident factor distribution, accident trend between sections and accident rates on the expressways. Afterwards, mitigation measures and safety improvements were discussed.

This report is presented dividing the content into various chapters in order to improve the readability.

Chapter 01 - Introduction

Provides the introduction part of the study. General background of expressway, problem definition for the study, objectives of the study and scope of the study were included.

Chapter 02– Literature Review

Collects and critically analyses the secondary information relating to accident analysis, based on international studies as well as local studies.

Chapter 03 – Research Methodology

Discusses the research design: approach and research strategy, concluding the chapter with an analysis, and presentation of data.

Chapter 04 – Data Analysis

This Chapter mainly analyses and presents the primary research evidences. A statistical data analysis is undertaken using SPSS, and the findings are presented in statistical tables and charts.

Chapter 05– Conclusions and Recommendations

This is the last Chapter of the dissertation, which provides the overall summary, together with the recommendations based on the findings.

CHAPTER 02 -LITERATURE REVIEW

An accident is an unfortunate incident, which occurs unexpectedly and unintentionally, typically resulting in damage or injury. Large numbers of people faced with injury or permanent disability in every year as per the result of accidents and damage or loss of property can be happened. Accidents can be prevented with appropriate safety precautions or awareness.

2.1 Accident Investigation and Reporting

The accident investigation process determines the root causes of accidents, injuries, property damage, and process in order to prevent them from occurring again. The importance of investigating is brought out when observing the following:

- Prevention of possibility to similar accident
- Improvement of safety measures
- Working environment development
- Educate users through awareness

Accident reporting is more important requirement. Authorities will be informed about the fatalities, causes, conditions on road etc. through the report. Then the decisions can be made based on the investigations.

Headings of the Accident Investigation Report are as follows in Sri Lanka.

- Date of accident
- Time of occurrence
- Accident location
- Injured or dead persons
- Causes for accident
- Road conditions and weather conditions
- Investigated by
- Authorized persons

- Description of accident
- Actions/activities at site (e.g. first aid treatments, safety arrangements)
- Witness details
- sketch of accident site
- Vehicles details
- Any other details (e.g. similar accidents, inspection details etc.)
- Signature of investigator and date of report

(Accident investigation, University of Greenwich in April 2016)

2.2 Accident data analysis

After information has been gathered, the next step is to conduct the actual analysis and to determine the cause(s) and other parameters of the accidents.

2.2.1 Factors affecting accidents

Mainly three types of factors affect road accidents.

- Human factor
- Vehicle factor
- Infrastructure/Environment factor

2.2.1.1 Human factors

Various types of information is received by users on while driving on expressway. Most of them are visual types (the road itself, other vehicles, pedestrians, signs, the passing scenery, etc). Moreover, the driver may be processing other information sources such as an auditory input (listening to the radio, talking on a cell phone, carrying on a conversation with another passenger), or an internal input (remembering directions or planning what to make for dinner).

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 distracted driving behavior, which are related to the 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).

Over 95% of motor vehicle accidents (MVAs, in the USA, or Road Traffic Accidents, RTAs, in Europe) involve some degree of driver behavior combined with one of the other factors (reference not mentioned). Even though, drivers always criticize road conditions, equipment failure, or other drivers.

2.2.1.2 Vehicle factors

Manufacturers are required by law to design and engineer cars that meet a minimum safety standard. The common types of failures are,

- Brakes losses,
- Thread separation or tire punctures
- Steering/Suspension failure

Only 10% of contributing factors are attributed to technical issues related to the vehicles according to the analysis (Rosolino et al., 2014).

2.2.1.3 Infrastructure/Environment

According to recent analysis, 30% of accidents are related to road characteristics, such as the pavement condition (in a percentage of 10%), geometry (10%), and other factors such as signals, guardrails, safety barriers, etc. (Rosolino et al., 2014).

JP research private limited has done research to study of accidents on Mumbai – Pune expressway in year 2014.As access controlled highway, The Mumbai Pune Expressway connects Mumbai and city of Pune and has following features and operational requirements.

- Six-lane roadway capacity
- Speed limit of 80 km/h
- Not permitted for two wheelers and three wheelers
- 94 km operational length

372 numbers of accidents has been examined by JP researchers between 7th October 2012(Open Date) and 31st October 2014 with 133 fatal victims and more than 300 serious injury victims.

Table 2.1 shows the influences of each factor in the occurrence of accidents on expressway.

Table 2.1: Influences of each factor in the occurrence of accidents

Factor	All Combinations (%)	Alone (%)
Human	83	58
Vehicle	19	13
Infrastructure	27	2

Source: (The Mumbai – Pune expressway road accidents study by JP researcher)

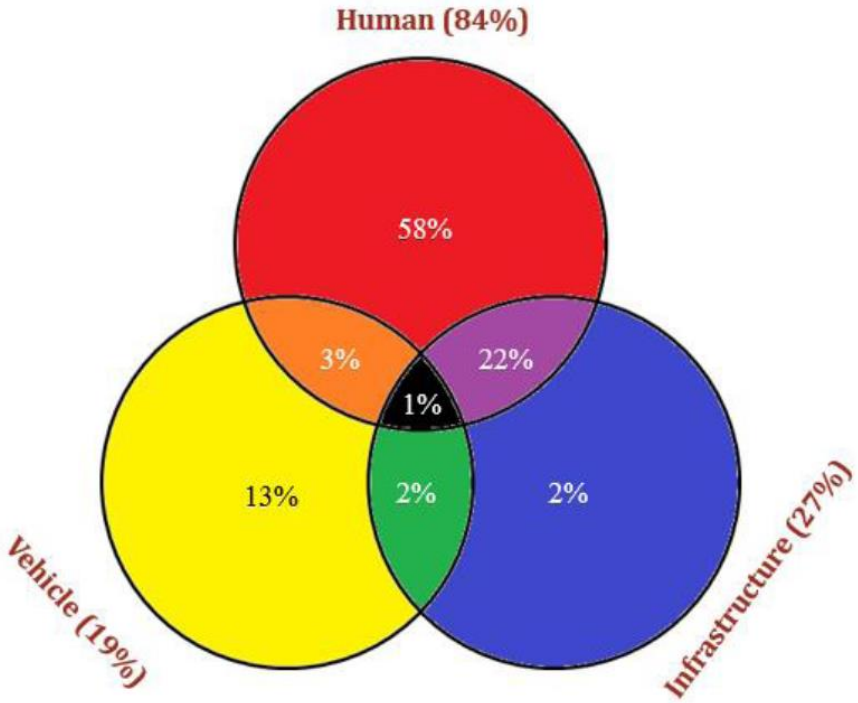

Figure 2.1: contributing factors distribution

Source: (The Mumbai – Pune expressway road accidents study by JP researcher)

A comprehensive study of road safety (Treat et al., 1977) found that human error was the sole cause, resulting in 57% of all accidents and was a contributing factor in over 90%. In contrast, only 2.4% were due solely to a mechanical fault and only

4.7% were caused by environmental factors. Other studies have also reported similar results.

2.2.2 Accident severity

Definitions to classify accidents are as follows.

- Fatal accidents - An accident with at least one fatality.
- Injury accidents - An accident with at least one or more victim but no fatalities.
- Property damaged only accidents - An accident with no injuries. (only vehicle and property damage occurs)

Study based on “Impacts of accident severity factors and loss values of crashes on expressways in Thailand” by V. Ratanavaraha, S. Suangka/ IATSS Research 37 (2014) 130–136 examine the severity of accidents in Thailand expressways using secondary data obtained from the Expressway Authority of Thailand.

The data includes time and location (e.g., accident time, accident management time, and accident location), environment (e.g., traffic lanes, weather condition, and physical characteristics of the accident location), accident severity (e.g., number of Injuries or deaths and number of damaged vehicle), and characteristics and causes of the accident. Past 03 years data from 2007 to 2009 has been selected for this study and classifying the severity of accidents following the accident factors, as shown in Table 2.2.

Table 2.2: The number of accidents disaggregated by accident severity

Variables		Unit	Property damage-only	Injury accident	Fatal accident	Total
Accident occurred		Number of accidents	1,455	700	39	2194
Speed		km./hr.	70	71	76	70
Traffic volume		PCU/day	3,391	3,402	2,862	3385
Time of day	Day time	Number of accidents	769	323	14	1106
	Night time	Number of accidents	686	377	25	1088
Weather conditions	Normal	Number of accidents	1,341	637	35	2013
	Rainy	Number of accidents	114	63	4	181
Number of lane	1-lane	Number of accidents	1,112	467	27	1606
	2-lane	Number of accidents	236	178	11	425
	3-lane	Number of accidents	106	51	1	158
	4-lane	Number of accidents	1	4		5
Cause of accident	Slow driving/unusual	Number of accidents	12	5	1	18
	reckless driving	Number of accidents	1,279	601	30	1910
	Sudden lane change	Number of accidents	71	41	1	113
	Drunk	Number of accidents	17	9	3	29
	Personal diseases/driver sleepiness	Number of accidents	38	32	4	74
	Equipment failure	Number of accidents	38	12		50
Type of location	Toll station	Number of accidents	181	12	1	194
	Curve	Number of accidents	249	132	6	387
	Straight	Number of accidents	853	448	26	1327
	Intersection	Number of accidents	46	25	2	73
	Junction	Number of accidents	21	11	1	33
	Upgrade	Number of accidents	36	32	2	70
	Downgrade	Number of accidents	69	40	1	110

Source: (“Impacts of accident severity factors and loss values of crashes on expressways in Thailand” by V. Ratanavaraha, S. Suangka/ IATSS Research 37 (2014) 130–136))

Mumbai Pune expressway road accident study shows accident severity distribution as depicted in figure 2.2.

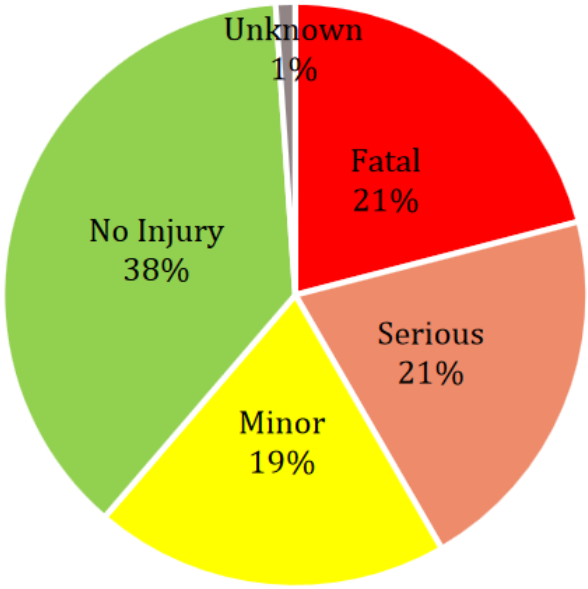

Figure 2.2: Distribution of 372 accidents by severity

Source: (The Mumbai – Pune expressway road accidents study by JP researcher)

2.3 Accident rate

Mainly two types of accident rates can be stated.

- Population based rates – Measures the risk to individuals on a comparative basis. For example, number of accidents per 100 people, number of accidents per vehicle.
- Exposure based rates –Measures the amount of travel exposed to risk. Accident rates based on vehicle miles/kilometers travelled (VKT) or vehicle hours travelled.

For analyzing expressway accidents, exposure based rates are more accurate and important to get a better image. To calculate accident rates based on the vehicle kilometers travelled (VKT), VKT needs to be calculated. 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 (Annual Average Daily Traffic), and span of the road sections, are the main variables selected. AADT is converted to annual value by multiplying of 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 or not (Hossain and Gargett, 2011).

2.3.1 Accident rate in Sri Lanka

According to the accident statistics of Sri Lanka Police, road accidents in several severity levels are given in Table 2.3

Table 2.3: Road Accidents in Sri Lanka (2004-2014)

Year	Fatal	Grievous Injury	Non Grievous Injury	Damage Only	Total
2004	2,055	4,225	13,140	31,588	51,008
2005	2,101	4,795	13,213	20,423	40,532
2006	2,069	4,729	12,158	14,801	33,757
2007	2,224	5,081	11,859	12,816	31,980
2008	2,176	4,941	11,288	11,459	29,864
2009	2,263	5,379	10,945	14,507	33,094
2010	2,579	6,124	12,560	16,390	37,653
2011	2,472	6,982	13,100	17,503	40,057
2012	2,317	7,209	14,680	17,939	42,145
2013	2,190	6,870	13,525	15,292	37,877
2014	2,260	7,071	12,781	13,854	35,966

Source: National Transport Statistics 2015

The fatal and accidents with injury is continuously increasing in Sri Lanka. Total road accidents show a marginal decline with 5.04 percent in 2014 due to reduction in non-grievous and damage only accidents.

Negligent driving and the high speeding of vehicles cause most fatal accidents. A number of 2,260 fatal accidents were recorded in 2014 and this reflects a 3.2% increase compared to 2013.

As per the study of "Estimation of Vehicle Kilometers travelled in Sri Lanka" by Darshika Jayasekera (Jayasekera, 2013), VKT for different types of vehicles in year 2012 is presented in Table 2.4.

Table 2.4: Vehicle Kilometers 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**

Source: Estimation of Vehicle Kilometers travelled in Sri Lanka" by Darshika Jayasekera (Jayasekera, 2013),

From the data from Table 2.3 and Table 2.4, the accident rate for the year 2012 in Sri Lanka can be calculated. Results are tabulated in Table 2.5.

Table 2.5: Accident Rate in Sri Lanka - Year 2012

Severity	**Accident rate per VKT x 10^{-6}**
Fatal	0.06
Grievous	0.19
Non Grievous	0.39
Damaged only	0.48
Total no of accidents	**1.12**

2.3.2 Accident rate in A2 road (Colombo – Galle – Hambanthota – Wellawaya) section from Moratuwa to Galle –Year 2012

Accident rates in A2 road section during the year 2012 are shown in Table 2.6

Table 2.6: Accident rates in A2 Road sections

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	0.3	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**

Accident rate in road sections, Angulana – Panadura and Hikkaduwa – Magalle which are closer to the main town areas shows higher values than others, while the total road section notifies 1.86 x 10^{-6} accidents per VKT.

CHAPTER 03 - METHODOLOGY

Initially, literature based on road accidents were reviewed to identify the methods of collecting data regarding accidents, way of accident data collection, data reporting procedures, accident factors, accident severity, way ofprocedure of accident analysis and the final outcome results required for the mitigation process etc.

Accident data were collected from EOM & MD (RDA) and the Expressway Police Ppatrolling Division. Traffic data, gGeometric data of road sections, road sections length details etc other relevant data were collected from EOM & MD (RDA).
Then A accident database was prepared according toutilizing the data while using and SPSS software for analytical purposeswas used to analyze data. Accident rates were calculated using accident data and traffic data.

Both sides of the road stretch were divided in to 100m segments, taking one segment as one spot. SPSS analysis was done to identify the accident prone area, while geometric data were used to identify the cross fall variations along the accident prone areas identified. Afterwards, site visits were carried out to inspect the accident-prone areas and traffic movement during rainy weather conditions.

Studies were done in depth for a selected time period, and using photos and videos obtained during the process, the factors which instigate accidents and injuries were reviewed.

Accidents Ttrends accidents occur between each interchanges were observed using accident rates. SPSS analysis data were observed obtained and the results were used to determine and mitigation measures and road safety improvements. were determined using the results. Road safety improvements were also determined according to outcome from analysis.

Figure 3.1 shows the flow chart of research methodology

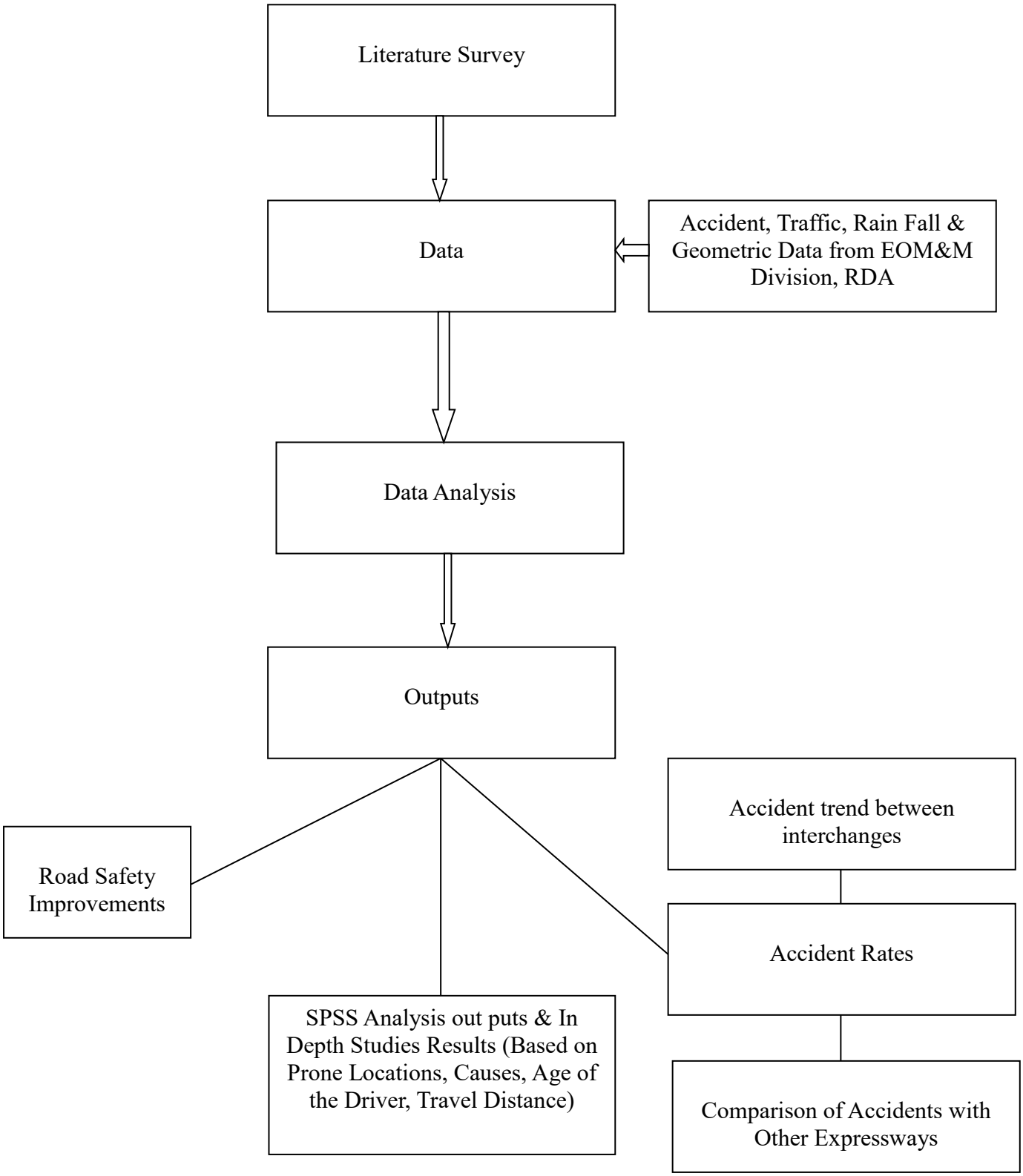

Figure 3.1: Research methodology

CHAPTER 04 – PRELIMINARY ACCIDENT DATA ANALYSIS

4.1 Statistical analysis of southern expressway accidents

Accident data between selected periods (from 2012/01/01 to 2016/04/30) from EOM & MD is divided in to four categories as shown on Table 4.1. The basis of the study primarily consists only of the accidents on the carriageway. Accidents on the ramp road, toll gates and non-reported accidents are not considered. police and RDA incident management teams were dispatched for data collection purposes, as per the information from the site which states that an incident has taken place.

Table 4.1: Southern expressway accident summery (2012/01/01 to 2016/04/30)

Description	Accident Summery				Total
	Fatal	Grievous	Non-Grievous	Property Damaged Only	
Total Accident	14	88	168	2434	2704
Accidents on carriageway	14	80	161	2020	2275
Accidents on ramp road, toll gates and non-reported accidents	0	8	7	414	429

Accident data sheet used by EOM&M Division, RDA is attached as Annex 02.
Accident data from 2012/01/01 to 2018/08/01 is attached as Annex 01.

Totally 2,275 accidents out of which 14 were fatal accidents were analyzed using the SPSS software. The SPSS analysis is inclusive basically of the year, day, time, location, type of accident, environment conditions, information on victims and reason for the accident.

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4.1.1 Accident types and factors distribution

The three main factors, which affect the probability of accidents occurring in the expressway, are categorized as below.

1. ***Human factors:***

Careless/Negligence, Fatigue/Drowsiness, Overtaking, Obstacle from outsiders, sudden brake, Sudden stopping of front vehicle, Alcohol, Phone and Reverse.

2. ***Vehicle factors:***

Tire punch, Fire, Steering wheel lock, Wheel, Engine trouble, Buffer, Axel, Bonnet, and Brake fault.

3. ***Infrastructure/Environment:***

Rainy weather/Wet surface, animal collision, Obstacle on road, etc.

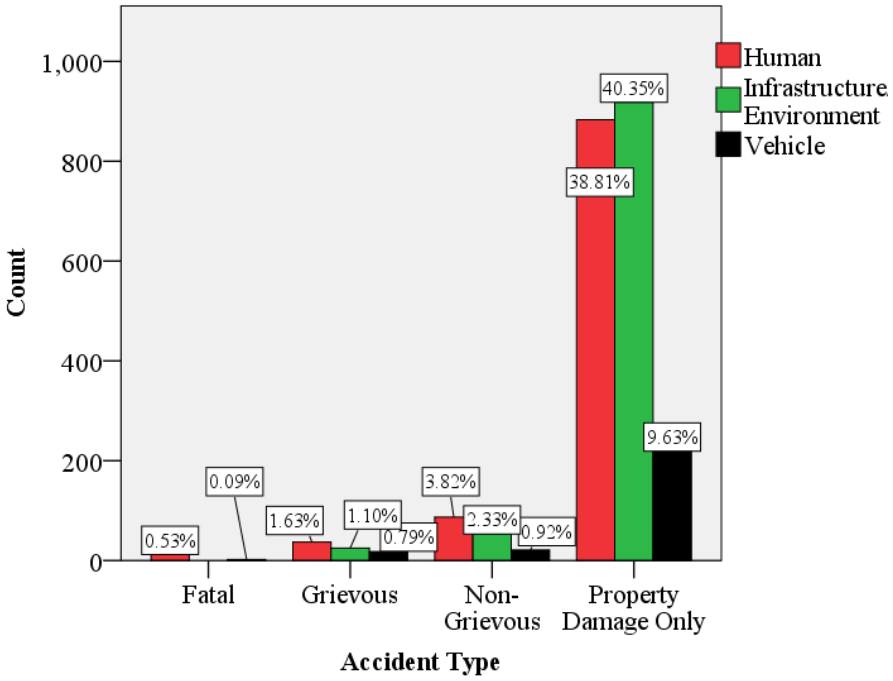

Figure 4.1: Accident types with accident factors

Human and Infrastructure/Environment factors have slightly equal probability to influence the occurrence of accidents. According to Figure 4.1, fatal, grievous and non-grievous accidents have occurred mainly due to the human factor

4.1.1.1: Human Factor

Figure 4.2 demonstrates the human factors, which affect accidents on the expressway. Carelessness/Negligence of the driver is the most vital parameter leading to accidents. However, Fatigue/Drowsiness also seems to have a major impact.

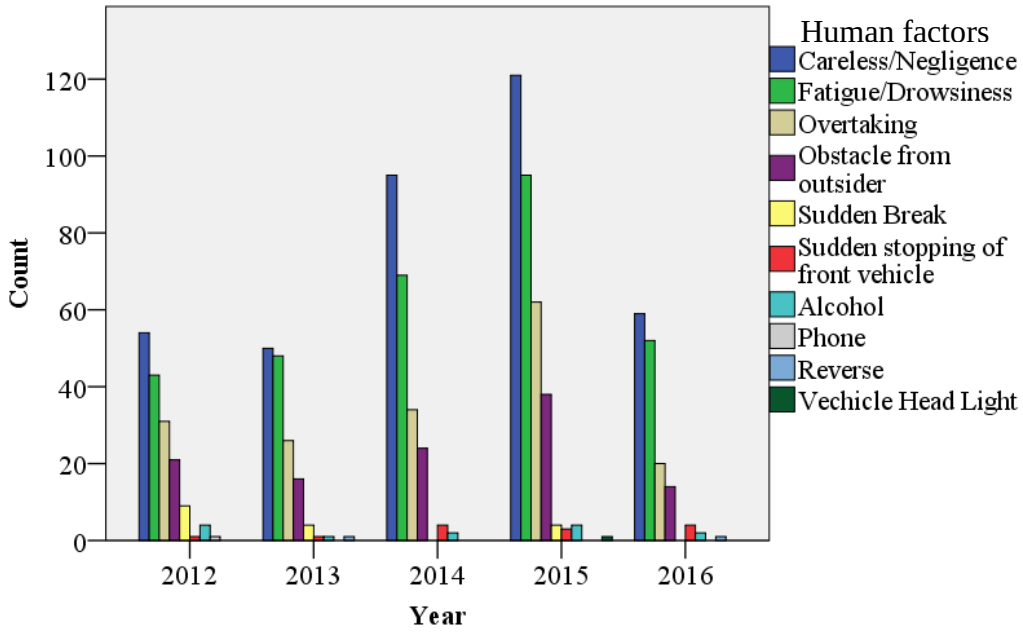

Figure 4.2: Human factors distribution

Most drivers have met with accidents due to their drowsiness during the journey. Driving on the expressway at a long stretch can severely affect the driver's fatigue level due to the monotony. Direct running distance and age factors shall be analyzed under the 'fatigue/ drowsiness' criteria. Even though, the running time or running distance before entering the expressway is of great importance, in this analysis,

travel period on expressway is the only category considered due to the unavailability of the above data.

Age of the drivers who got involved with accidents caused due to fatigue was divided into groups with 5 year intervals starting from age 18, the legally accepted age one can start driving. Figure 4.3 illustrates the percentages of accidents that have occurred in accordance with the age of the driver.

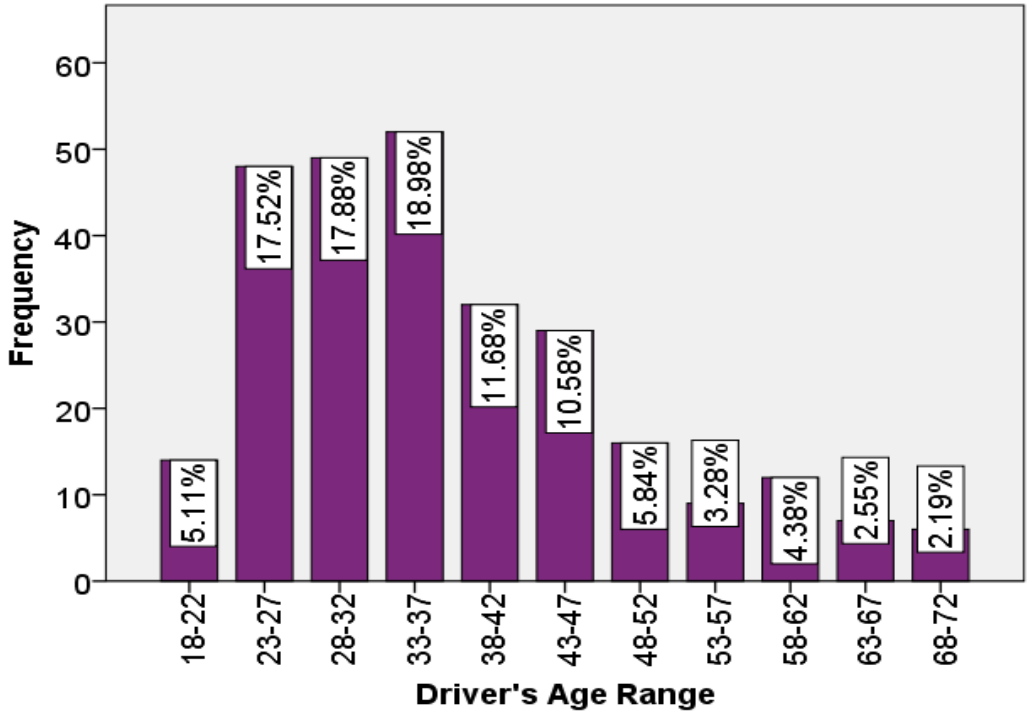

Figure 4.3: Driver's age affect for accident due to fatigue/drowsiness

Accordingly, the age group which is prone to get into such accidents the most is the group containing 23 to 37 year old people. This point needs to be focused on, to administer any possible solutions that may lead to the reduction in accidents due to fatigue.

Having to drive without a break, could also affect fatigue levels drastically. As such, expressway sections in between entry and exit should be considered along with the fatigue analysis as shown in Figure 4.4.

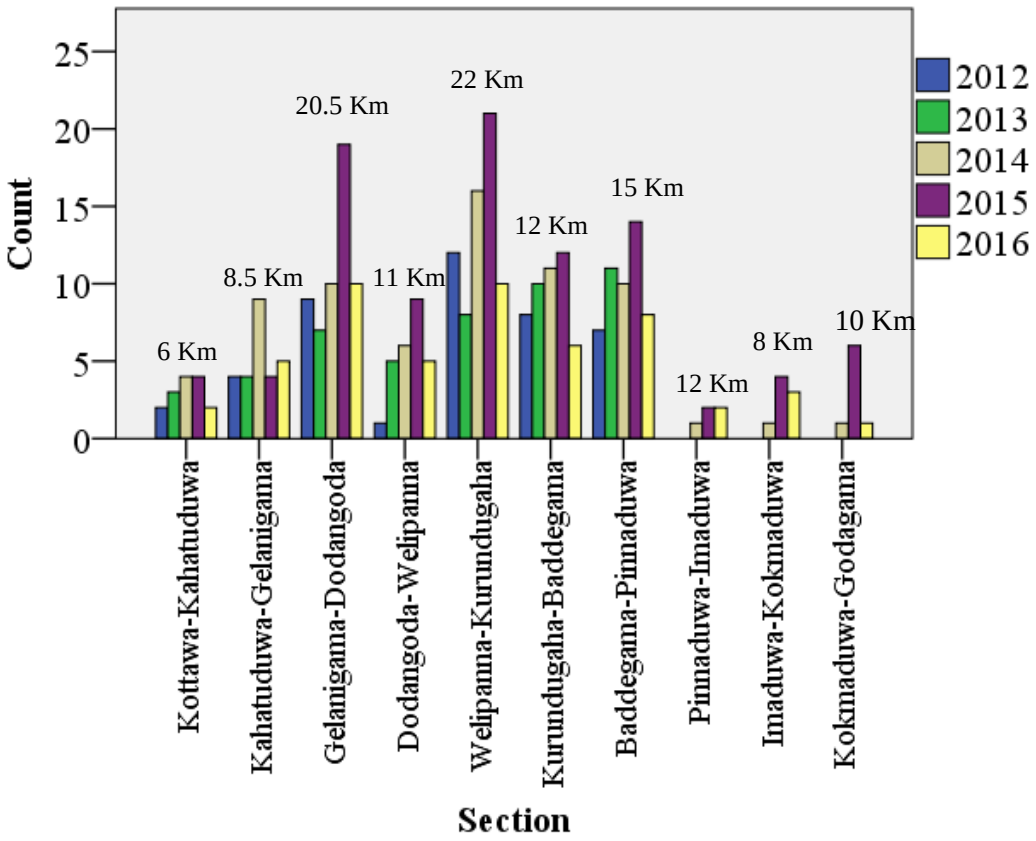

Figure 4.4: Fatigue accident distribution in each section

Sections with more than 20 Km that cover a long distance, such as those in between Gelanigama – Dodangoda and Welipanna – Kurudugahahave are sections that had experienced a high rate of accidents due to fatigue, during each and every year. The section from Pinnaduwa to Godagama have been considered only in 2015 as having operated the whole year.

Basically accidents due to fatigue have been increasing each year, stating in accordance to the graph. It is also evident that there is acceleration in the number of accidents, when observing that the first three month data from 2016 indicate a higher number of accidents, which is even more than half of the accidents that have taken place in the entire 2015, in most locations.

4.1.1.2: Infrastructure/Environment factor

Environment is the second main factor, which has triggered the occurrence of accidents. Accidents due to rainy weather in each year are shown in Figure 4.5.

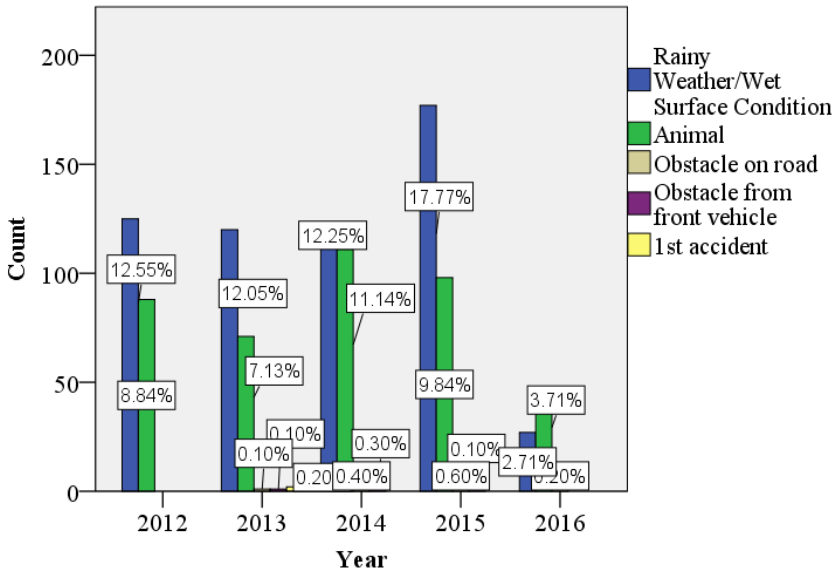

Figure 4.5: Environmental factors which lead to accidents

Aside from the wet climatic conditions that obtrude safe passage, animal intrusion can also be noted as a major concern. An expressway should grant the users a safe passage, free from obstacles. Especially as an animal intrusion cannot be predicted nor anticipated, there is a grave need in identifying the animal category and discovering a successful mitigation process.

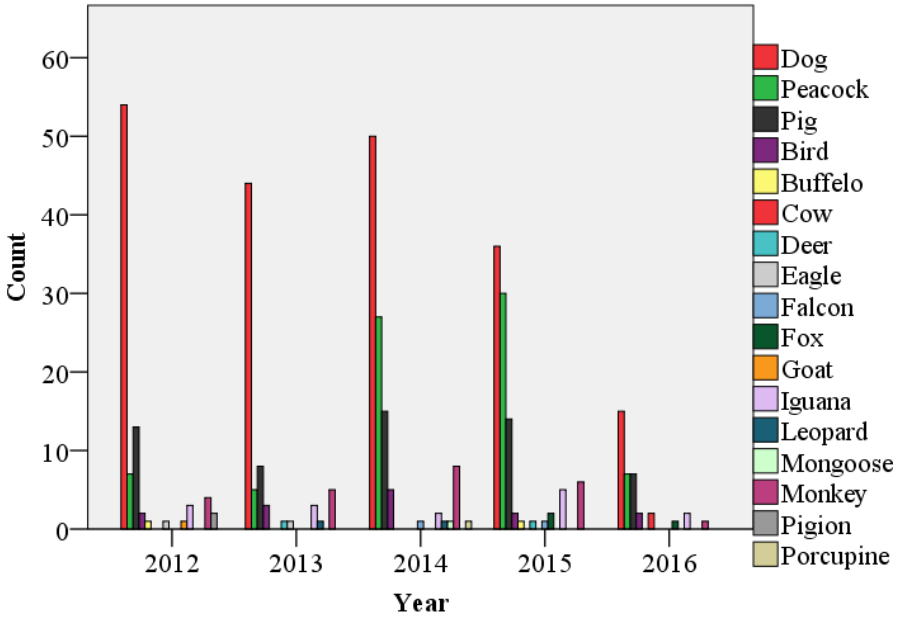

Figure 4.6: Animal categories distribution

Figure 4.6 indicates how most collisions have been associated with dogs. Peacocks, pigs, iguanas, monkeys and birds too have been victims of the highest tier. In order to trace down the sections in which collisions have a high probability in occurring, an analysis had been carried out. The results are shown in Figure 4.7.

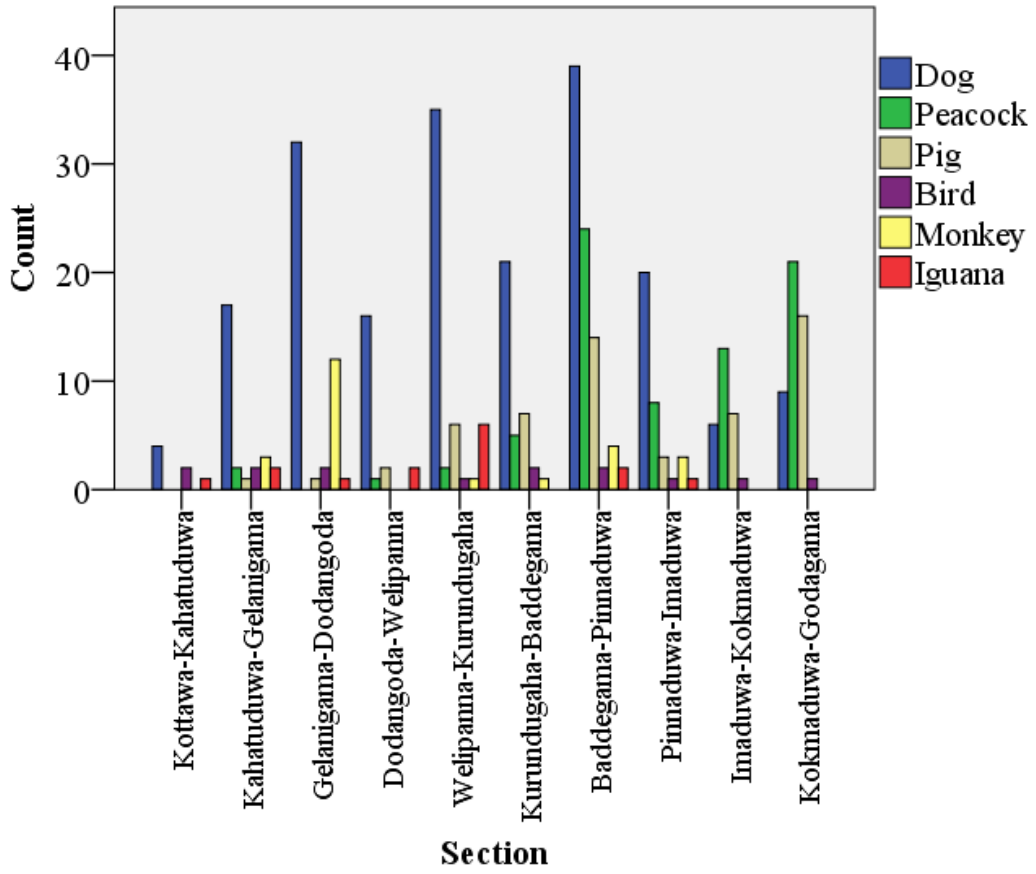

Figure 4.7: Animal collision

Dogs are presented with each section accidents as considerable amount. But Baddegama to Godagama section have experienced more accidents due to peacock and pig intrusions. Natural path of their day-to-day activity would be crossed within this region during construction and it has produced such amount of accidents.

4.1.1.3: Vehicle factor

Vehicles should be in an optimum condition when entering an expressway, otherwise there is a high risk during travelling at a high speed. Drivers are unable to control the vehicle if a mechanical failure occurs. Contribution of each factor for vehicle related accidents is illustrated in Figure 4.8.

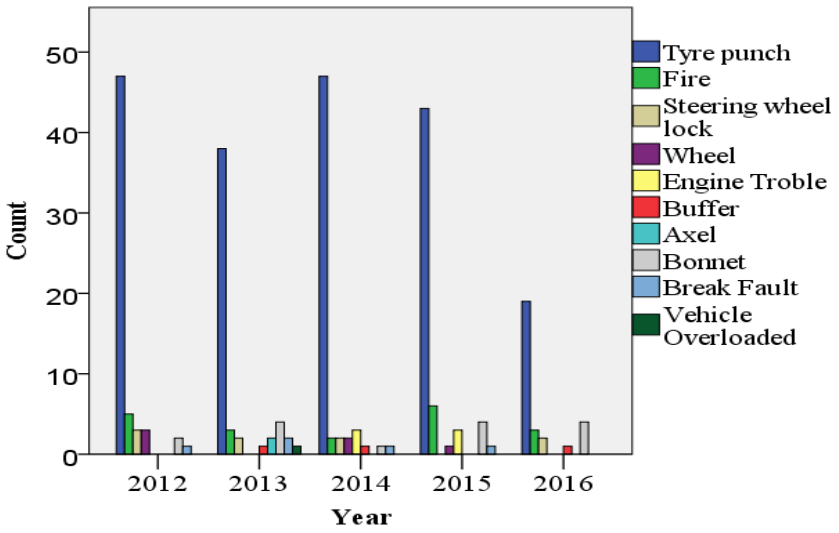

Figure 4.8: Vehicle factors distribution

Tire punch is observed to be the most significant reason, while there are also incidents where fire has taken place with the overheating of the engine or due to other mechanical faults.

Furthermore, main factors for the expressway accidents such as Rainy weather, Careless/Negligence, Fatigue/Drowsiness, Animal intrusion, Overtaking, Obstacle created from outsiders, mainly due tire punch of another vehicle, can be compared with each other also considering the year. Summarized results are illustrated in Figure 4.9.

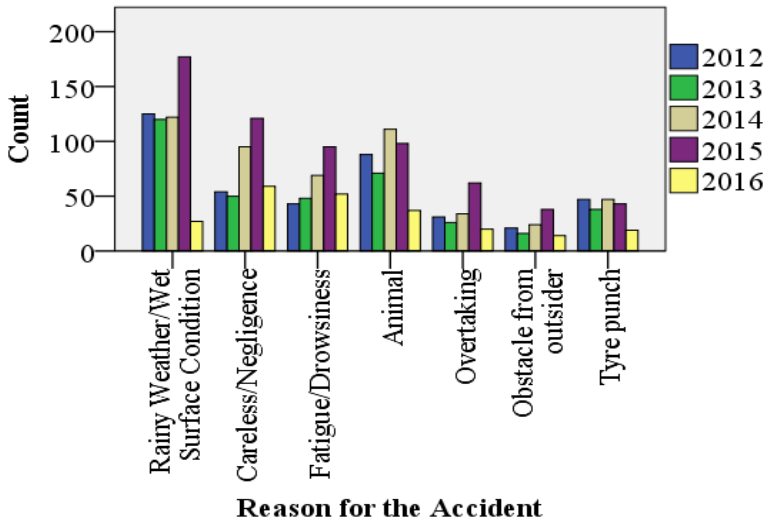

Figure 4.9: Yearly distribution of main reasons for accident

Other than animal intrusion and tires being punctured, which continue to happen approximately in the same frequency each year, each factor has shown an increasing pattern up to 2015. (Here 2016 has been analyzed considering only a four months period).

4.1.2 Frequency of Accidents

Figure 4.10 illustrates the accident distribution in days of the week.

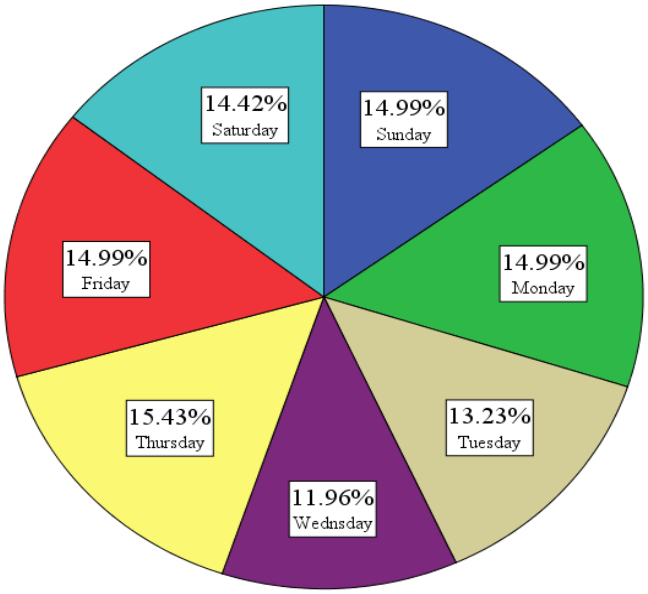

Figure 4.10: Accident distribution with days of a week

When taking into account the percentage of accidents occurring each day of the week, a slightly equal distribution can be seen. However, number of accidents is reduced toward the middle of the week.

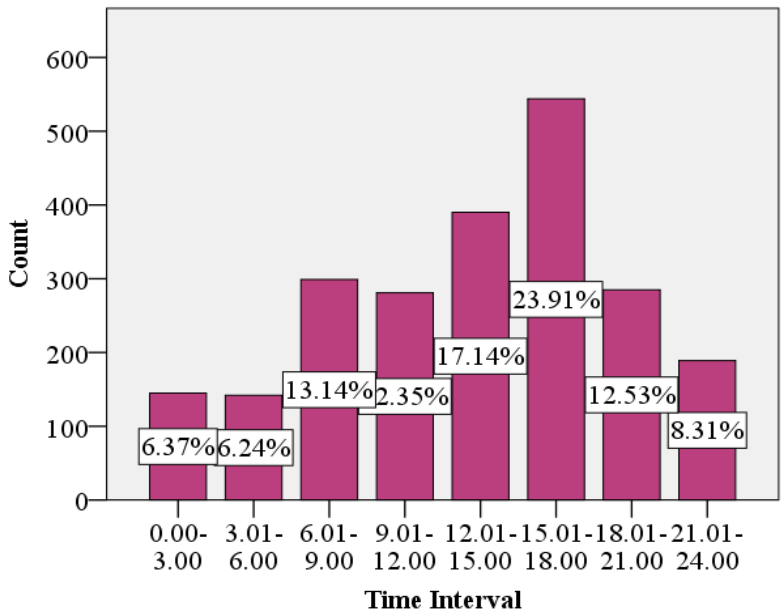

Figure 4.11: Total accident distribution with time frame

According to Figure 4.11, 23.91% out of the total number of accidents have taken place during the 15.01-18.00 hour time period. Moreover, the highest percentage of accidents has taken place between the 12.01-18.00 hour period.

Yearly accident distribution also follows the same pattern as shown in Figure 4.12.

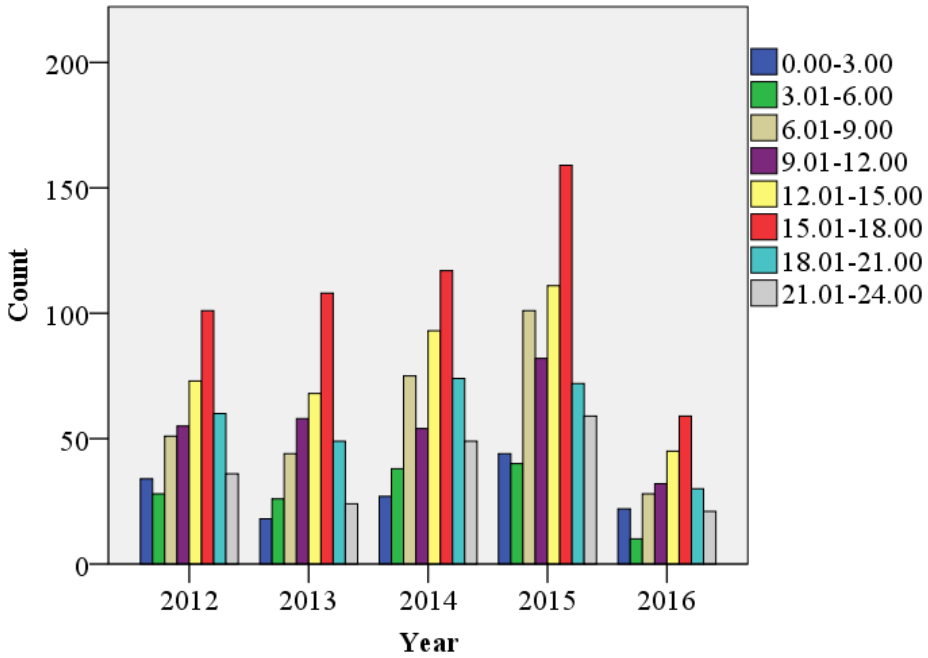

Figure 4.12: Yearly accident distribution with the time frame

Daily accident distribution with the time has also proven that during the 12.01-18.00 hour period there were more accidents on the expressway. During the mid-week it can be observed that the number of accidents has reduced as per the Figure 4.13.

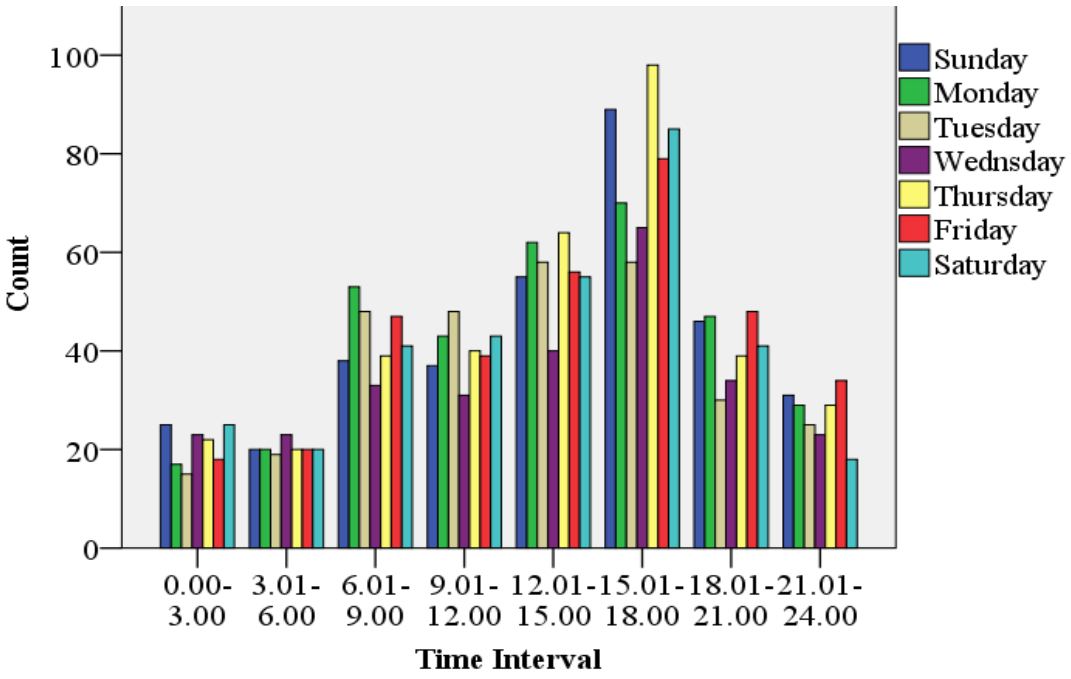

Figure 4.13: Daily accident distribution with time frame

4.1.3 Accident prone areas

Accident prone location analysis has been done with the SPSS software and thereafter, prone areas have been identified. A 100m segment has been considered as one spot/location. Each location has been inspected to check the environment and damage area. Table 4.2 and Table 4.3 show the accident prone area with the damage area and the number of accidents in RHS and LHS separately.

Table 4.2: Accident prone area (RHS)

No	Section (Km)	Damage Area	Total No of Accidents
1	5.8-5.9	Both	18
2	5.9-6.0	Both	10
3	8.0-8.1	Both	23
4	20.85-20.95	Center median	9
5	22.1-22.2	Center median	13
6	27.8-27.9	Center median	10

Table 4.3: Accident prone area (LHS)

No	Section (Km)	Damage Area	Total No of Accidents
1	19.85-19.95	Center median	7
2	20.95-21.05	Center median	23
3	47.8-47.9	Center median	8
4	55.15-55.25	Center median	8
5	55.25-55.35	Center median	19
6	58.7-58.8	Center median	17
7	59.9-60.0	Center median	10
8	65.0-65.1	Center median	14
9	89.85-89.95	Center median	12
10	90.5-90.6	Both	9

Yearly distribution shows that number of accidents has increased in some locations and decreased in some locations. Anyhow, accidents have taken place at each spots repeatedly as denoted in Figure 4.14.

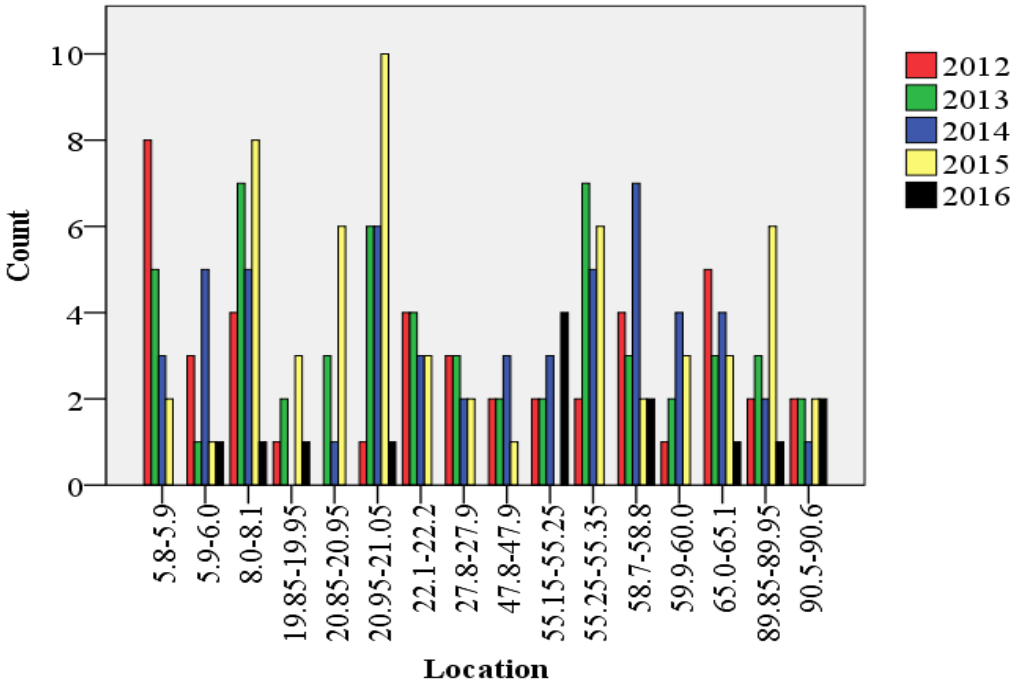

Figure 4.14: Yearly accident distribution at accident prone areas

Repeated occurrence of accidents at each spot is required to be analyzed carefully. Figure 4.15 illustrates that 59.56% of accidents have occurred due to the rainy weather/wet surface condition. Most accidents at each point have been affected by the rain.

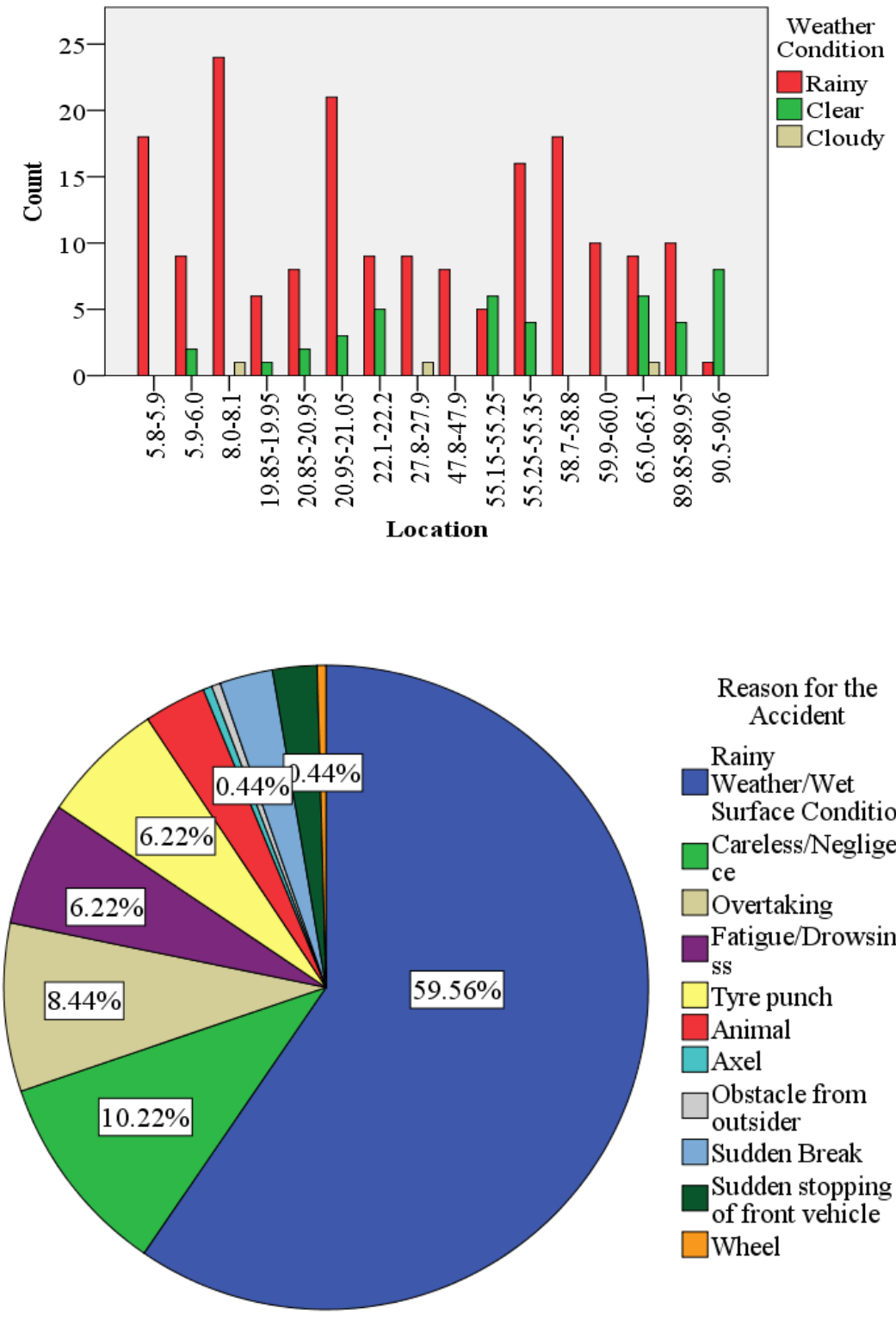

Figure 4.15: Reasons for the area to be prone to accidents and weather condition at the time of occurrence of the accident

Surface water collection due to rain has been identified at some spots. Therefore, the geometry of those locations has to be investigated. Following Figure 4.16 gives the cross-fall variation at prone locations.

❖**5.8-5.9 & 5.9-6.0 (RHS)** – 28 Accidents

New Location	Cross Fall	
	LHS	RHS
5.856	2.5	-2.5
5.876	2.134	-2.13
5.896	1.578	-1.58
5.916	1.023	-1.02
5.936	0.467	-0.47
5.946	0.189	-0.19
5.956	-0.09	0.088
5.976	-0.64	0.644
5.996	-1.2	1.199
6.016	-1.76	1.755
6.036	-2.31	2.311
6.046	-2.5	2.5

❖**8.0-8.1 (RHS)** – 23 Accidents

New Location	Cross Fall	
	LHS	RHS
8.046	-2.5	2.5
8.056	-2.36	2.355
8.076	-1.8	1.8
8.096	-1.24	1.244
8.116	-0.69	0.688
8.136	-0.13	0.133
8.146	0.145	-0.15
8.156	0.423	-0.42
8.166	0.7	-0.7
8.176	0.978	-0.98

- **58.7-58.8 (LHS) – 17 Accidents**
- 55.15-55.25 & 55.25-55.35 (LHS) – 27
- **20.85-20.95 (RHS) & 20.95-21.05 (LHS) – 31**

Same cross fall as above pattern

Figure 4.16: Cross fall variation at accident prone locations

Cross-fall has suddenly changed within the point of the 100m segments. Such transitions are present at each segment. So, water flow rate near the transition have reduced and as a result water has stagnated in these areas. Some segments have sag curves with such transitions and in these areas water has collected, forming puddles during the rain.

If rain prevails when a driver uses the expressway there is an inducement of shock when passing such locations and a sudden application of break can cause the vehicle to slide without control. The hydroplaning action also can be the cause for the accidents on such segments.

4.2 Accident rate analysis of southern expressway

The total number of accidents, which is 2,704, was taken for the rate analysis. An accident per vehicle kilometer travelled is used for the investigation. Traffic volume data from EOM & MD have been converted to vehicle kilometers by using distance travelled and accident rate.

Accident Rate = Number of accidents/ (Traffic volume*Travel distance)

4.2.1 Accident rates on southern expressway

Vehicle travel distance on the expressway in each year has been calculated. Accident rates are based on vehicle kilometers travelled.

Table 4.4: Accident rates on southern expressway

Yearly Accident Summery			**Accident Rate (Accident per vehicle million Km)**
Year	**Total Accident**	**Vehicle Travel Km**	
2012 Total	496	201626016	2.46
2013 Total	471	245312500	1.92
2014 Total	603	391558442	1.54
2015 Total	851	467582418	1.82
2016 Total	283	189932886	1.49

According to Table 4.4, accidents have been taking place at a high rate at the initial stage of the expressway's operation. But with time, the accident rate has reduced and started to continue at a constant pace. Total accident rate was calculated as 1.81 accidents per million vehicle kilometers travelled, for the whole section.

But during the year 2015 it has increased slightly compared to the previous year. Total number of accidents and vehicle kilometers travelled has increased with time. During the year 2015, accidents have increased more compared to the vehicle travel kilometer than to the previous year.

4.2.2 Sectional accident rates on STDP

Eleven (11) interchanges have been divided in to 10 sections and the accident rate has been calculated based on the sectional travel data.

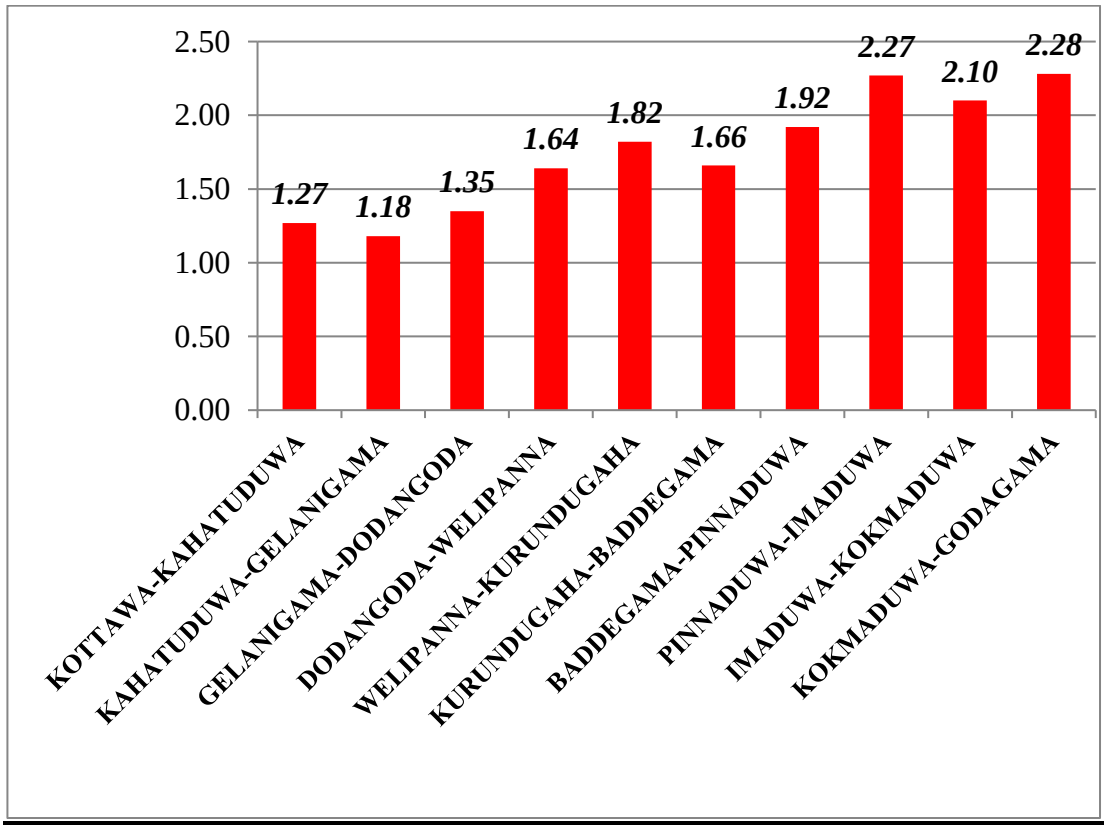

Figure 4.17: Sectional accident rate distribution

Basically sectional rates have increased from Kottawa to Godagama direction as per the Figure 4.17. Pinnaduwa to Godagama section has a high accident rate compared to Kottawa to Pinnaduwa section. But Pinnaduwa – Godagama section has a less number of accidents compared to the other sections. Accident rate is a parameter that aids in distinguishing whether the relevant area has a less or more risk of accidents occurring. However, each section should be further analyzed to identify the cause, and take proper alleviation measures based on the results.

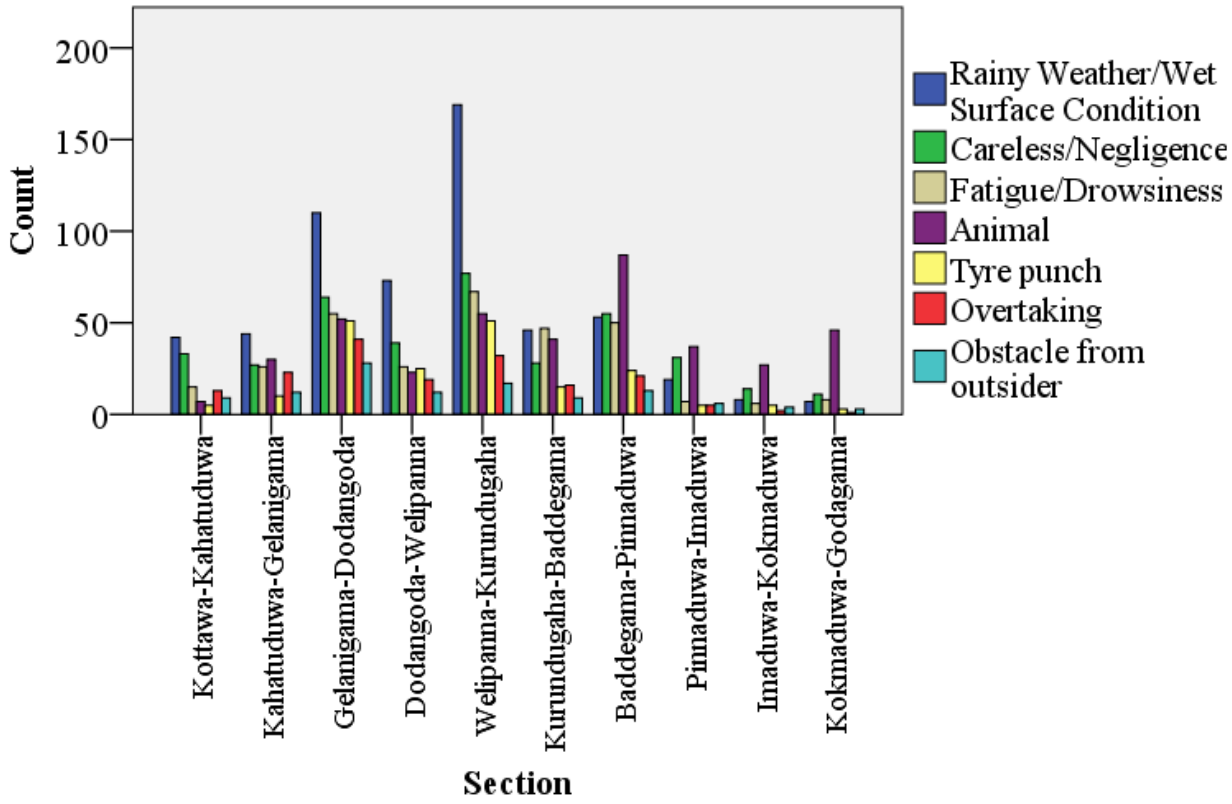

Figure 4.18: Main causes which affect sectional accidents

Rainy weather is the most significant factor that has an impact on the occurrence of accidents in between Kottawa to Baddegama sections, as depicted in Figure 4.18. Baddegama to Godagama sections have shown animal intrusions as the main factor.

Most sections from Kottawa to Pinnaduwa have a decreasing yearly rate distribution though from Pinnaduwa to Godagama section it is vice versa. Figure 4.19 illustrates the yearly accident rate distribution in each section.

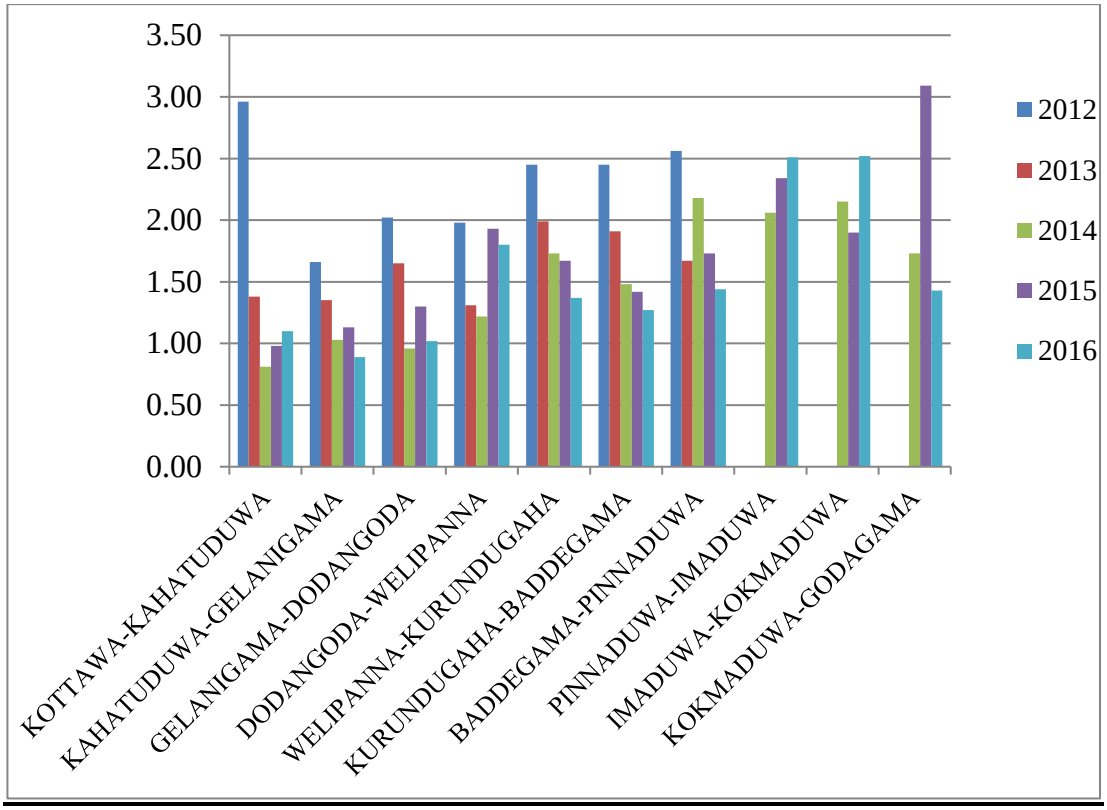

Figure 4.19: Yearly distribution of sectional accident rates

Nevertheless, the accident rate within most sections has deviated from the decreasing pattern during 2015. Only Welipanna to Baddegama, and Imduwa to Kokmaduwa sections have shown a considerable amount of decreasing rate.

4.2.3 Comparison of accident rate in expressway (In Sri Lanka)

Southern expressway (STDP) commenced its traffic operation in the end of 2011. After that Colombo - Katunayake expressway (CKE) had been facilitated to allow traffic movements during 2013 and the Outer Circular Highway (OCH) operated

with traffic in 2014. Accident rate per million kilometers travelled has been illustrated in Figure 4.20.

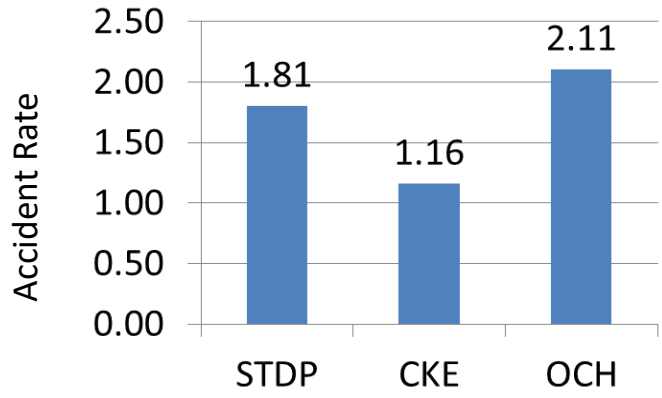

Figure 4.20: Accident rates distribution in Sri Lankan expressways

CKE has shown a lesser accident rate compared with the other two expressways. Normally a less number of accidents have occurred in CKE. On the other hand, OCH has shown the highest rate compared to the others.

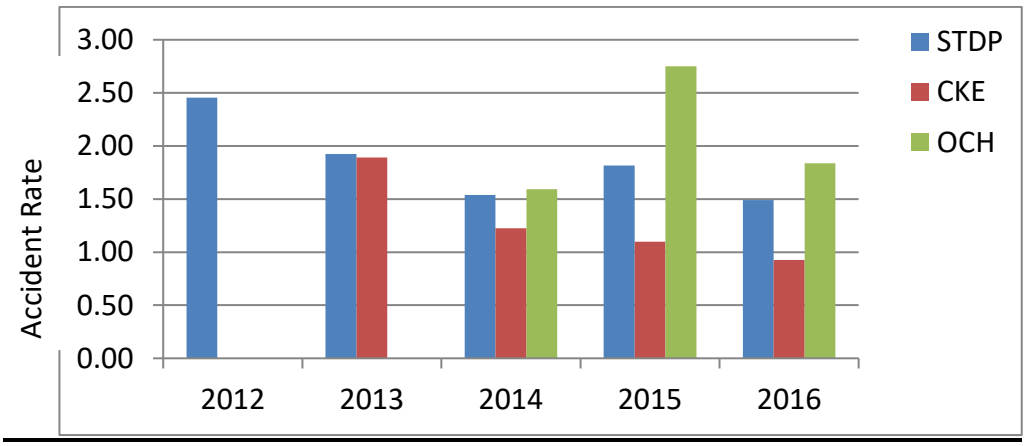

Figure 4.21: Yearly accident rate distribution in expressways

Figure 4.21 illustrates the yearly accident rate distribution in STDP, OCH and CKE. The accident rate has increased from 2014 to 2015 within OCH, and again decreased

during 2016. CKE has shown the accident rate decreasing pattern from the beginning and STDP has reached the uniform region.

4.3 Mark limitations of existing data recording procedure.

SPSS analysis has given more area distribution relevant to the expressway accidents. But an accident on the expressway has to be analyzed furthermore to identify relevant causes and mitigation measures. Five months from December 2015 to April 2016 has been selected for this study. Sample size is 92 (number of accidents). The main considerations are the following areas.

- Factors influencing accidents
- Factors influencing injuries

Two case studies have been carried out to determine the above factors.

Case study 01 - (Fatal accident)

Accident at 73.15Km (LHS)

One fatal accident from the sample has been selected for the case study. The driver had fallen asleep during the journey and as a result had met with an accident. It was raining at that moment and the vehicle had slipped and crashed on the embankment guardrail at first. Then had crashed again with the center median guardrail and rest at the outer lane of carriageway, with one fatality as shown in Figure 4.22

Figure 4.22: Accident at 73.15Km (LHS)

Following observations were made for the above incident.

1) Factors that had influenced the accident: Fatigue/drowsiness and the rainy weather condition (Human and Environment)

2) Factors that had influenced the injury: The way the vehicle had crashed and the fact that the driver had not used the seat belt.

Case study 02 - (Grievous accident)

Accident at 114.92Km (LHS)

A jeep had just moved from the relevant exit and stopped at the shoulder nearby the entrance at the merging point to the expressway. Then the driver had tried to reverse his vehicle in order to exit. Suddenly, a lorry had come and crashed with the rear side of jeep. (Video stream also has been inspected). Damage to the two vehicles is shown in Figure 4.23.

Figure 4.23: Accident at 114.92Km (LHS)

Following observations have been made for the above incident.

1) Factors that had influenced the accident: Reversing (Human) when reversing is strictly prohibited in the expressway and Carelessness/Negligence of the driver (Human).
2) Factors that had influenced the injury: Driver had not used the seat belt and the impact that had occurred due to the high speed.

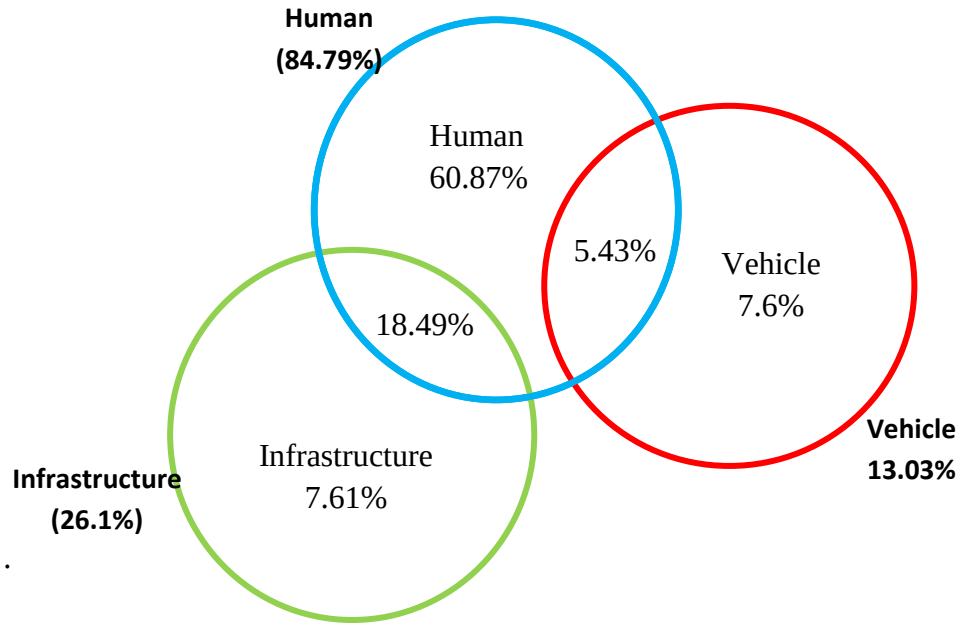

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Figure 4.24: Involvements of factors regarding expressway accidents

Human factor was the main parameter involved in the expressway accidents. Involvement of both vehicle and environment factors could not be found in the selected sample but there are rare incidents where all three (3) factors have contributed for a single accident.

There were twelve (12) accidents that had lead to injuries and one fatal accident in the selected sample. Severity of those injuries was based on the following factors.

1. Usage of seat belts.
2. Crash severity.
3. Crash pattern:
    - ***a.*** Crashing on side and center guardrails
    - ***b.*** Vehicles going off road from guardrail openings. (Figure 4.25)

Figure 4.25: Guardrail opening

- **c.** Crashing with the guardrail end buffer. (Figure 4.26)

Figure 4.26: Guardrail end terminal/buffer

4. Crashing against a vehicle, which has stopped on expressway

CHAPTER 05- CONCLUSIONS AND MITIGATION MEASURES

5.1 Conclusions

Following conclusions are being made based on the results from the data analysis.

- Evening (from 12.00 to 18.00 hrs) can be more critical for the expressway users throughout the week. The 12 to 18 hour period is the time in which most accidents have occurred. So accident mitigation measures shall be addressed considering this period of time.
- Accidents due to animal collision have taken place on the expressway and preventable measures should be taken. Accidents have occurred at the same frequency each year. Identified sections shall be carefully investigated and arrangements would be made for the mitigations. Baddegama to Pinnaduwa and Kokmaduwa to Godagama sections have shown more pig collisions. Also Baddegama to Godagama area has shown accidents involving peacocks. Collision of dogs takes place commonly on the expressway irrespective of the particular section.
- Tire punch and other mechanical failures in vehicles have caused a number of breakdowns on the expressway with the same frequency up to date. Such incidents will generate a bottleneck on the roadway and will act as obstacles on the road as well. This will be the cause for another accident and measures shall be taken thereof to avoid these situations.
- Rain was the main factor which has caused many accidents in the accident prone areas. During the site inspection it has been observed that some areas were stagnated with water during the rainy period due to geometric variations. Corrections have to be implemented as an urgent safety requirement.
- Case studies show the percentage of human factor involvement on expressway accidents. Considering that, Carelessness/Negligence of the drivers and Fatigue/Drowsiness would be carefully dealt with through the accident mitigation process.

- Seat belt is the main safety provider for the driver and passengers. So expressway users have to be enforced to wear the seat belts during the journey. Areas in which guard rails are open, and end terminals should be avoided, along with vehicles that had broken down or come to a halt on the expressway. Then the severity of the injury can be minimized.
- Accident rate has decreased and has continued in a regular pattern. With the increasing AADT, number of accidents on the expressway also has increased and the situation has turned worse. Therefore, accident rates should be minimized as much as possible with time.
- In the year 2015, accident rate has increased compared to the previous year and the decreasing pattern has deviated. Most sections have shown the accident rate increasing pattern during 2015.

- Pinnaduwa to Godagama section commenced its operation within the year 2014. So animal intrusion have caused more accidents in the new section compared to other sections. Although, less vehicle kilometers travelled were presented within the above section, number of accidents has escalated due to the higher number of animal intrusions compared with other sections.
- Less traffic movement within the short distance has been observed in OCH, compared with other two expressways. If less number of accidents has happened within the OCH, the highest rate will be given. CKE, in contrast has a less accident rate due to the provision of adequate road facilities. It has a carriageway with adequate shoulder width and water flows out from the center to the road edge during rainy situation and there are no stagnations. Also, street lamps have been provided throughout the whole section. CKE has presented a decreasing pattern distribution and is recommended as a safe road compared with other expressways.
- In STDP, accidents have occurred at the same frequency compared with the increasing vehicle kilometers travelled. Mitigation improvements should be initiated as an urgent requirement.

- The case study based on the southern expressway accident shows that there is not only one factor but two or more factors concerning Humans, Vehicle and Infrastructure.

5.2 Mitigation measures according to investigation findings

1. Enforcement strategy should be enhanced during the evening every day. Police patrolling on the expressway needs to be upgraded and more routines shall be implemented. Over speed, detections also should be increased in the evening compared to the other times.
2. People who wish to use the expressway need to be well aware of the proper usage of the expressway. Especially when rainy weather prevails they should follow the safe driving pattern recommended. Safety massages and warning signs would be displayed on variable message signboards. Also, police enforcement should be increased at the rainy areas and periods.
3. Animal collisions are avoidable. Dogs, pigs, iguana and most of animals have entered the expressway from the ROW fence bottom. ROW fence is damaged at most of the areas due to poor maintenance. As such, frequent inspections of the ROW fence shall be carried out and such openings shall be closed. A concrete layer can be applied at the bottom of the fence to seal the gaps. (Figure 6.1 show the ROW section)

Figure 6.1: ROW fence

4. Peacocks and other types of birds cannot be avoided according to the method explained previously. Therefore, information boards regarding the presence

of such animals at relevant sections should be installed to notify the users, thus promoting vigilance.. (As an example, “Peacocks ahead” massage should be displayed from Baddegama to Godagama area).

5. A secondary fence needs to be introduced along the embankment guardrail as per the Figure 6.2 to avoid such animal intrusions. This is the best solution when it comes to minimizing accidents related to animal collisions. However, will not present an aesthetic look and will cause maintenance issues.

Figure 6.2: Secondary fence along with embankment guardrail

6. Vehicle conditions such as tire condition, lights, loading conditions etc. can be checked at the entrance points. Tire punch was the main vehicle factor involving accidents. Heavy articulated vehicles such as prime movers, bowsers etc. usually having experienced tire punches on the roadway had stopped at the shoulder. So the carriageway also has been disturbed due to the less shoulder width on the Southern expressway. Upstream vehicle flow will be distrupted with such vehicles, leading to grievous accidents. Therefore, a proper system shall be implemented to promote the vehicle filtering process at the entrance points. Shoulder width should be increased during other expressway constructions.
7. Water collection at accident prone areas has to be minimized. Southern expressway consists with a one directional water flow surface from one edge

to the other edge. Thus, there is a situation where more water gets collected at one side of the carriageway. Center median drain can be introduced at these areas as a remedy. Geometric corrections also shall be carried out.

8. Improvement in skid resistance is the best solution for accident prone areas. With retexturing or overlaying of the friction course (porous asphalt), skid resistance can be improved.
9. Driving performance and knowledge of safe driving should be improved by, media advertisements, safety guidance books, consideration of expressway driving when issuing the license (Motor traffic department should consider that), police enforcement through patrolling, speed detection during the day and night time and information messages through the VMS.
10. Fatigue was most common among middle-aged drivers. Drivers aged between 23 to 37 years (that means initial stage of driving to mid stage) should be well educated about using the expressway correctly. I correspondence, 'landscape planning' instead of only focusing on the construction of the expressway would refresh drivers throughout the journey.
11. Interchange section length has a direct relationship with fatigue. Considering that, long sections should be avoided during future expressway constructions. New interchanges can be suggested within such sections.
12. Rest area will provide the parking facility and refreshment facility for expressway users. Southern expressway has only one rest area for the whole 125km section. This is not acceptable and rest areas need to be introduced as per the acceptable intervals. Drivers who experience exhaustion during driving can be facilitated with such arrangements. Also heavy vehicles that are heavily loaded cannot travel a long distance without a pause. Tires could get heated and lead to blasting. Such incidents on an expressway could create bottlenecks and may lead to more accidents. Rest areas with acceptable intervals will minimize such situations.
13. Continuous rumble strips or groves along the shoulder section will generate sound with the tire movements on that. Figure 6.3 shows the rumble strip arrangement on the shoulder. Drivers who fall asleep will move towards the shoulder and it is expected that the sound created would alert them.

Figure 6.3: Rumble strips along the shoulder

14. Guardrail end terminal should be avoided to minimize the severity of injuries. Embankment guardrail opening sections should be closed. Figure 6.4 illustrates the new arrangement of such a guardrail section.

Figure 6.4: Re-arrangement of embankment guardrails