INVESTIGATION OF ACCIDENTS IN COLOMBO KATUNAYAKE EXPRESSWAY

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Degree of Master of Engineering in Highway and Traffic 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

Expressways are developed to provide high mobility link between major cities in a country. Colombo Katunayake Expressway is 26 km expressway connect Colombo to Katunayake where major airport located. Since expressways are designed for high speed traffic flows ensuring safety is important in the future.

The objective of this study is to identify road accident causing factors related to road, user and environment factors in expressways. CKE is used as a case study for the research.

It is identified that majority of accidents 66.4% of total accidents cause due to road user (driver) behavior and vehicle related problems. Severity of accident has increased when there is a combination of the above factors (road, user and environment).

This would suggest the average accident rate 1.3 per million vehicle kilometer. Only one fatal accident has recorded during the period which is a motorbike entry and crash with a car.

Since this is a partially open expressway there is an issue relates to vehicle road worthiness. Therefore, we can expect to significantly reduce the accident rate through improving road user awareness and education on safe practices. Significant issue related to road characteristics is surface water accumulation on the expressway at reverse curves due to the problem of change of super elevation and cross fall. Therefore, need to add design improvement such as groves or use of porous pavement to improve drainage on such sections or by installing variable speed sign on such sections to notify drivers.

Key words:

Mobility — safety— accidents — user — environment— expressways— behavior— crash

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W.R.G.M. Bandara (138304D)

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List of Abbreviations

GDP	- Gross Domestic Product
EOMM&D	- Expressway Operation Maintenance and Management Division
RDA	- Road Development Authority
CKE	- Colombo Katunayake expressway
RoW	- Right of Way
LHS	- Left Hand Side
RHS	- Right Hand Side
RAI	- Road accident investigation
VKT	- Vehicle kilometer travelled
MFNSV	- Multi function network survey vehicle

1 INTRODUCTION

Sri Lanka is a developing country so the expressway network has a major role in the development of the country. After the first expressway opening of the Southern expressway to the public there was much attracted to using it. RDA was planning and constructing several other expressways to enhance the safety and mobility of the inland transportation.

On 27th October 2013 Colombo Katunayake Expressway (CKE) was opened for the public as the second expressway in Sri Lanka. CKE has three tolling stations and five interchanges along its 26 km length, (see figure 1-1).CKE is the major link between Bandaranayke International Airport to Colombo and Katunayake export zone and city of Colombo.

1.1 Background

There are five interchanges from Peliyagoda to Katunayake along the 26km. The road is designed in three sections and design speed is 80km/h and 100 km/h. But the posted maximum speed limit posted is 100 km/h.

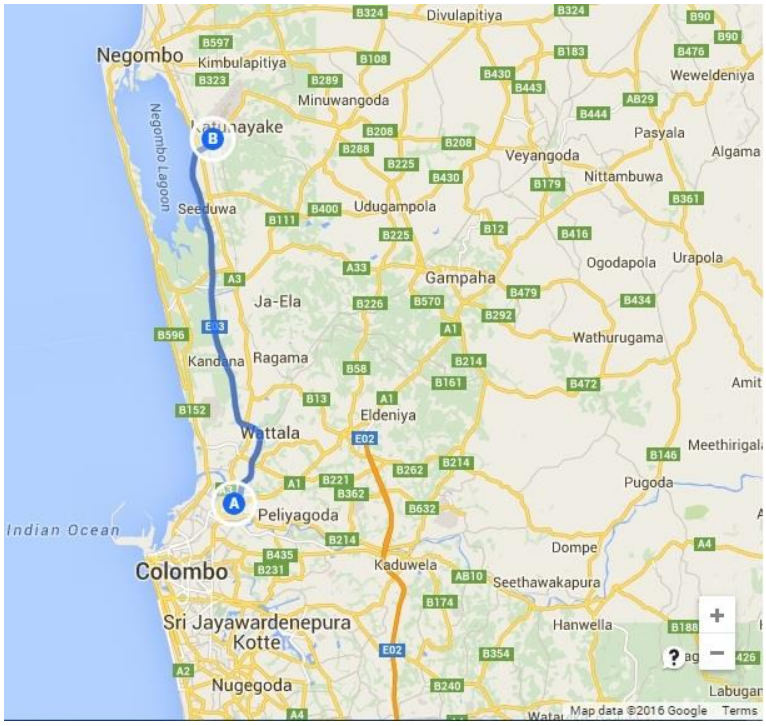


Figure 1-1 Road map of CKE

Table 1-1 Design speeds

Section 1, K 0+000 to K 8+300	80 km/hr
Section 2, K 8+300 to K 21+200	100km/hr
Section 3, K 21+200 to K 25+800	80 km/hr

The entire road is constructed over embankment, it is completely illuminated with center median double arch light poles. Center median and side guard rails have fixed for the entire length of the road.

The Road Development Authority has a different unit to maintain and operation of the expressway called Expressway Operation, Maintenance and Management division (EOM&M)

For the help of EOM&M division, Sri Lanka police has formed a separate police division called expressway police division and they are at each interchange. For firefighting and first aid, there are separate unit under police in some interchanges.

Traffic accident recording and handling is done RDA and police staff jointly. These data have been used for analysis of the accidents. Table 1-2 gives the roadway and operating characteristics of CKE.

Table 1-2 Horizontal alignment design values

Elements of design	**Unit**	**Expressway**	**Ramp**
Design Speed	Km/ hr	100/80	60/30
Sight distance	m	160/110	-
Minimum radius	m	700/400	150/30
Min. radius without super elevation	m	5250/3350	1900
Max. Super elevation	%	6	6
Cross fall	%	2.5	2.5

(MCC, 2009)

Table 1-3 Vertical alignment design values

Elements of design			Unit	Expressway	Ramp
Max. Grade	Exit	Up	%	2.59	3
		Down			4.738
	Entrance	Up			4.573
		Down			2.8
Min. Grade			%	0	0.3

(MCC, 2009)

Table 1-4 CKE pavement frictional characteristics

Road	Location	MFNSV Measured Texture Depth / mm	British Pendulum Results
CKE	1+000 RHS, 0.3m , Inner lane	0.46	70
CKE	1+000 RHS, 0.3m , middle lane	0.43	65
CKE	1+000 RHS, 0.3m Outer lane	0.43	70
CKE	5+000 LHS, 0.3m Inner lane	0.42	60
CKE	5+000 LHS, 0.3m Outer lane	0.44	60
CKE	5+000 RHS, 0.3m Inner lane	0.43	65
CKE	5+000 RHS, 0.3m Outer lane	0.49	65
CKE	10+000 LHS, 0.3m Inner lane	0.43	60
CKE	10+000 LHS, 0.3m Outer lane	0.40	65
CKE	10+000 RHS, 0.3m Inner lane	0.49	55
CKE	10+000 RHS, 0.3m Outer lane	0.48	65
CKE	15+000 LHS, 0.3m Inner lane	0.47	65
CKE	15+000 LHS, 0.3m Outer lane	0.46	65
CKE	15+000 RHS, 0.3m Inner lane	0.42	70
CKE	15+000 RHS, 0.3m Outer lane	0.42	65
CKE	20+000 LHS, 0.3m Inner lane	0.39	65
CKE	20+000 LHS, 0.3m Outer lane	0.41	65
CKE	20+000 RHS, 0.3m Inner lane	0.32	65
CKE	20+000 RHS, 0.3m Outer lane	0.4	65
CKE	25+000 LHS, 0.3m Inner lane	0.53	70
CKE	25+000 LHS, 0.3m Outer lane	0.53	70
CKE	25+000 RHS, 0.3m Inner lane	0.58	65
CKE	25+000 RHS, 0.3m Outer lane	0.61	65

All above numbers are in acceptable region for an expressway (RDA, 2013). Given in Table 1-4 the frictional performance of the road is in a satisfactory considering both macro texture and friction value.

Table 1-5 Road features

No of Lanes in toll free Section	6 (3 for each direction)
No of Lanes	4 (2 for each direction will tolling)
Lane width	3.750 m
Shoulder	3.000 m
Guardrails	For centre median & both edge of shoulders
Illumination	Full road is Illuminated
Operation	RDA, EOM&M Division and Expressway Police
User Fees	Yes
Right of way fence	Yes, with a protective fences

Table 1-6 Average daily traffic

Year	Days	Traffic	ADT
2013 (From Oct. 27th)	66	985782	14936
2014 (Up to july)	212	3654487	17238

As given in Table 1-6 ADT has increased by 15% per an annum 14936 in 2013 to 17238 in 2014.

1.2 Problem Definition

Expressways are constructed to provide high mobility road links within the highway network. Therefore, the safety of these expressways is of paramount importance. This is especially relevant when considering the high volume of traffic expected to be operating on the CKE. To ensure the road user safety is maintained during operation with the relevant risk factors needs to be identified on expressways.

1.3 Objectives

The research study aims to analyze the accident data available for the CKE and identify causal factors for accidents relating to the road, user and the environment.

1.4 Scope

Evaluating existing accident data on expressways & identifying the cause of factor related to roadway, User & environment factors. Accident data collected from the CKE opening 2013.10.27 to end of April 2015 was considered for the analysis.

2 LITRATURE REVIEW

2.1 Accident analysis of southern expressway

Solutions are needed to drain water from stagnant locations. In addition, it is important to keep the speed of the vehicle within the limits of the expressway on a safe trip. It will not be of any real reason, because this study only examines the reasons for the accidents that contributed to the road network environment. However, paying attention to these findings can reduce the risk of injury. Especially, the distance is 40 km, the driver is feeling drowsy and therefore can cope with accidents. Therefore, road users should be aware of this situation. (Chinthanie, 2015)

The accident rate in Southern Expressway is higher than the similar road corridor A2 value while fatality rate has lower value than same road. However, fatality rates in southern expressway, A2 road and whole countries are heavily deviating with the international figures leading towards an unsafe trend. Therefore, it is essential to take immediate action to implement a safety improvement program. (Chinthanie, 2015)

The accident rate on the Southern Expressway will have a value over the same corridor A2. However, the fatal percentage of the Southern expressway, A2 Road and the entire country is not very different with those who are heading towards an unsecured trend. Therefore, an immediate action should be taken to implement a safety improvement program. (Chinthanie, 2015)

Table 2-1 Accident causing factors in Southern expressway

Accident causing factor	2011	2012	2013
Human errors (%)	54	44	52
Road environment (%)	37	40	32
Vehicle related issues (%)	9	17	15

In here human errors considered as speedy driving, sudden stopping, incompetent driving, overtaking, negligence and fatigue. Road surface condition, road geometry, weather, animal hits and stone hits have taken as road environment factors. Vehicle

road worthiness factors like the condition of tire, braking errors, other sudden electrical and mechanical failures have taken as vehicle relates issues.

Human factors should be analyzed for a suitable methodology recorded data for accurate data are not sufficient.

It can be concluded that there is no adverse effect on time (day time or night time) an accident on a particular road section.

The accident rate based road section had calculated on the Southern expressway. The number of road accidents in each road section was divided in that road section. The accident happened in the Kottawa Kahathuduwa section is higher due to temporary interchange at Kottawa. (Chinthanie, 2015)

Table 2-2 Accident rates based on vehicle kilometer travelled in Sothern expressway

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	1.8
Welipanna - Kurudugaha	39.03	83	2.13
Kurudugaha - Baddegama	20.94	48	2.29
Baddegama - Pinnaduwa	23.19	65	2.8
Total road	**190.15**	**405**	**2.13**

(Chinthanie, 2015)

Table 2-3 Southern expressway sectional accident rates

Road Sections	**No. of Accidents**	**No. of Accidents / km**
Kottawa - Kahathuduwa (6km)	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

(Chinthanie, 2015)

Table 2-4 Annual accident data from 2006 to 2016 on A2 road

Road section along A2 road	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Dehiwala - Moratuwa	568	537	433	429	459	440	616	395	307	296	242
Moratuwa - Panadura	395	428	347	436	427	385	640	357	288	273	284
Panadura - Kaluthara	379	270	202	226	192	252	211	196	171	154	189
Kaluthara - Aluthgama	219	198	193	181	174	194	205	168	167	189	169
Aluthgama - Ambalangoda	280	230	255	366	331	433	309	226	178	213	196
Ambalangoda - Hikkaduwa	112	120	109	121	128	177	114	83	118	101	68
Hikkaduwa - Galle	225	222	231	262	268	235	260	158	155	165	132
Galle - Habaraduwa	97	99	101	88	88	95	76	107	72	83	70
Habaraduwa - Weligama /Godagama	228	197	189	168	201	267	299	250	219	251	308

(Peiris, 2017)

As shown in Table 2-4 Undergraduate student W.A.T.K.R. Peiris and Dr. H, R, Pasindu analysis done in 2017. A Compered corresponding section of the Galle road Southern expressway has a significantly lower accident rate. Which suggest expressways in Sri Lanka are comparatively safer than normal highways in Sri Lanka.

2.2 Accident trends in developing countries.

2.2.1 Mumbai – Pune Expressway Road Accident Study

The Mumbai-Pune Expressway is a controlled access way linking India's commercial capital, Mumbai, to Pune, Asia, an educational and information technology hub. This breakaway 6-lane road is an alternative to the old Mumbai-Pune road and helps to reduce the travel time between the two cities. The speed limit is 80 miles per hour. Three-wheelers and three-wheelers are not permitted to use many sections of the expressway. Public vehicles running on the expressway are cars, trucks and buses. The expressway is 94.6 kilometers. It is reported that there are traffic accidents, fatal and serious injuries.

155 road extreme roads covering the period from January to December 2016 were analyzed and analyzed by the JRR. These reports, as well as the Mumbai-Pune Expressway, are an in-depth analysis of these dangers. This report identifies these "evidence factors" based on the number of accidents that these factors are based on. The rating is to help online road safety investment planning planners, decision makers and road safety stakeholders using the data online road safety strategies.

The 155 crashes examined in 2016 include 63 fatal crashes (41%) and 36 serious injury crashes (23%). These crashes resulted in 118 fatal victims and about 300 serious injury victims. Distribution of 155 accidents by contributing factors influencing the occurrence of accidents

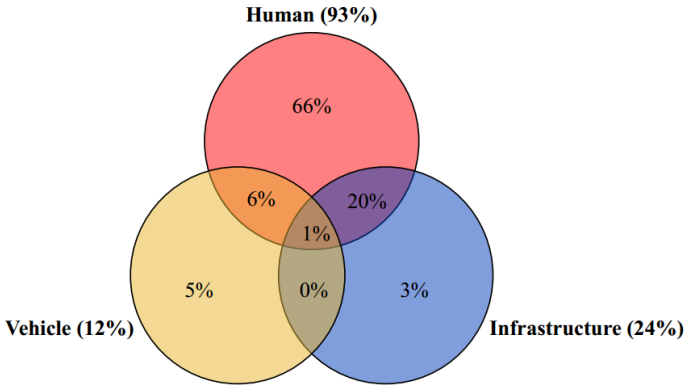


Figure 2-1Distribution of 155 accidents by contributing factors influencing the occurrence of accidents

(JP RESEARCH INDIA PVT LTD, 2016)

2.3 Road safety in developed countries

Table 2-5 shows the summary of reported road traffic accidents in high income countries as population based rate. In these countries have law enforcements to ensure the safety of road users.

Table 2-5 Population based accident rates in developed countries

Country	Population numbers for 2013	GNI per capita for year 2013 in US $	Income level	Estimated road traffic death rate per 100 000 populations
Australia	23 342 553	65 390	High	5.4
Austria	8 495 145	50 430	High	5.4
Belgium	11 104 476	46 290	High	6.7
Canada	35 181 704	52 200	High	6.0
Finland	5 426 323	48 820	High	4.8
France	64 291 280	43 460	High	5.1
Germany	82 726 626	47 270	High	4.3
Greece	11 127 990	22 690	High	9.1
Iceland	329 535	46 400	High	4.6
Ireland	4 627 173	43 110	High	4.1
Israel	7 733 144	33 930	High	3.6
Italy	60 990 277	35 860	High	6.1
Japan	127 143 577	46 330	High	4.7
Netherlands	16 759 229	51 060	High	3.4
New Zealand	4 505 761	35 550	High	6.0
Norway	5 042 671	102 610	High	3.8
Singapore	5 411 737	54 040	High	3.6
Spain	46 926 963	29 920	High	3.7
Sweden	9 571 105	61 760	High	2.8
Switzerland	8 077 833	90 760	High	3.3
UK	63 136 265	41 680	High	2.9
USA	320 050 716	53 470	High	10.6

(WHO, 2015)

In Sri Lanka GNI per capita for the year 2013 in US $ is 3170 and the estimated road traffic death rate per 100 000 populations is 17.4 (WHO, 2015)

Fatalities per 10,000 licensed motor vehicles, has a trend of steady decreasing in west countries after 1960. But in developing countries the trend shows a continues increasing. (WHO, 2015)

2.4 Methods and examples of road accident data analysis

2.4.1 Aim of data analysis

One of the basic aims of data analysis is to identify the main problems in the field of road safety. The efficiency of accident prevention depends significantly on the reliability of the collected and estimated data and the appropriateness of the used methods. (Holló, 2006)

2.4.2 Theoretical definition of risk

$$\text{Accident risk} = \frac{\text{Number of accidents}}{\text{Units of exposure}}$$

The best theoretical estimate and the commonly used unit of exposure is the number of vehicle-kilometers. The accident rate (number of personal injury accidents related to the number of vehicle-kilometers) and the accident density (number of personal injury accidents related to the length of a road section) are used mainly in the field of black spot identification and analysis, and for the comparison of accident risk on different road categories. (Holló, 2006)

2.5 Road accident investigation guidelines for road engineers

Accident data basically can be used in two ways:

- To determine the common characteristics of accidents in order to elaborate the effective countermeasures.
- To identify the locations, together with the traffic volume data, where the probability of accidents is significantly higher than average (so-called black spots).

In the first case have to produce very simple frequency tables. Which can have an overview about the most frequent characteristics of road accidents. (Mikulík, 2007)

2.5.1 Accident rates

i. Accident density (A_d)

$$(A_d) = \frac{A}{LT}$$

Where:

L : the length of the investigated road section or road network (km).

A : the number of accidents occurred on the section or network with a length "L".

T : the number of years.

This ratio is calculated annually. The problem is that this ratio does not take into account the traffic volume. Therefore, it has the highest value for heavy traffic. (Mikulík, 2007)

ii. Accident rate (A_r)

$$(A_r) = \frac{A.10^6}{365.AADT.LT}$$

Where:
AADT : annual average daily traffic (vehicle/day)

In most cases this ratio is calculated annually. This ratio is calculated as the theoretical view of a random event. Based on the concept of this ratio, the numbers have a linear connection danger and traffic volume. A link between vehicle volumes and accidents can be summarized. (Mikulík, 2007)

2.5.2 The relationship between traffic volume and accidents

$$A = a.Q^b$$

Where:
A : number of accidents
Q : measure of traffic volume
a, b : constants

If b = 1, 1% increase in traffic volume is associated with a 1% increase in the number of accidents.

For injury accidents if b = 0.911, which means that there is a nearly linear relationship between the frequency of accidents and the traffic volume, at least within the interval of the usual traffic volumes.

Based on this relationship, it can be said that increased traffic volumes are basically connected with increasing accident numbers and vice versa. (Mikulík, 2007)

2.5.3 Preliminary information required for accident investigation

- Location
- Time of notification
- Who notified the officer and how?
- Weather and visibility conditions
- General information as to the seriousness of the accident injuries, hit and run, the amount of traffic congestion, etc.
- Whether or not additional support is proceeding to the scene, such as towing trucks, ambulance, or additional Police patrols.

By obtaining such information prior to arrival at the scene, the investigators may more quickly and efficiently respond to the needs of the situation. (Explorers, 2014)

2.6 Traffic accident application using geographic information system

Highways and transport engineers are heavily dependent on geographic information systems. Previously, our predecessors used paper maps for centuries. Although a record system with large paper-based data files on the highway has some consolation, such systems have serious disadvantages and hidden costs. GIS (Geographic Information System) is not used to describe the computer systems that include a global map environment and additional information, such as a global information system.

Nowadays, many highway agencies have been using GIS for analyzing accident data. Identifying places of interest are the most important part of emergency studies. Using the system, collecting traffic accidents and road data, selecting the variables for relaying to calculate mean and standard deviations to calculate the frequency and number of ratios, as well as calculate the frequency and number of ratios, in accordance with accidents data and locations, fixed-load data analysis, slide and position analysis. Sort the risk factors and frequencies and the selected criteria.

Highway accidents have failed to reduce road accidents. Particularly with regard to the location of a public image of the data is necessary information about conflict situations. More accurately, the stationed data will help guide the way for road, highways, road improvements, vehicle maintenance, emergency medical services, and engineering. (Mohamad, 2005)

2.7 Measures to reduce accident risks

Divide the wide ranging policies for traffic safety measures into the five categories below (Oguchi, 2016)

i. Traffic safety facilities and road traffic environment.
ii. Regulations and law enforcement.
iii. Education and publicity.
iv. Improvement of vehicle safety standards.
v. Emergency medical care.

3 METHODOLOGY

After studying the literature, it was decided to analyze under the following categories in CKE.

3.1.1 Road infrastructure related issues.

Under this category engineering design related issues and maintenance practices were considered. CKE is paved on year 2013. After the construction IRI, Pavement friction values, and macro texture, depth were investigated through MFNSV. (RDA, 2013)

Surface water drainage during rain and its depth is a critical factor on expressways due to excessive settlement, super elevation and cross fall changes water stagnation can be occurred. Road geometry in horizontal curves and vertical curves need to be provided as design specifications. Under this minimum curve radius and minimum and maximum gradient on the expressway need to incorporate.

During the day there can be seen high traffic volumes in CKE. During this period proper road signs, pavement markings, and road way obstacle can lead to accidents.

3.1.2 Road user and the vehicle related issues.

It can be seen some drivers drive under the influence of alcohol. Inexperienced drivers face vehicle maneuvering difficulties in excessive speed, merging and overtaking malpractices and sudden stopping in an emergency situation. Sometimes it could be seen mobile phone use while driving this direct effect to the reaction time of the driver.

Some older drivers try to use the expressways, with two wheelers and three wheelers. Sometime even they drive the wrong direction, entry through exit points can be seen due to confusion and poor awareness.

Fatigue is the enemy of most of the drivers. After several hours of driving some don't take a rest and drive. Ultimately they met with accident suddenly due to drowsiness. Rarely, it can be seen some tire punch while travelling and breaking losses. If the driver could not control the vehicle during that incident, he met with an accident.

3.1.3 Weather and other environmental factors.

During the rainy weather wet surface reduce the friction between vehicle tire and the road. This increases the braking distance or the slippery and hydroplaning effect to vehicles. In severe rain conditions, cloudy or foggy environment, and during dusk and dawn driver eye sight will reduce. On expressways, with higher speeds, these factors cause accidents.

100m sections of the expressway considered as a location in the accident data collection and analysis process. Data collected by RDA has used for the analysis.

3.2 Data collection

3.2.1 Responsibility of data collection

In local road traffic police does the work. But in expressways there is a separate division under RDA called EMO&M. They attend to accidents and incidents to support those who use the expressways. On expressways police and RDA do separate data collections simultaneously. To collect traffic accident data RDA gets information from other road users, Police, and CCTV video stream established on the road.

Table 3-1 Accident data collection for the period

YEAR/ MONTH	Accident Type			
	Fatal	Grievous	Non Grievous	Property Damage
2013-YEAR (26th October to December 31)	0	0	0	44
2014-YEAR (January to December)	1	7	1	180
2015-YEAR (January to April 30th)		4		49
Total Accident	1	11	1	273

The above table shows the categorized accident distribution over the selected period for the analysis. Above accident data were analyses with an exposure base rate like VKT, accidents per vehicle kilometer and rates were compared with southern expressway data.

4 DATA ANALYSIS

4.1 Data analysis

Colombo Katunayake Expressway is a short (25.6 km) expressway. So it could analyze accident locations without using advanced Geographic information systems.

Here I have used 100m intervals as accident locations (Location took from approaching direction)

With the development of the expressway network it must use advanced software for data collection, entry, analysis and identification of accident black spots and accident prone locations.

4.2 Traffic volume calculation for accident analysis

Tolling data in each toll gate were used to calculate the million vehicle kilometer travelled. Entrance and exit data with distance from interchanges were used. In below table it shows sectional vehicle traffic in million kilometers in each month separately for the selected period.

Table 4-1 Vehicle km travelled in CKE for the selected period

From	To	2013			2014												2015			
		10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
Peliyagoda	Ja ela	0.55	3.24	4.16	4.33	3.84	4.22	4.24	4.26	4.17	4.44	5.04	4.61	4.69	4.45	5.25	5.09	4.42	4.87	3.69
Ja ela	Katunayake	0.27	1.57	1.99	2.07	1.83	1.98	2.02	1.98	1.93	2.04	2.35	2.11	2.13	2.03	2.42	2.37	2.05	2.22	1.65
Katunayake	Ja ela	0.26	1.53	1.97	1.94	1.71	1.88	1.94	1.91	1.88	2.00	2.21	2.01	2.02	1.95	2.37	2.23	1.93	2.12	1.84
Ja ela	Peliyagoda	0.49	3.04	4.00	4.01	3.57	4.00	4.05	4.09	4.04	4.34	4.74	4.39	4.45	4.28	5.11	4.67	4.18	4.65	3.99
Total	Veh km in millions	1.57	9.38	12.12	12.34	10.95	12.08	12.24	12.24	12.02	12.82	14.34	13.12	13.29	12.71	15.16	14.36	12.58	13.86	11.17

To calculate above sectional traffic details entrance and exit tolling were used for the selected period.

4.3 Accident rate distribution

Table 4-2 Accident rate distributions

Time period		2013			2014												2015				Average
		10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	
Category	Veh km in millions	1.57	9.38	12.12	12.34	10.95	12.08	12.24	12.24	12.02	12.82	14.34	13.12	13.29	12.71	15.16	14.36	12.58	13.86	11.17	
	Fatal	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	
	Grevious	0	0	0	0	0	1	0	2	1	1	0	0	2	0	0	2	0	2	0	
	Non Grevious	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
	PDO	3	21	20	16	14	26	17	14	16	12	12	14	19	8	12	17	13	13	6	
	Total	3	21	20	16	14	28	17	16	17	14	12	14	21	8	12	19	13	15	6	
Fatalities per million veh km		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.078	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
Grevious per million veh km		0.000	0.000	0.000	0.000	0.000	0.083	0.000	0.163	0.083	0.078	0.000	0.000	0.150	0.000	0.000	0.139	0.000	0.144	0.000	0.044
Non Grevious per million veh km		0.000	0.000	0.000	0.000	0.000	0.083	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
PDO per million veh km		1.911	2.239	1.650	1.296	1.278	2.151	1.389	1.144	1.331	0.936	0.837	1.067	1.430	0.630	0.792	1.184	1.034	0.938	0.537	1.251
Grevious & Non Grevious per million veh km		0.000	0.000	0.000	0.000	0.000	0.165	0.000	0.163	0.083	0.078	0.000	0.000	0.150	0.000	0.000	0.139	0.000	0.144	0.000	0.049
Total accident per million veh km		1.911	2.239	1.650	1.296	1.278	2.317	1.389	1.308	1.414	1.092	0.837	1.067	1.580	0.630	0.792	1.323	1.034	1.082	0.537	1.304

According to the above rate analysis PDO accident has the highest accident rate. But these rates are lower compared to Southern expressway values. (Chinthanie, 2015)

In CKE there cannot be seen much Grievous and Non Grievous accidents. The fatal accident rate is very low.

4.4 Sectional accident rates

Table 4-3 Sectional accident rates

From	To	Accident rate per km per mi. veh. km
Peliyagoda	Ja Ela	0.06
Ja Ela	Katunayake	0.14
Katunayake	Ja Ela	0.09
Ja Ela	Peliyagoda	0.06

According to the above analysis, highest vehicle flow has in between Peliyagoda to Ja-Ela and Ja-Ela to Peliyagoda. But the highest sectional accident rate has recorded from Ja-Ela to Katunayake section. According to Sri Lanka police speed data the number of high speed fines has recorded in this section. It clearly shows excessive speed has a trend to increase the number of accidents in CKE.

Table 4-4 Accident rate per km length

		Peliyagoda to Ja ela	Ja ela to Katunayeke
Katunayake Direction	Number of accidents	79	52
	Length km	16.2	8.8
	Accident per km length	4.88	5.91
Colombo Direction	Number of accidents	69	31
	Length km	16.2	8.8
	Accident per km length	4.26	3.52
Both direction together		9.14	9.43

Above accident values has considered along the expressway without considering accidents near Ja ela toll gates.

4.5 Category wise accident distribution

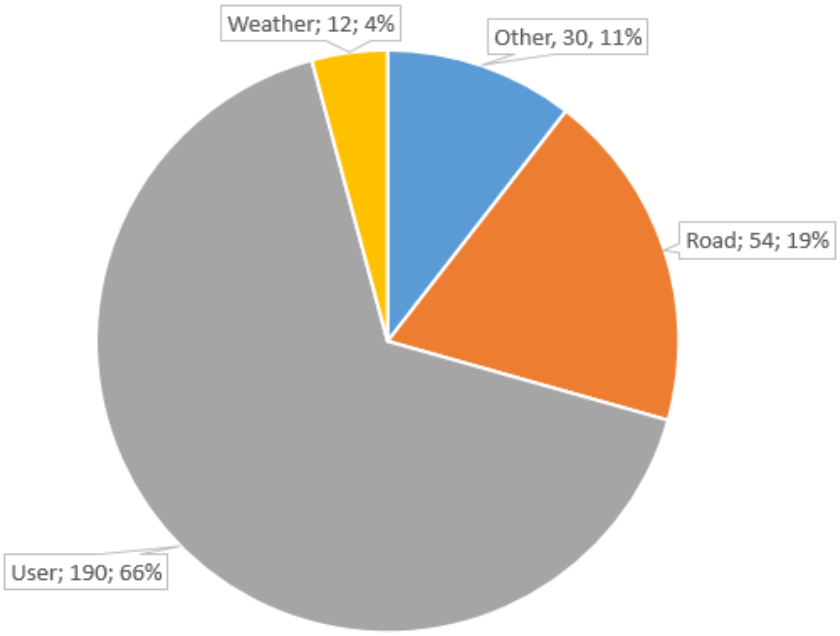


Figure 4-1 Accident distribution

As shown in above graph most of the accidents happens due to the vehicle user related issues. But there are some improvements need road surface and maintenance practices to help drivers to reduce some accidents while travelling in rainy weather.

4.5.1 User related category accident distribution

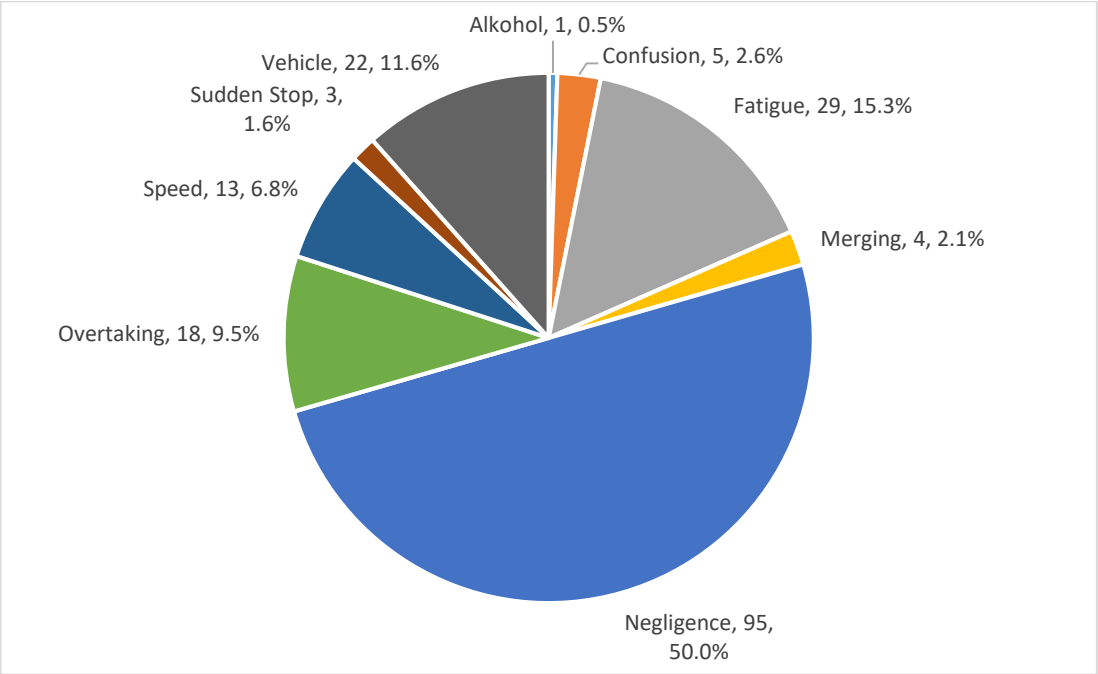


Figure 4-2 User related category accidents redistribution

4.5.1.1 Accident or breakdown in critical points.

Many of expressway users has familiarized with 1969 customer care number and they inform to call center regarding breakdown and accidents. But some users do not know what to do in an emergency situation inside the expressway. If the road user informs an accident or a breakdown expressway operation staff will come and do the proper barricading to avoid further accidents. But, there are some accidents recorded due to blocking an inner lane by a breakdown vehicle or accident vehicle blocking without informing to expressway operation staff.

4.5.1.2 Slow moving vehicle in inner lane.

Sometimes slow-moving vehicles (Speed below 40Kmph) travels on the inner lane of the expressway. During this time some second vehicle drivers use the left side for overtaking. During this short time another third vehicle driver comes with a high-speed far away from these two vehicles. Third vehicle driver does not have a clear picture of what is in front of him. When the second vehicle takes left side overtaking the speedy vehicle tries to go through inner lane and take the overtaking as usual. Unfortunately, he met with an accident with that slow moving vehicle in the inner lane.

This type of accident accidents happens where minimum sight distance is provided. But design limits have satisfied. This is a good combination of driver behavior. Some tend to drive at very slow speeds and some SUV user tends to use higher speed than posted.

4.5.1.3 Inexperienced drivers and aggressive driving patterns.

Most of the accident has recorded with who is having a temporary driving license due to another fine before the accident. In Sri Lanka there is 14 days to get paid the fine for a traffic violation. But during this period they have met with an accident on the expressway.

Some drivers try to overtake every vehicle in front and always try to keep 100 kmph all the time. They are reluctant to follow the 100 kmph and in front of him. They always try to be the first on the road. Unfortunately, in sever road conditions they met with an accident.

Another group of drivers is trying to earn time on the road. Sometimes they travel about 140 kilometers on high speed. But the maximum safer, speed of CKE is 100 km and some 120 km in some areas.

4.5.1.4 Mobile phone using while driving.

Most of expressway experience drivers know that where is security cameras placed and where can be policed patrolling will be. So they check their mobile phones while driving. Take calls with and without using hands free. Finally, when there is any sudden change in traffic or weather condition change they met with accidents.

4.5.1.5 Drinking and driving.

Since the CKE link Colombo to Negambo and Puttalum. Early morning traffic from Colombo to outward it can be some severe accidents due to this reason. Most party times and night activities end in the early morning and drive under the influence of alcohol. These kind of accidents can see during 12:00 to 04:00.

4.5.1.6 Fatigue.

Some drivers come from very far from to Katunake international airport to pick passengers. During this journey some southern section drivers have travelled along

several hours. But they don't have much experience on expressways. Same time to Katunayake airport busy with night time. During this night time due to lesser traffic flow in CKE drivers use their maximum speed and in an emergency even for an animal crossing he will meet with an accident.

4.5.1.7 Vehicle road worthiness.

In Sri Lanka we use a much older vehicle even on expressways. For the entry to the expressway at the entry point police people check the worthiness of the vehicle to give permission to run on expressways. Most of the time vehicle older than 3 years from the year of manufacture need to check carefully. For local roads there is no reliable way to stop running these kind of vehicles. At any time, such a vehicle can enter to CKE since it is a half open expressway. There are some records loosing brake system, emergency tire punches while travelling, etc.

4.5.2 Road related accident distribution

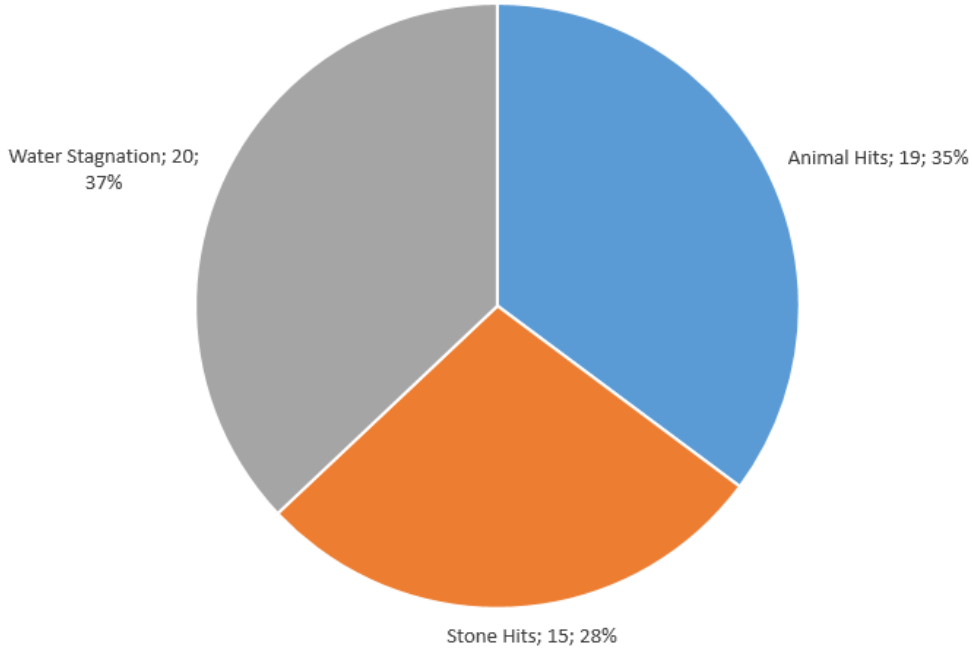


Figure 4-3 Road related accident redistribution

4.5.2.1 Water stagnation points and accident severity.

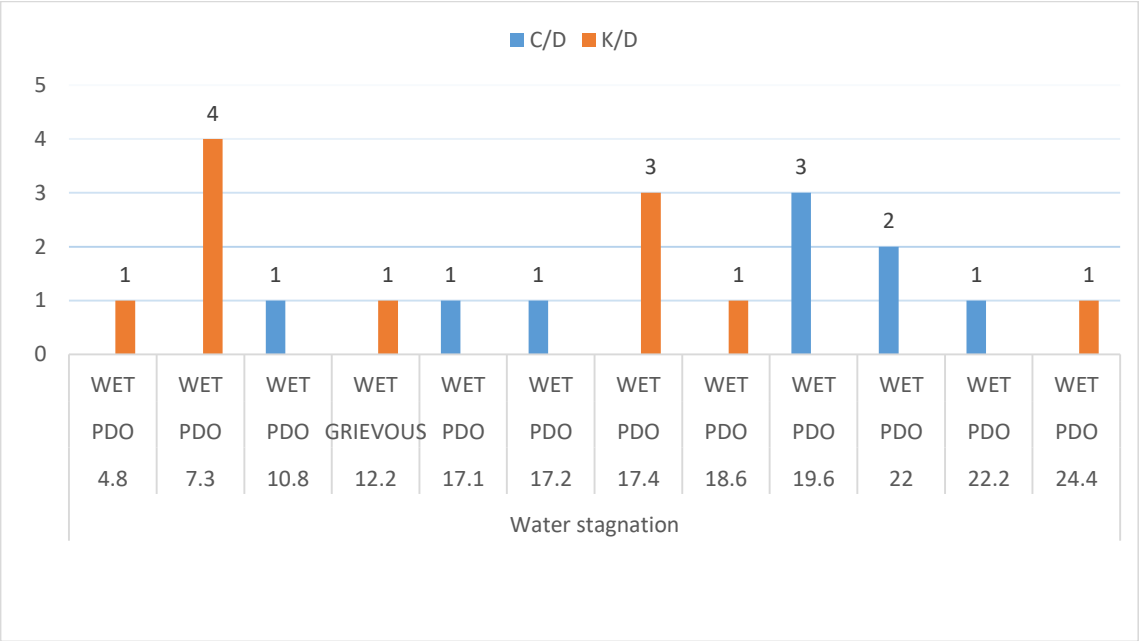


Figure 4-4 Water stagnation point and accident severity

As in above figure it shows some accident black spots during rainy weather. There are four locations in both directions. Two in each direction. All these points are in reverse curves. Due to super elevation change in these points has created this water stagnation issues.

4.5.2.1.1 Problems with water stagnation

During the rain many of accidents happen due to hydroplaning action. Loss of traction & stability cause braking and maneuvering loss due to

1. Speed of the vehicle
2. Condition of tires
3. Tire pressure
4. Pavement surface condition & texture
5. Water depth

From above factors speed of the vehicle, condition of tires, and tire pressure can be controlled by the road user. This may reduce the vulnerability towards an accident. But most of the drivers do not reduce their speed during the rain. Most drivers try to keep the 100 kmph speed all along the expressway. By doing so they try to earn time

expressway as well as to enjoy the ride in sever weather conditions. Unfortunately, if there is any deficiency in road condition, there is a high risk to meet with an accident.

The pavement surface condition & water depth should be controlled by the road agency.

So far the expressway road surface is at a satisfactory level.

Figure 4-5 Tire condition of an accident vehicle

Figure 4-6 Water stagnation after a rain in 7.3 km KD

Water stagnation on the expressway pavement shall be rectified without delay. Adequate gradient and cross falls should be maintained. In many of reverse curves water stagnation points could be identified due to super elevation changes along the curve. Above points should be rectified in an acceptable manner. During heavy rains, it cannot be avoided the water depth due to the high intensity of the rain. But to avoid forming accident blackspots EOM&M division has taken actions like introducing grooves to sweep out the water immediately after the rain.

4.5.2.2 Stone hits on the expressway.

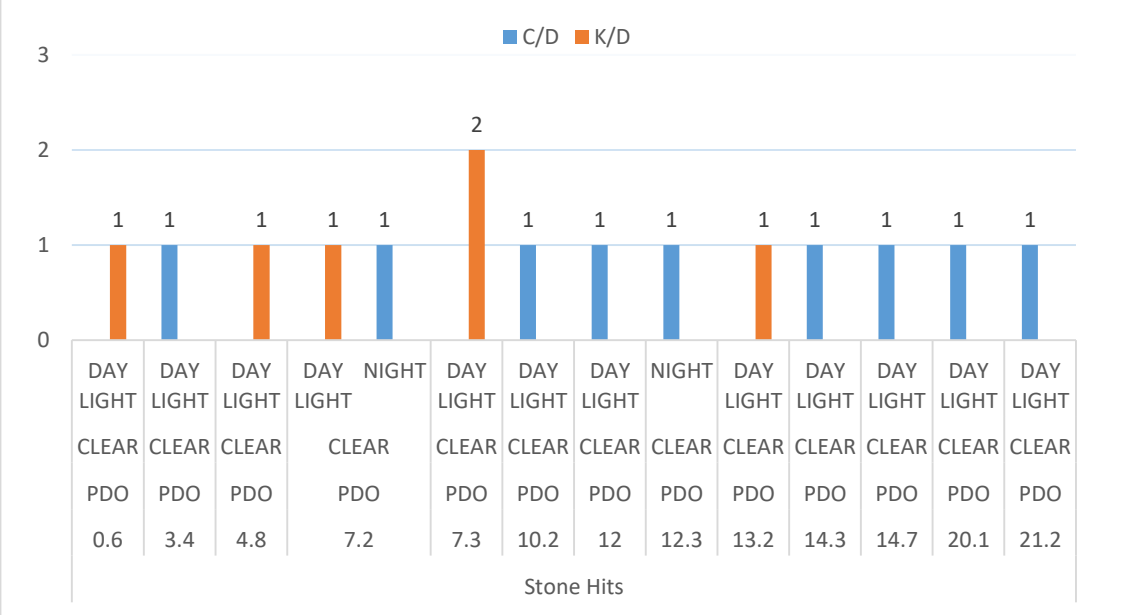


Figure 4-4-7 Stone hits over the expressway

There is no special road section with stone hits other than 7.2-7.3 km. This location has a specialty. At this point CKE goes through an underpass which is the link road of Negambo Colombo. There is a possibility to fell stones from above the road.

4.5.2.3 Animal hits on the expressway.

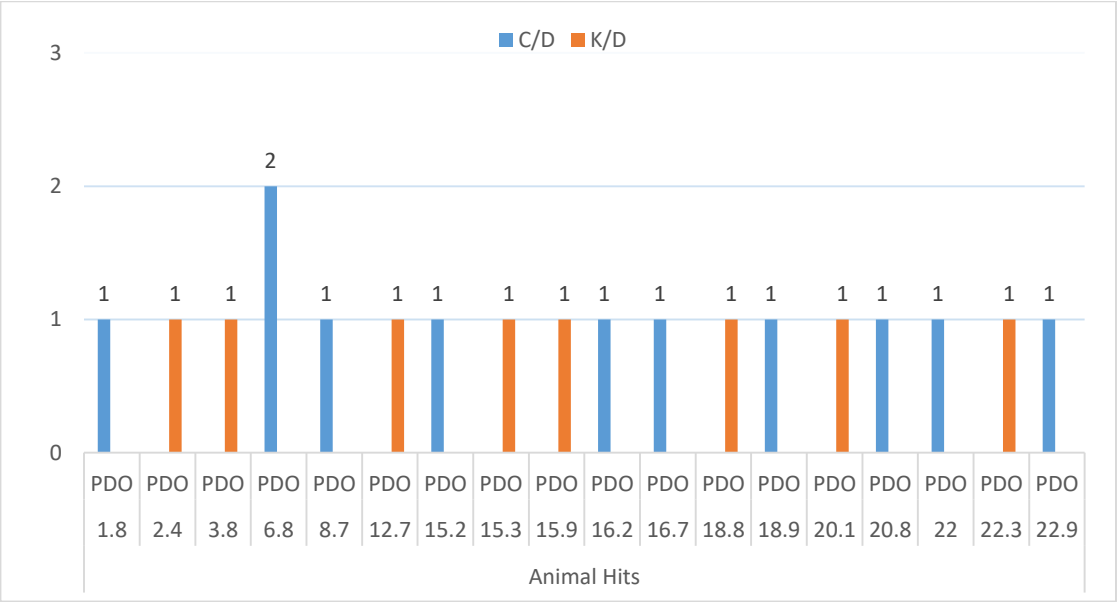


Figure 4-8 Animal hits over the expressway.

At 6.8 km there are some houses near the expressway So it can be seen some dogs come through the safety net provided at RoW.

4.5.2.4 Maintenance practices

At present in CKE grass trimming, watering activities handle with labors. Some labors do not obey the instruction given on resource development trainings. So some drivers complain regarding their behavior & stone hits while grass trimming with machines.

4.5.3 Accident over the weather condition

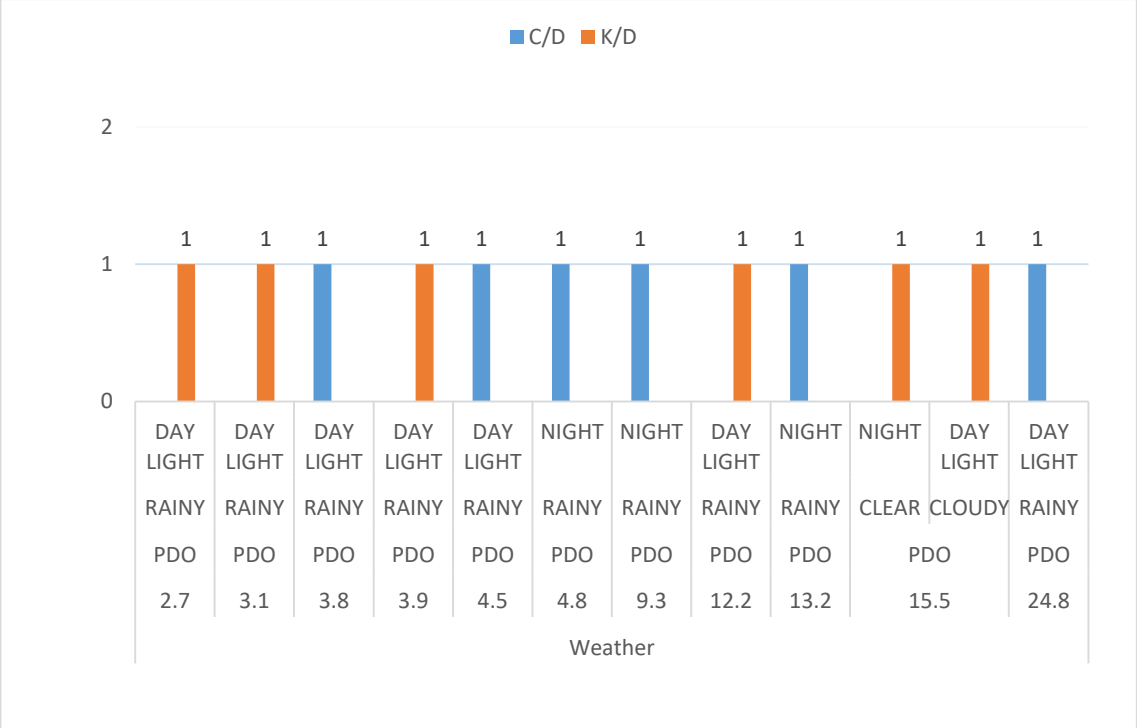
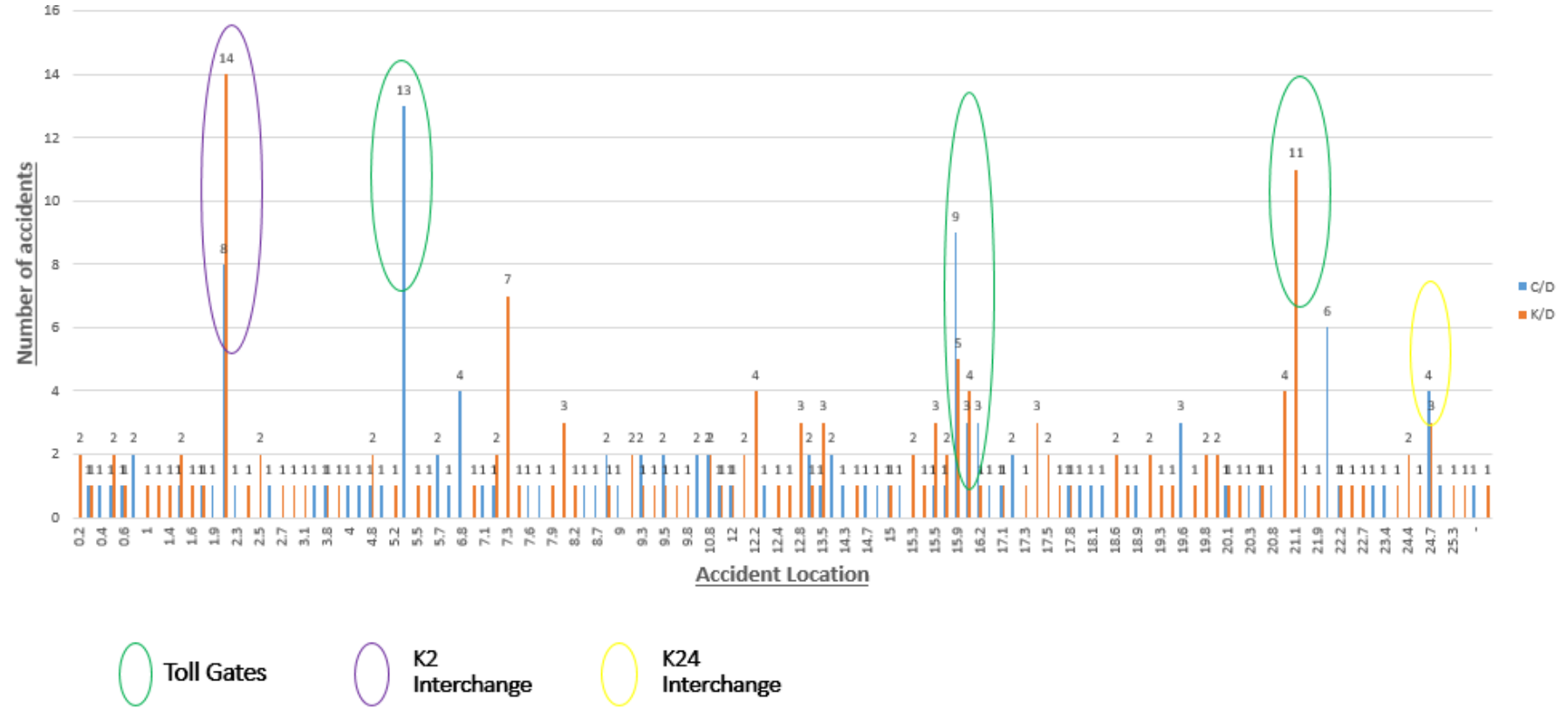


Figure 4-9 Accident over the weather condition

CKE is a fully illuminated road. So there cannot be seen any difference in day time and night time accidents due to severe weather.

4.5.4 Other specially identified accident prone low speed areas and reasons.

As an expressway user's vehicle speed controlling and maneuvering has a major role in accident avoiding. Special in deceleration lanes it should follow posted speed. It could identify a large number of accidents in low speed areas such as,



4-10 Accident distribution on both directions

4.5.4.1 Accident near toll gates (K5, K16, K21)

At present most of expressway users know that they have to pay the toll tee at the exit point. So, they have to reduce the vehicle speed and stop at the booth. But some driver does not reduce the speed for away from the booth, they try to reach the booth as much as can with the running speed about 80 kmph. But the posted speed has reduced to 20 kmph with in the last 50m. Due to an above reason some drivers met with an accident with other vehicles or fixed object like a gate barrier. Some driver tends to take the best lane to go thought as much, as quickly in last several meters and drivers tries to shift their lanes. This practice also leads to an accident near toll gates. I could identify that some older vehicle come to the toll gate and met with accident because they travelled with higher speeds, but not stopped at a shorter distance as they thought.

Some accident has recorded due to chatting with people inside the vehicle and mobile phone checking while they are in moving queues.

4.5.4.2 Accident at Interchanges entry & exit (K2, K16, K24)

From NKB to K2 it is a toll tree area with one way three lanes. So there are a large number of vehicle movements in the K2 interchange area. Other than this there is a link road from Colombo - Kandy road to Colombo – Negambo road. So many vehicles travel through this bypass road through the K2 interchange. On this bypass road there are two main traffic light control junctions very close. In this section most of commercial vehicles can be seen, due to less traffic compare to above two local roads. Some inexperience commercial vehicle drivers have met with an accident when they take turns from Colombo to Kandy direction. Because in this movement designer has provided minimum curve radius. For commercial vehicles it is the critical factor. At K24 Negambo to Colombo right has recorded some accidents. Inexperienced truck drivers have been recorded in accident reports at this location.

4.5.4.3 Congested areas (Monday morning traffic jam at toll free section from K0 to K2)

After the weekend in every Monday there is a significant queue at the NKB exit point. It takes approximately an hour to reduce the traffic in this location. During this time period some drivers are not following their lane properly. As a result, accident may occur.

In this area drivers must be careful and use low speed below 40 kmph. But most of the drivers do not follow the speed posted.

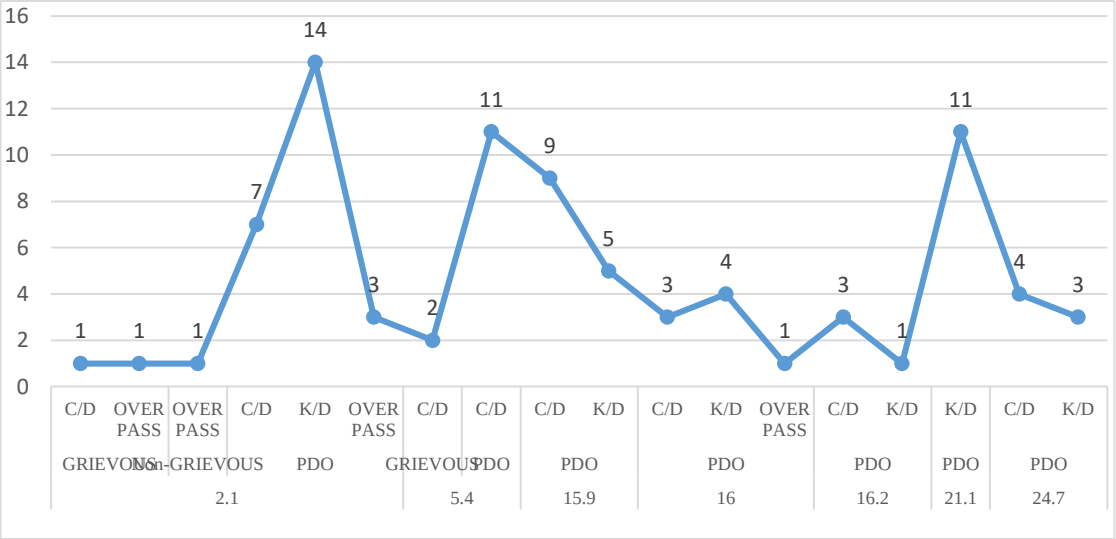


Figure 4-11 Number of accident distributions in low speed road sections

4.6 Accident reducing factors compared to Southern Expressway

The expressway is fully illuminated so the driver can see even without will vehicle head lights switch on. In an emergency high speed moving vehicle losing its lights can cause accidents. But in CKE they will not face to such an accident. In a sag curve and in a horizontal curve sight distance can be maintained easily in CKE due to full road illumination. It could be seen some accident reduction CKE in night time compared to southern expressway.

Headlight glare cutter act as an accident reducing factor. During the night time glare from coming vehicles has an effect on accident. CKE has a center median with plants. It acts as a glare cutter. This has reduced the number of accidents in the night time.

CKE is a shorter expressway. There is no time to get tired due to travel in the same speed for a long time. In CKE travel time for 25.6km takes about twenty minutes for many vehicles other than some commercial vehicles. So, it could be seen some accident reduction in driver fatigue category.

In southern expressway there are some sections with low traffic flow. But in CKE every time there is considerable vehicle flow in each kilometer. Due to this constant traffic flow, level number of high speed vehicles has reduced. So it has a reduced number of accidents.

Compared to a southern expressway vehicle user in CKE has to face a large number of traffic police patrolling teams and RDA patrolling teams. And in other hand, number of CCTV camera in a kilometer is higher than the southern expressway. So, drivers tend to maintain lane discipline and proper speed limits while on the expressway. These factors have reduced some amount of accident compared to southern expressway.

Lane width and shoulder widths are wider than the southern expressway. Constricted effect while travelling in CKE lesser compared to southern expressway. This has a reduction in kissing, overtaking accidents and an accident on parked vehicles.

By providing the necessary safety vehicle with proper standards while maintenance activities and traffic management activities have reduced some accidents.

Southern expressway has constructed over varies cut and fill sections. So the shoulder side guard rail not provided continuously over cut sections. Due to this variation each end of a cut section there a nose arrangement to start the guard rail in fill section. But in CKE there a continues guard rail over the expressway. According to these variations the severity of crashes has reduced in CKE.

RDA operation staff having the experience gained from southern expressway. But in early times in southern expressway EOM&M divion had no experience. It has reduced some accidents due to having two years' expressway operation.

4.7 CKE accident rates compared to the other Sothern Expressway.

Compared to southern expressway accident rate analysis done in 2015 there is a reduction in accident rates in CKE.

Table 4-5 Summary of research

Comparison Criteria	**Units**	**Southern Expressway**	**CKE**
Accident rates per VKT	Accidents x veh.km $x10^{-6}$	2.40	1.30
Accident per km length in critical section	No. of Accidents x km^{-1}	16.00	9.43

(Chinthanie, 2015)

5 CONCLUSION & RECOMMENDATIONS

Driver behavior is the major factor for accidents in CKE. Negligence, inexperience drivers and aggressive driving patterns could be seen in the accident investigation process. Vehicle road worthiness has a major impact on the severity of the accidents. Accident severity has increased when there a combination with driver discipline, road related issues and bad weather conditions.

The accident rate on CKE is considerably less compared to Southern expressway and other developing countries like India, Bangladesh etc.

It could be identified four locations with hydroplaning happens during the rain. Those locations can be rectified with simple solutions like grooving.

There was no major deviation in accident rate during day time and night time because the entire road is illuminated. But during the day time there are a number of accidents due to higher vehicular traffic.

Further avoidable accident happens on CKE. These accidents can be reduced by adding some improves to road maintenance system and giving driver training to inexperience aggressive drivers. Public awareness programs and distributing accident analysis data to road user may reduce some kind of accidents happens due to negligence.

Table 5-1 Automatic rain detector

Speed limit reduction during rain has a major impact on accident reduction and their severity reduction. For that variable speed sign and warning blinkers may helpful. Installing automatic rain detectors with warring blinkers (blinking with amber and red color) near reverse curves and other vulnerable areas where hydroplaning may occur during heavy rains will give some awareness to the road user before reaching the critical road sections. Awareness and education programs on safe practices can expect a significant reduction in accidents through improving road user behavior.

Very basic maintenance practices like grass trimming near the shoulders with hand held devices can be avoided and need to introduce some machines with self-safety barricades with crash cushions. Continues road sweeping and cleaning can be introduced to reduce PDO accidents like a stone hitting.

Monthly accident updates in public media like TV news, newspaper articles, introducing expressway FM channel all along the expressways will enhance the awareness.

Upgrading driving license tests to suit expressway users. Continues resource developed by EOM&M division is essential to improve safety standards.

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