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**STUDY OF DRIVER BEHAVIOR AT ENTRANCE  
RAMPS OF EXPRESSWAYS IN SRI LANKA**

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Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree  
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## **DECLARATION**

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

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The above candidate has carried out research for the Masters thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Prof. W.K. Mampearachchi

Signature of the Supervisor:

Date: 07/08/2023

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## ABSTRACT

Driver behavior characteristics have a significant influence on the design of an expressway interchange ramp terminal in relation to traffic safety. In general, ramp terminals are more prone to accidents because of their function, which includes traffic merging, diverging, and changing lanes more frequently. These factors increase driving anxiety and lead to more accidents. In addition, due to the adoption of various design standards in various projects, the ramp terminal lengths of Sri Lankan expressways differ from one another.

The primary goal of this research is to examine how drivers behave at the entrance ramp terminal in relation to crucial influencing elements such as vehicle entry speed, ramp terminal entry zone, and expressway through traffic speed at the proximity of the entrance ramp terminal. The research also aims to explore ways to enhance drivers' behavior in this context.

Six interchanges - Kerawalapitiya, Kothalawala, Kottawa, Galanigama, Pinnaduwa, and Godagama - were selected for further study based on the variation in acceleration lane lengths among them.

The study utilized video data from a Closed-Circuit Television camera installed at the Kottawa Interchange on 27 February 2020. CCTV cameras were not available at the other five Interchanges; a drone survey was carried out at those locations on 14 October 2020.

The analysis was based on two important parameters identified through a literature survey: 1. Vehicle entry speed to the expressway and 2. Vehicle entry zone to the expressway through the entrance ramp terminal.

The speed of the vehicles as they enter the expressway is significantly lower than the speed of expressway vehicles, except at Godagama Interchange, according to the analysis. The entry speed into the expressway is 60 kmph on average for all six interchanges. This necessitates a larger space between oncoming expressway traffic and entering traffic using the acceleration lane. Another significant aspect was that the vehicles entering the expressway did not use the expressway acceleration lane as anticipated. At the Kottawa Interchange, a higher percentage of vehicles entering the expressway (20%) was observed beyond the ramp's tapering. In violation of the safety regulations, 27% of vehicles at the Godagama Interchange entered the expressway in the chevron area. When all interchanges are considered, only 50% of the vehicles entered the expressway through the designated zone, while the remaining 50% using the ramp taper, the chevron region, or beyond the ramp taper.

The research results support the conclusion that drivers lack the necessary knowledge to use the expressway ramp terminal, as revealed through a careful investigation of driver behavior, including how they enter the expressway and at what speed. In order to educate the drivers before they enter to the expressway The phrase "Prepare for the Expressway Speed" has been selected as the appropriate wording for the signboard as a result of a survey that was conducted among design engineers involved in the field of geometric design of roads in Sri Lanka. Additional variable speed signboards displaying from ramp speed to expressway speed along the ramp have been identified as a secondary measure to promote uniform speed at the expressway entrance.

Based on the research results, it is recommended to inform drivers about the expected way to enter the expressway through the entrance ramp terminal using signboards, television programs, or printed media.

**Keywords:** Expressway, Entrance Ramp Terminal, Entering Speed, Driver Behavior

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## LIST OF ABBREVIATIONS

<b>Abbreviation</b>	<b>Description</b>
EOM&M	Expressway Operation Maintenance & Management
AASHTO	American Association of State Highway and Transportation Officials
CCTV	Closed Circuit Television
RDA	Road Development Authority

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# CHAPTER 1

## INTRODUCTION

A country's transportation system directly influences its economic development. The development of a road transportation system is crucial in the context of Sri Lanka because the country significantly depends on it compared to other modes of transportation including rail, sea, air, intermodal, and pipeline. As a result, the Sri Lankan government invested substantially in the development of the country's road network system, including expressway network.

The 95-kilometer southern expressway connecting Kottawa and Pinnaduwa was opened on 27 November 2011, becoming Sri Lanka's first-ever expressway. Currently, Sri Lanka has 312 kilometers of expressways that are in operation. A list of Sri Lanka's expressways is shown in Table 1.1.

Table 1.1 List of Expressways in Sri Lanka

Number	Name of the Expressway	Length (km)	From	To	Completion Year
E 01	Southern Expressway	200	Kottawa	Mattala	2020
E 02	Outer Circular Expressway	28.8	Kottawa	Kerawalapitiya	2019
E 03	Colombo Katunayaka Expressway	25.8	New Kelani Bridge	Katunayaka International Airport	2013
E 04	Central Expressway Section 2	40.9	Mirigama	Kurunegala	2022
E 06	Magampura Expressway	16.5	Anderawewa	Hambantota	2019

Source: EOM&M Division of Road Development Authority

## 1.1 Background

A significant number of interchanges have been constructed along the expressway network in Sri Lanka to enable access and exit for the expressways. The precise amount of interchanges, including system and half interchanges, is 38. The interchanges in Sri Lanka's expressway network are shown on a map in Figure 1.1. Sri Lanka has an average proportion of interchanges per 8 km length of expressway compared to other countries. This is due to a number of factors, including Sri Lanka's likely higher road density, the fact that few expressways pass through urban or semi-urban regions, and other geopolitical considerations. Due to the fact that each interchange has four exit and entrance terminals, with the exception of half interchanges, which only have two, this contributes to the larger number of entrance and exit terminals.

The primary purpose of the interchange of an expressway is to facilitate vehicles entering or leaving the expressway. The drivers must speed up as they enter the expressway at an interchange in order to reach the appropriate speed to match the expressway speed. On the other hand, when exiting an interchange from an expressway, vehicles must slow down to the ramp design speed. In both situations, it is hazardous for the safety of the traffic and it would significantly disrupt the regular flow of traffic on the main expressway. Additionally, when approaching an interchange, drivers must make several judgments simultaneously. Therefore, while considering road safety, an interchange's proper design is extremely important.

Ramps, acceleration or deceleration lanes, a physical nose, a painted nose, auxiliary lanes, and a taper are just a few of the different elements that can be featured in an interchange design. In order to achieve optimal design on the interchange while considering road user safety into consideration, the appropriate dimension and configuration of the aforementioned features are crucial.

Ramp terminal is one of an interchange's key components. The area next to the through lanes is referred to as the ramp terminal, and it includes tapers, islands, and speed change lanes, such as acceleration and deceleration lanes. The length of the acceleration and deceleration lanes is critical in order to provide sufficient space for drivers to increase or decrease their speed as necessary. Additionally, drivers use the acceleration lane length to enter the expressway when there is a wide enough gap at the main expressway through lane.

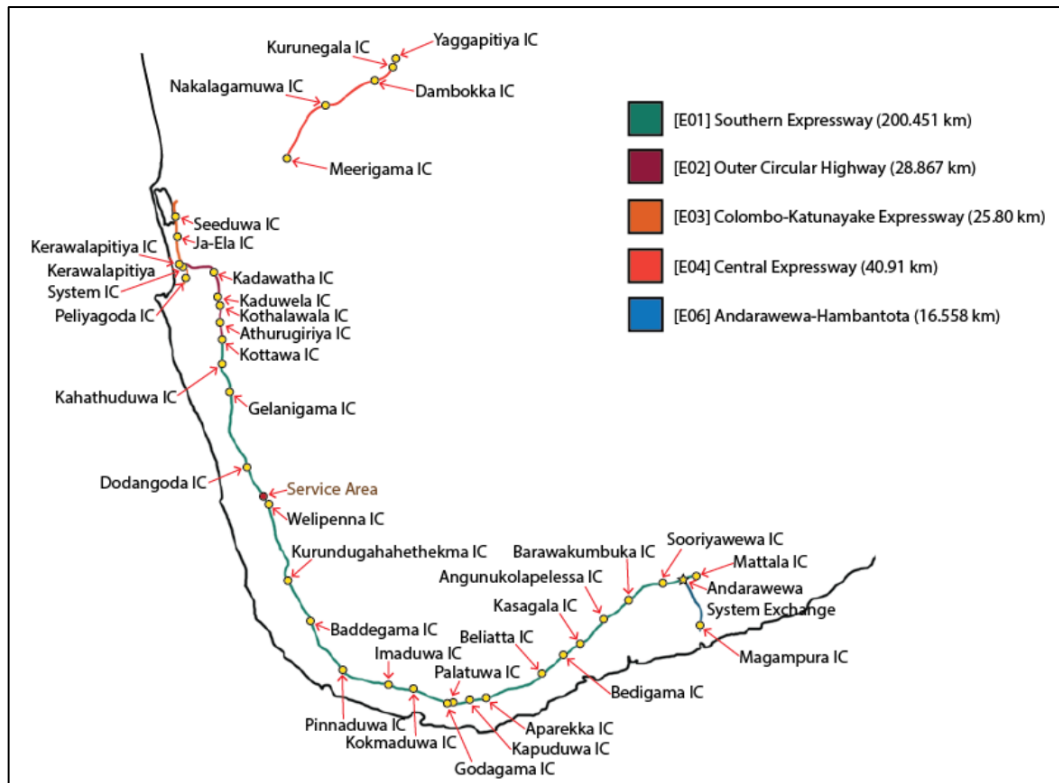


Figure 1.1 The Interchanges in Sri Lanka's Expressway Network  
 Source: EOM&M Division of Road Development Authority

## 1.2 Problem Definition

In Sri Lanka, many types of Design Guidelines, such as AASHTO, Japanese, etc., were frequently used for expressway geometric design. As a result, the expressway design demonstrates the inconsistencies of using these standards in design. Consequently, different acceleration and deceleration lane lengths and configurations are adopted in the interchanges by project-wise basis, as discussed in Chapter 2.

Apart from that, no research has been done into how drivers use the ramp terminal, including whether they enter the highway at the appropriate speed or from which position along the ramp terminal in Sri Lanka.

## 1.3 Objectives

Objectives of this research study are:

1. review the ramp terminal designs used in Sri Lanka's expressway construction;
2. examine how drivers behave at the entrance ramp terminal in relation to crucial influencing elements such as vehicle entry speed, ramp terminal entry zone,

and expressway through traffic speed at the proximity of the entrance ramp terminal; and

3. examine ways to enhance drivers' behavior at entrance ramp terminal.

## **1.4 Scope**

Six interchanges, namely those located at Kerawalapitiya, Kothalawala, Kottawa, Gelanigama, Pinnaduwa, and Godagama, were taken into consideration for the study from the Outer Circular (E 02) and Southern Expressway (E 01). The interchanges were selected based on their geometry at ramp terminals.

## **1.5 Scope of the Report**

The report consists of six chapters.

Chapter 1 offers an introduction and background to the research study.

Chapter 2 provides a summary of the relevant international research conducted, alongside an examination of the ramp terminal geometry and configurations utilized in Sri Lankan expressways.

Chapter 3 outlines the methodology employed to achieve the scope of the research.

Chapter 4 presents the research findings and analysis.

Chapter 5 outlines the proposed improvements for the acceleration lane.

Chapter 6 concludes the study and provides recommendations.

## CHAPTER 2

### LIERATURE REVIEW

An important component of the ramp design is the merging area, often known as the entrance ramp terminal. The merging area is where drivers decide to merge and enter the expressway.

There are numerous tasks involved in the merging process to the expressways. A number of actions must be completed by the driver throughout the merging process, according to a study on the driver behaviour model of merging. Although they are seamlessly combined by the driver, the duties are discrete actions that must be carried out in the right order in order for the merging manoeuvre to be successful. Those are:

1. Steering on ramp curve;
2. Moving from a ramp to a Speed Change Lane;
3. Increase Speed;
4. Looking for a gap; and
- 5(a).Moving from Speed Change Lane to Expressway or
- 5(b).Abort. [1]

These actions are shown in the Figure 2.1

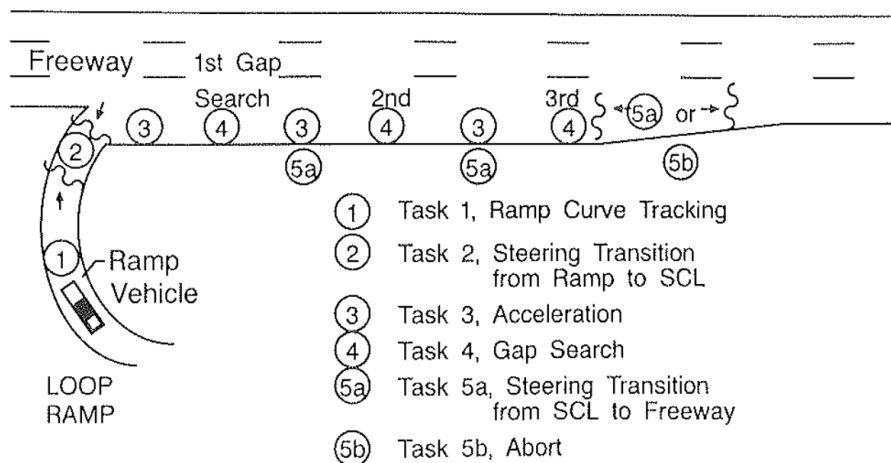


Figure 2.1 Components of Merge Manoeuvre

Source: Driver Behaviour Model of Merging [1]

The drivers' behaviour at expressway entrance ramps terminals can be assessed based on a number of variables as follows:

- Type of entrance ramp terminals;
- The location of the ramp terminal where drivers enter the expressway;
- Acceleration lane length;
- The speed of the vehicles entering the expressway through the ramp;
- The speed of the through traffic on the expressway; and
- The volume of traffic on the expressway and ramp, etc.

## **2.1 Types of Entrance Ramp Terminals**

The portion of a ramp that is adjacent to the main travel path, including speed-change lanes, tapers, and islands, is called the ramp terminal. Ramp terminals can be either the at-grade type or the free-flow type. Only free flow type ramp terminals are covered in this section. Based on the total number of lanes on the ramp, terminals are further classified as single-lane or multi-lane. Depending on how the speed-change lane is formed, they are further classified into parallel and taper types [2].

According to a study on the Potential Crash Risks of Expressway On-ramps and Off-ramps, it was discovered that the frequent lane changes and merging operations are mostly responsible for the disparities in risks. In comparison to other lanes and portions, median lanes and sections after acceleration lanes have relatively higher risks [3].

According to a study on the Analysis of Driver Behavior Characteristics in Low Volume Freeway Interchange, the expressway's through traffic is influenced up to 350 meters from the merging point. [4]. Furthermore, it may be stated that the lane flow distribution changes 200 to 300m prior the gore and continues for a maximum of 500 meters after the gore according to the study on macroscopic traffic flow changes around ramps in Netherlands. It returns to a level that is similar to that on a typical expressway portion after 500m. The lane densities have returned to their prior level 900m downstream of the gore [5].

### 2.1.1 Taper - Type Entrance Ramp Terminal

The Figure 2.2 shows the taper type entrance terminal [2]

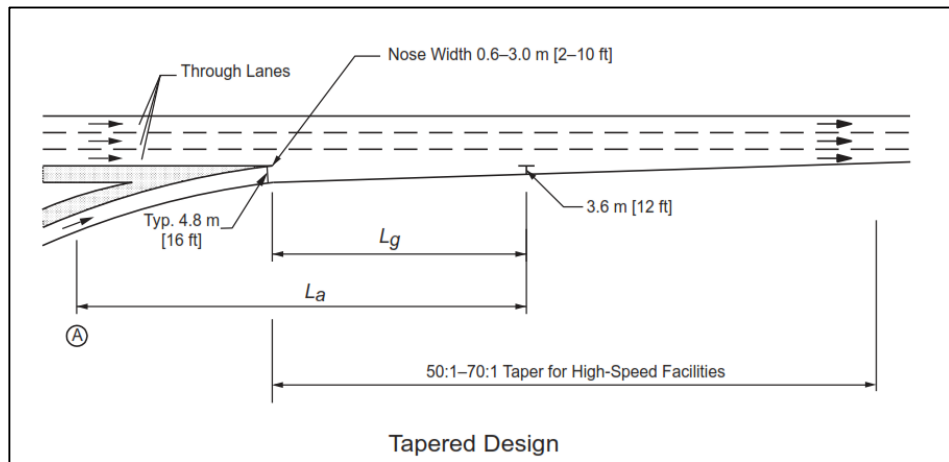


Figure 2.2 Taper Type Entrance Ramp Terminal

Source: AASHTO Green Book 2011

Long and uniform taper connects the entrance to the expressway. The outside margin of the acceleration lane and the edge of the through-traffic lane should taper off at a rate of about 50:1 to 70:1 (longitudinal to lateral), according to operational studies. In order to design taper-type entrances, the gap acceptance length,  $L$ , is also taken into consideration [2].

The taper-type entrance typically runs without any issues at all volumes up to and including the merging sections' design capacity. The entering driver can identify and take advantage of a gap in the through-traffic stream by only slightly adjusting speed [2].

### 2.1.2 Parallel - Type Entrance Ramp Terminal

The Figure 2.3 shows the Parallel-type entrance terminal [2].

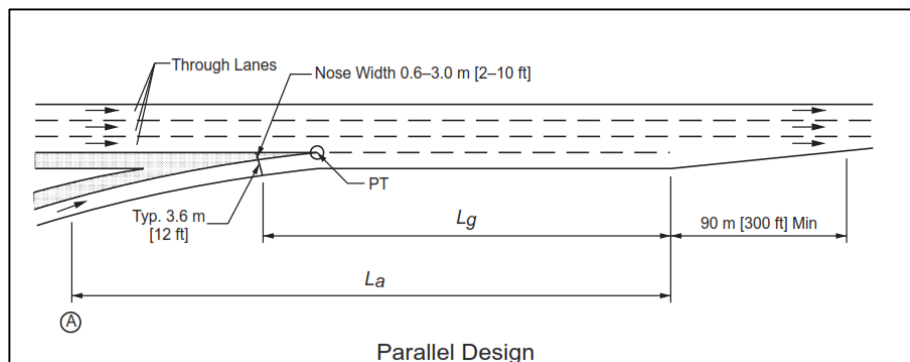


Figure 2.3 Parallel - Type Entrance Ramp Terminal

Source: AASHTO Green Book 2011

The parallel-type entrance provides an extra lane with sufficient length for a vehicle to reach up to nearly expressway speed before merging. A taper is provided at the completion of the additional lane. The procedure for entering the expressway is similar to changing lanes to the right. The side-view and rear-view mirrors allow the driver to keep an eye on surrounding traffic [2].

A curve having a radius of at least 300m and a length of at least 60m should be provided before the added lane. Whenever the curve radius is small, motorists frequently bypass the acceleration lane and enter the expressway directly. Because of this behavior, undesired merging operations occur. A parallel-style acceleration lane's downstream taper should be long enough to gradually guide the vehicle onto the expressways through lane. A taper length of approximately 90m is appropriate for design speeds up to 110km/h [2].

The length of a parallel-type acceleration lane is typically calculated from the point where the left edge of the ramp's traveled way joins the expressway's traveled way to the start of the downstream taper. Acceleration develops along the ramp before connecting with the expressway in the case of the taper-type entry, but it typically develops downstream from this point in the case of the parallel-type entrance [2].

However, a portion of the ramp proper may also be taken into account when calculating acceleration length if the curve immediately prior to the acceleration lane has a long radius of at least 300m and the driver on the ramp has an unobstructed view of traffic on the expressway to their right. Table 2.1 lists the minimum acceleration lengths for entrance terminals [2].

Long acceleration lanes provided by parallel-type entrances offer advantages in efficient traffic operations and low crash frequencies that are well known. A long acceleration lane gives the merging vehicles more time to find a gap in the through-traffic stream. Wherever the ramp and expressway are expected to carry traffic volumes nearly comparable to the design capacity of the merging area, a 360m long acceleration lane with a taper is preferred [2].

According to study on the safety evaluation of acceleration and deceleration lane lengths, minimum acceleration lane lengths are comparable to the minimum lengths recommended by AASHTO from both a safety and economic perspective [6].

Table 2.1 Acceleration Lane Lengths

Metric									
Acceleration Length, $L$ (m) for Entrance Curve Design Speed (km/h)									
Highway		Stop Condition	20	30	40	50	60	70	80
Design Speed, $V$ (km/h)	Speed Reached, $V_a$ (km/h)	and Initial Speed, $V'_a$ (km/h)							
		0	20	28	35	42	51	63	70
50	37	60	50	30	—	—	—	—	—
60	45	95	80	65	45	—	—	—	—
70	53	150	130	110	90	65	—	—	—
80	60	200	180	165	145	115	65	—	—
90	67	260	245	225	205	175	125	35	—
100	74	345	325	305	285	255	205	110	40
110	81	430	410	390	370	340	290	200	125
120	88	545	530	515	490	460	410	325	245

Note: Uniform 50:1 to 70:1 tapers are recommended where lengths of acceleration lanes exceed 400 m.

Source: AASHTO Green Book 2011

### 2.1.3 Entrance Ramp Terminal Details of Expressways in Sri Lanka

Analysis of 15 interchanges on the Southern Expressway, Outer Circular Expressway, and Katunayake Expressway revealed that acceleration lane lengths varied from one interchange to another. This might occur as a result of different design standards being adopted in different projects. The lengths of the acceleration lanes are displayed in Table 2.2 together with other information, such as the types of interchanges, taper lengths, and deceleration lengths.

Table 2.2 Lengths of Acceleration Lanes with other Details

Name of Interchange	Kadawatha		Kaduwela		Kothalawala		Athurugiriya		Kottawa		Kahathuduwa		Galanigama	
Type of Interchange														
Cross Road	A 001		AB 10 & B 214		B 263		B 240		A 004		B 084		A 008	
Type of Ramp	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Acceleration/Deceleration Length	200	240	200	240	165	210	240	250	200	240	155	410	155	410
Length of Taper	120	60	120	60	85	50	110	60	110	60	100	90	100	90

Name of Interchange	Dodangoda		Welipanne		Kurudugah ahetekma		Baddegama		Pinnaduwa		Imaduwa		Weligama		Godagama	
Type of Interchange																
Cross Road	B 304		B 157		B 014		B 012		A 017		A 017		B 067		A 024	
Type of Ramp	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Acceleration/Deceleration Length	155	410	155	410	250	355	250	355	266	368	100	370	236	346	225	225
Length of Taper	100	90	100	90							155	90				

## 2.2 The Location of the Ramp Terminal where Drivers Enter the Expressway

In several nations, research on the use and driver behaviour of expressway ramp entrance and exit terminals have been conducted. The research performed in the city of Lebanon to assess how the Indiana Toll Road and Interstate 65's acceleration and deceleration lanes are used found that: a) A sizable proportion of the general population is unaware of how to appropriately use the lanes; and b) On Interstate 65, the acceleration or deceleration lanes traffic moves at a far slower rate than the traffic in the through lane [7]. Figure 2.4 depicts the vehicle entrance speeds and lateral placement of the left rear wheel at the North Bound entrance ramp on State Route 39 Interchange in Interstate 65 expressway.

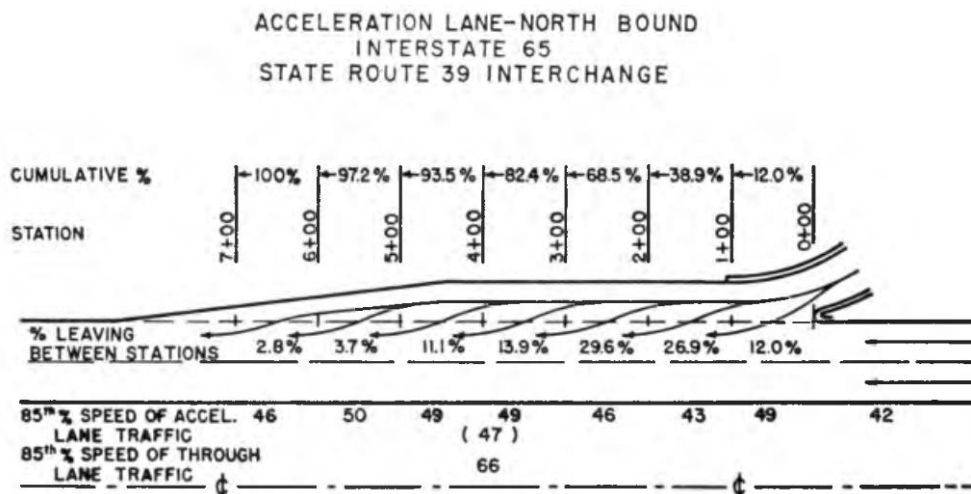


Figure 2.4 Speeds and Lateral Placement of Cars Path of Left Rear Wheel

Source: Use of Acceleration and Deceleration Lanes [7]

The extent of the time gap that merging ramp drivers accepted appeared to be mainly affected by the volume of traffic in the right-hand lane of the expressway [8].

The majority of drivers made it almost to the final stretch of the ramp with sufficient sight distance and velocity change length to merge into the outer lane of the expressway successfully. Drivers merged more forcefully just past the entry ramp gore to avoid becoming stranded at the end of the velocity change lane if a ramp had insufficient sight distance and/or acceleration lane length [8].

### **2.3 Length of the Acceleration Lane**

A major consideration while designing the expressway ramp terminal is the length of the acceleration lane. Prior to entering an expressway, drivers utilize the acceleration lane to increase their speed as much as possible closer to the expressway speed. Under "Types of Entrance Ramp Terminal," section 2.1, the design specifications and recommended length of the acceleration lanes have been addressed. The utilized lengths and associated problems in constructed expressways are more the emphasis of this section.

After the merge point, the driver needs 10–15 seconds to reach a stable traveling condition [4].

According to studies on the length of the acceleration and deceleration lanes on the ramp of the Qingdao-Yinchuan expressway in China, vehicles from the ramp to the mainline should accelerate to a particular speed for safety when merging with the expressway. Moreover, on the exit ramp, a vehicle's deceleration cannot affect the safety of the upstream through vehicles in order to ensure the safety of the diverging area. The ramp should therefore feature an auxiliary lane in addition to the acceleration and deceleration lanes for safety [9].

After gaining an unobstructed view of the moving traffic in the expressway's right lane, drivers tended to initiate the simultaneous acceleration/merge operation. If slopes, buildings, or barricades were blocking the ramp driver's view of the expressway's outer lane, acceleration did not begin until the view cleared near the ramp. The acceleration length before to the ramp gore is a significant portion of the acceleration length in the AASHTO acceleration length model for tapered entrance ramp terminals. The AASHTO model may give an inaccurate representation of the possible acceleration length if the driver's view is obscured before the ramp gore [8].

The operation was excellent on all of the ramps when the convergence angle was 30 degrees or less. It would seem that a desired design criterion would have a low (less than 50 or 60 degrees) convergence angle and a long (at least 215m) acceleration lane. Each of these ramps featured an acceleration lane of at least 215m in length (for the ramps under study, which had a 215m length, this distance was measured from the physical nose, which was roughly 0.6m from the pavement edge). The physical nose would be shifted back around 46m if a more preferable 0.3m offset were utilized, making 262m the ideal minimum acceleration lane length to be used with a 3m offset [10].

Very poor functioning was observed at every entrance ramp that had convergence angles of 100 degrees or more and/or acceleration lane lengths under 108m [10].

The operation on the descent ramps under study performed far better than would have been predicted based just on the acceleration lane length and convergence angle. Evidently, these ramps' improved field of vision enables ramp drivers to choose a gap while they are about 62m upstream of the nose, speed to catch up with it close to the nose, and join fast. As a result, some of the acceleration occurs before the physical nose, potentially reducing the requirement for an extended acceleration lane. Due to the presence of downhill entrance ramps, one may further conclude that a depressed expressway would provide greater merging performance than an at-grade or elevated expressway[10].

The regression analysis revealed several variables that significantly affected the distance travelled by vehicles prior to merging, including a) acceleration lane length, b) ramp length, c) relative effective grade between ramp and expressway, d) angle of convergence, e) ramp offset at the nose, and f) the sum of merging volume and speed. There were several factors that tended to reduce the distance that vehicles traveled when merging, including: 1) a shorter acceleration lane; 2) a longer ramp; 3) a lower relative effective grade; 4) a greater angle of convergence; 5) a smaller offset at the nose; and 6) a smaller product of merging volume and speed [10].

The general association between speed change lane length and collision frequency along the stretch implies that collisions decline as lane length increases [11]. The summary of acceleration lane lengths for 16 interchanges in Sri Lanka are shown in Table 2.3.

Table 2.3 Lengths of Acceleration Lanes

Interchange	Type of Ramp Terminal	Acceleration Length (m)
Kerawalapitiya	Parallel	200
Kadawatha	Parallel	240
Kothalawala	Parallel	210
Kaduwela	Parallel	240
Athurugiriya	Parallel	250
Kottawa	Parallel	240
Kahathuduwa	Parallel	410
Galanigama	Parallel	410
Dodangoda	Parallel	410
Welipanne	Parallel	410
Kurudugahahetekma	Taper	355
Baddegama	Taper	355
Pinnaduwa	Taper	368
Imaduwa	Parallel	370
Weligama	Taper	346
Godagama	Parallel	225

## 2.4 The Speed of the Vehicles Entering the Expressway through the Ramp

The drivers should accelerate their speed to be equivalent to or significantly closer to the speed of the expressway before entering it, as mentioned in Paragraph 2.3. The drivers should accelerate their speed to be equivalent to or significantly closer to the speed of the expressway before entering it, as mentioned in Paragraph 2.3.

The study conducted in the city of Lebanon to evaluate the usage of acceleration and deceleration lanes on the Indiana Toll Road and Interstate 65 revealed that, even when the expressway's design speed was 110kmph, the average velocity of ramp drivers on all recorded entry ramps consistently exceeded 50% of the expressway's design speed. Consequently, designing entrance ramps for speeds slower than those at which drivers typically operate is inappropriate. Traffic volume appeared to have a greater impact on expressway right-hand lane time headways than complex ramp design elements [8].

Figure 2.5 shows the speed variation while entering the expressway through ramp at the Middlebury Interchange at Indiana Toll road.

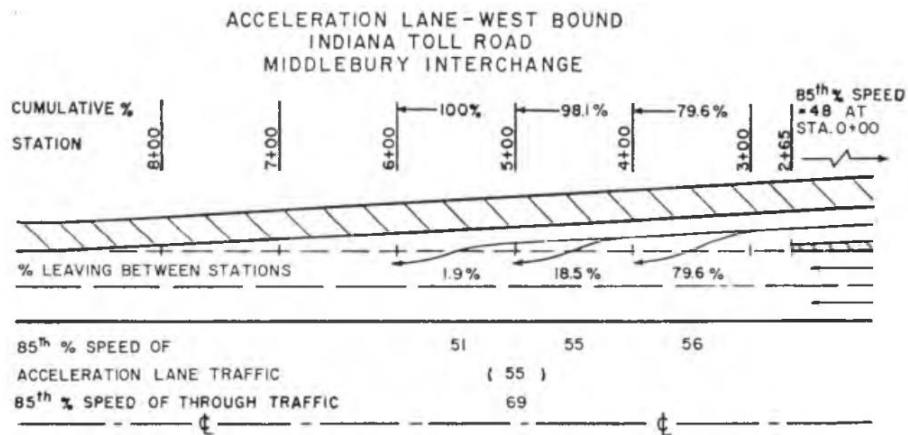


Figure 2.5 Speeds and Lateral Placement of Cars Path of Left Rear Wheel

Source: Use of Acceleration and Deceleration Lanes [7]

In accordance with a research conducted at five interchanges along the Qingdao-Yinchuan expressway, the operating speed from the beginning of the ramp to the end of acceleration is shown in Figure 2.6 [9].

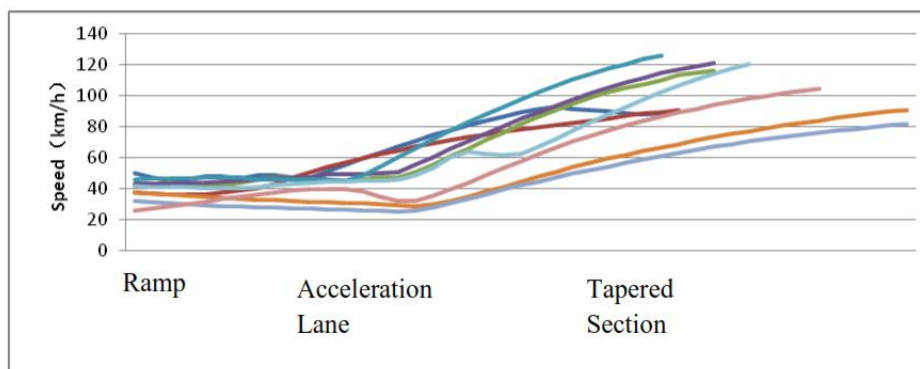


Figure 2.6 Operating Speed of the Entrance Ramp

Source Study on the Safety Length of Acceleration & Deceleration Lane of Left Ramp on Freeway [9]

According to the Figure 2.6, the operating speed keeps the reasonably steady acceleration at the entry ramp. When changing lanes into the mainline, the operating speed becomes noticeably greater and increases to 100km/h.

Further, field observations in the study on using the VISSIM simulation model and the Surrogate Safety Assessment Model for estimating field measured traffic conflicts at expressway merge areas revealed that drivers would slow down their cars as they approached the ramp terminal to determine if there was a suitable gap in the

expressway mainline traffic. \*Then speed them up on the acceleration lane before merging into it [12].

## **2.5 The Speed of the Through Traffic on the Expressway**

The expressway's through lane traffic speed at the entrance ramp terminal is crucial when considering the required entrance speed through ramp into consideration. The speed of the vehicles entering through the ramp should roughly match the speed of the vehicles traveling through the expressway's outer through lane. This enables drivers to adopt the appropriate gap acceptance criterion while negotiating expressway traffic.

Where the ramp had sufficient sight distance and acceleration lane lengths, ramp vehicles had little impact on the inner lane speeds on expressways. Especially when there is heavy traffic on the expressways and ramps, inadequate sight distances and/or inadequate acceleration lane lengths frequently resulted in considerable reductions in expressway inner lane speeds [8].

According to the research done by Synthia Tagar and Srinivas S. Pulugurtha, increasing the imposed expressway speed limits may have an impact on some drivers' aggressive driving styles and ensure a generally uniform driving speeds. However, the results vary depending on the severity level, traffic, and the geometry of the entry ramp speed-change lane [13].

According to the field observations at the study on Using VISSIM Simulation Model and Surrogate Safety Assessment Model for Estimating Field Measured Traffic Conflicts at Expressway Merge Areas, vehicles traveling on the outside lanes of expressway mainlines occasionally make lane changes when vehicles from entrance ramps are approaching the ramp terminal. When the headway and gap time of the arriving vehicle on the ramp are less, the vehicle in the outside lane of the expressway will slow down and make a lane-change manoeuvre to move into the inner lane [12].

## **2.6 The Volume of Traffic on the Expressway and Ramp**

The number of lanes required on the expressway and ramp, the length of the acceleration lane terminal, the taper length, and other factors are significantly influenced by the volume of traffic on both the expressway and the ramp. Moreover, this volume determines the presence of gaps that enable vehicles to enter the expressway more safely. The interval between the successful entry of two vehicles into

the outer lane at a specific point in the merging area is termed a merging gap. The concept of gap acceptance plays a crucial role in defining how the flows of the expressway and the ramp interact. The ramp driver is assumed to measure each gap in the shoulder lane and decide whether to merge (accept the gap) or wait (reject the gap) [14]. According to Greenshields an acceptable average-minimum time gap is one that is accepted by 50% of the drivers [21].

More precisely, it can be said that the headway distribution at the expressway's nose point of the entrance ramp terminal is the determining element that permits vehicles coming from the ramp to enter the expressway through lane. Due to ramp design, the right lane expressway headways were affected least noticeably. The distribution of headways appears to be mostly influenced by expressway volume [8].

According to the study on traffic behaviour and ramp design, there is little difference in wheel paths for increasing expressway volumes with any given ramp volume. This fact does not necessarily imply that expressway volume is unimportant for deciding ramp length, but it does imply that when appropriate length is available, it will be used during both light and heavy volumes. Additionally, the same study's unexpected finding was that the length of the ramp used decreased as the ramp volume increased [15].

According to what was previously described, the expressway traffic volume is crucial for a proper and secure merging on to expressway through the entrance ramp terminal.

## CHAPTER 3

### METHODOLOGY

#### 3.1 Methodology Adopted for Interchanges

As a first step, the literature that is currently accessible was reviewed to determine how drivers behave at interchange entrance ramps in various countries in relation to ramp speed, vehicle entry zone, expressway through traffic speed, and expressway traffic volume.

Six interchanges, namely Kerawalapitiya, Kothalawala, Kottawa, Gelanigama, Pinnaduwa, and Godagama, were selected for the research from a review of 16 interchanges on all of Sri Lanka's expressways, excluding the central expressway. These interchanges were selected after taking into account the various acceleration lengths and ramp terminal types.

Secondly, the Closed-Circuit Television (CCTV) data were collected from the Expressway Operation Maintenance & Management Division, RDA for the Kottawa Interchange entrance ramp towards the Kadawatha direction on 27 February 2020. The entire entrance ramp terminal was covered by CCTV camera at Kottawa Interchange. Since there was no CCTV camera available at the other five Interchanges, a drone survey was carried out in those locations on 14 October 2020.

The video footage was analyzed by dividing it into frames at the end of each second. With this frame count, the time taken to cover a predetermined distance was computed. As the lane markings on the entrance ramp are standardized in Sri Lanka, distances along the lane markings are known. Using these measurements, the speeds of vehicles on both the ramp and through lanes of the expressway were calculated based on the two sets of data mentioned above.

As illustrated in Figure 3.1, the entrance ramp terminal divided into five zones based on the configuration of the entrance ramp to facilitate data analysis. The number of vehicles entering the expressway was counted at each zone. When counting vehicles for each zone, the placement of the vehicle's left rear wheel as it passes the give way lane marking was taken into consideration.

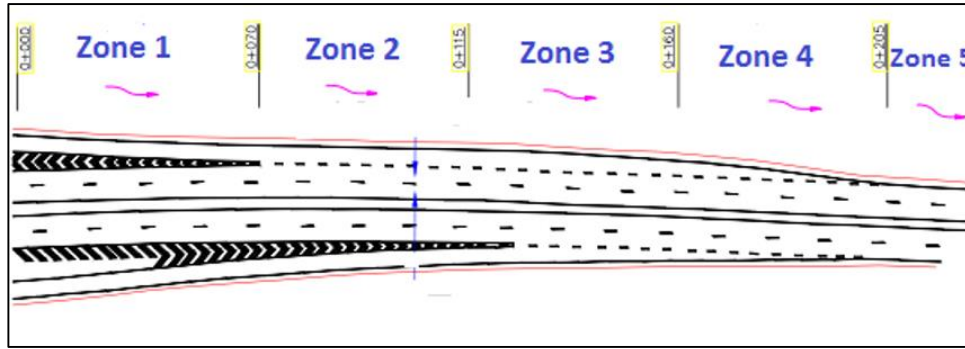


Figure 3.1 Zone Arrangement for Entrance Ramp Terminal

Zone identification for parallel-type ramp was as follows:

1. Zone 1: Chevron area;
2. Zone 2: Acceleration lane (First half of the Acceleration lane);
3. Zone 3: Acceleration lane (Second half of the acceleration lane);
4. Zone 4. Taper of the acceleration lane; and
5. Zone 5: Shoulder of the Expressway.

Zone identification for taper type ramp was as follows:

1. Zone 1: Chevron area;
2. Zone 2: Acceleration lane (First one third of the acceleration lane);
3. Zone 3: Acceleration lane (Second one third of the acceleration lane);
4. Zone 4. Acceleration lane (Third one third of the acceleration lane); and
5. Zone 5: Shoulder of the Expressway.

## 3.2 Questionnaire Survey

Two questionnaire surveys were conducted as part of this study to determine the best signboard placement for the entrance ramp and to learn more about the drivers' knowledge of the entrance speed and the entry zone to the expressway through the entrance ramp terminal.

### 3.2.1 Questionnaire Survey 1

In order to address the low speed of entrance vehicles, a survey was conducted among the Design Engineers and who are involving in the field of Geometric Design of roads in Sri Lanka to choose the appropriate signboard arrangement at the entrance ramp terminal. The questionnaire and its results are attached in the Appendix A & B.

### 3.2.2 Questionnaire Survey 2

The second questionnaire survey was conducted to investigate drivers' knowledge of the expressway's entry speed and entry zone. The survey was designed to cover a wide range of driver characteristics such as age, education level, experience and geographic location. The questionnaire and its results are attached in the Appendix C&D.

Flow chart of the research methodology is shown in the Figure 3.2

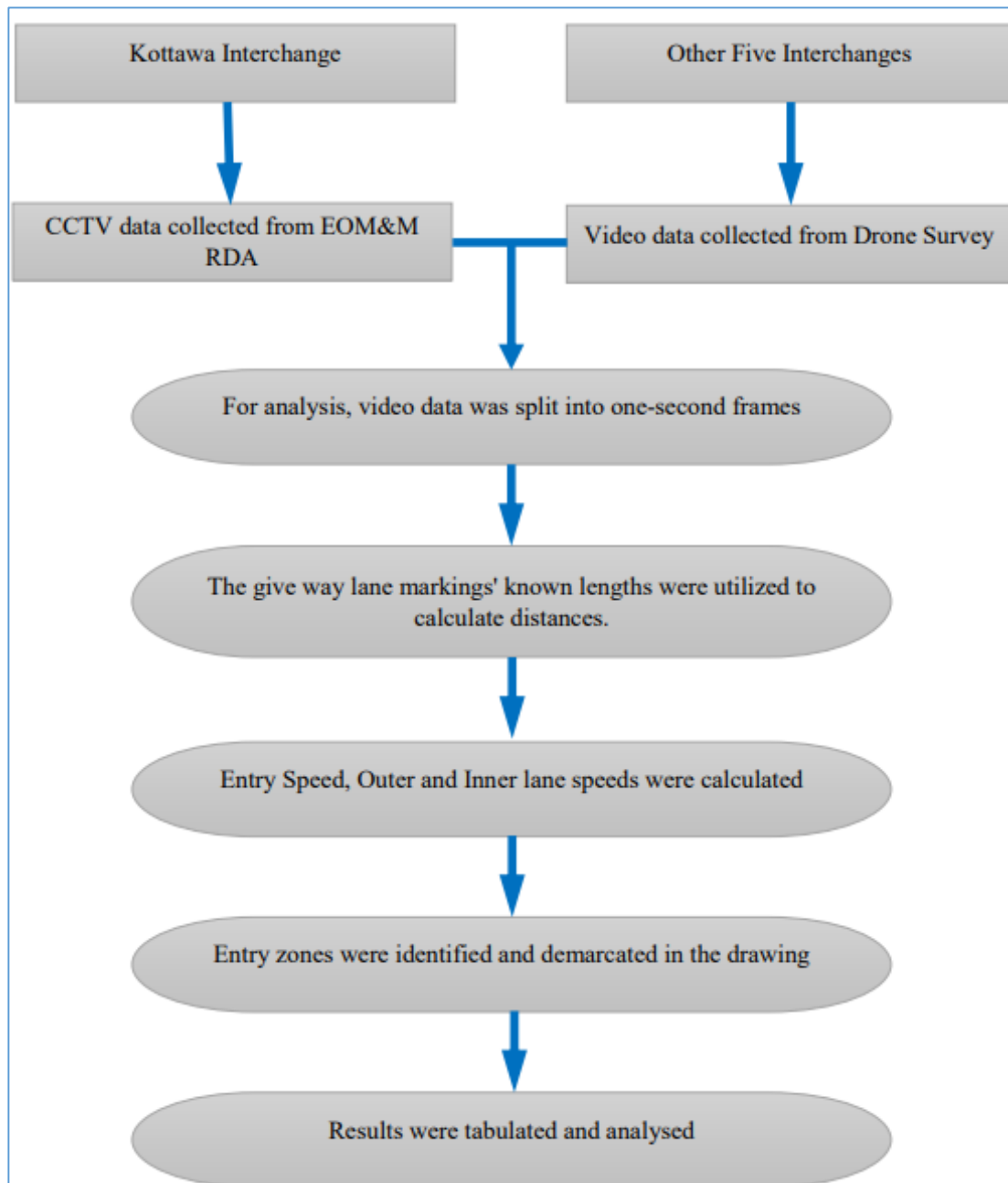


Figure 3.2 Flow Chart for Research Methodology

## CHAPTER 4

### RESULTS AND ANALYSIS

The Table 4.1 summarizes the results of video footage analysis for various interchanges. For the analysis, the following operational features were considered:

1. The location of the ramp terminal where drivers enter the expressway (lateral placement of vehicles path) – Entry Zone;
2. The speed of the vehicles entering the expressway through the ramp – Entry Speed;
3. The speed of the through traffic (Inner and outer lanes) on the expressway;
4. Acceleration Lane Length;
5. Headway distribution at the nose point of the expressway outer lane;
6. Speed of vehicles based on vehicle categories and types by visual observations; and
7. Speed of vehicles based on the condition of the vehicle by visual observations.

This section discusses the various combinations of the aforementioned factors in order to gain a clear understanding of the driver behavior at the entrance ramp terminal on Sri Lankan Expressways.

#### **4.1 Entry Speed, Entry Zone, Flow Rate and Speed of the Vehicles at Ramp and Through Lanes**

This section graphically depicts the lateral placement of vehicles entering the expressway's outer lane from ramps, as well as the speed and flow rate of vehicles traveling through ramps and expressway through lanes.

Table 4.1 Summary of Entry Zone, Entry Speed and Through Lanes Flow Rate

Interchange Name		Kerawalapitiya (E 02-1)	Kothalawala (E 02-3)	Kottawa (E 01-1)	Gelanigama (E 01-3)	Pimaduwa (E 01-08)	Godagama (E 01-11)	Average Speed & Total %
Outer Lane	Speed(kmph)	86	74	84	82	95	83	84
	Flow Rate (Veh/hr)	194	565	478	297	140	42	
Inner Lane	Speed(kmph)	108	87	98	94	100	99	98
	Flow Rate (Veh/hr)	33	453	427	92	156	16	
Entry Ramp	Entry Speed(kmph)	55	51	54	55	67	78	60
	Flow Rate (Veh/hr)	270	176	517	204	144	120	
Percentage Entry to the Expressway	Zone 1 (%)	0	1	0	8	0	27	6
	Zone 2 (%)	15	7	12	14	36	34	20
	Zone 3 (%)	22	21	26	28	61	27	31
	Zone 4 (%)	63	71	42	50	3	12	40
	Zone 5 (%)	0	0	20	0	0	0	3

#### 4.1.1 Kerawalapitiya Interchange

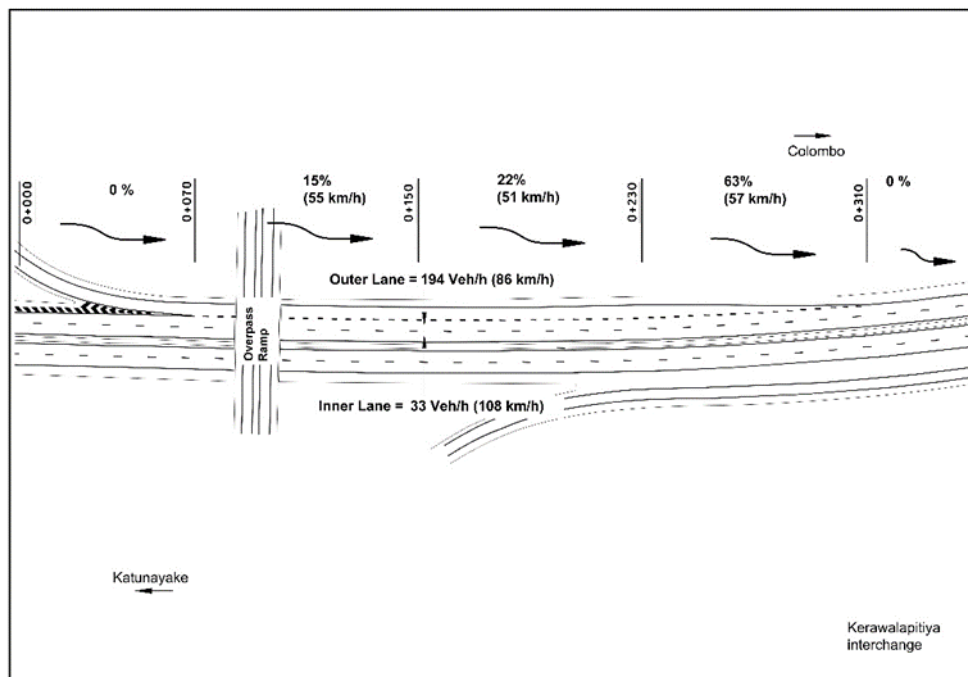


Figure 4.1 Entry Zone, Ramp Speed and Through Lane Flow Rate of Kerawalapitiya Interchange

Kerawalapitiya Interchange for southbound traffic was the first acceleration ramp terminal studied. This ramp terminal is of the parallel-type. The majority of acceleration lane vehicles, 63%, merged into the through lane at an average speed of 57kmph within Zone 4. This implies that the majority of drivers did not use the acceleration lane as intended. The following highest percentage, 22%, entered the through lane at an average speed of 51kmph within Zone 3. The remaining vehicles, 15%, entered the through lane at an average speed of 55kmph within Zone 2.

The average speed of the vehicles passing through the entrance ramp was 55kmph. Within the conflict area, the average speed of the outer through lane traffic was 86kmph. In this area, the speed difference between ramp traffic and through lane traffic was 31 kmph (86-55). The difference is substantial.

The outer lane traffic flow rate was 194veh/hr, while the inner lane traffic flow rate was 33veh/hr. The average speeds of the two lanes were 86 and 108kmph, respectively. The Figure 7 shows the percentage entries at each zone with other details.

#### 4.1.2 Kothalawala Interchange

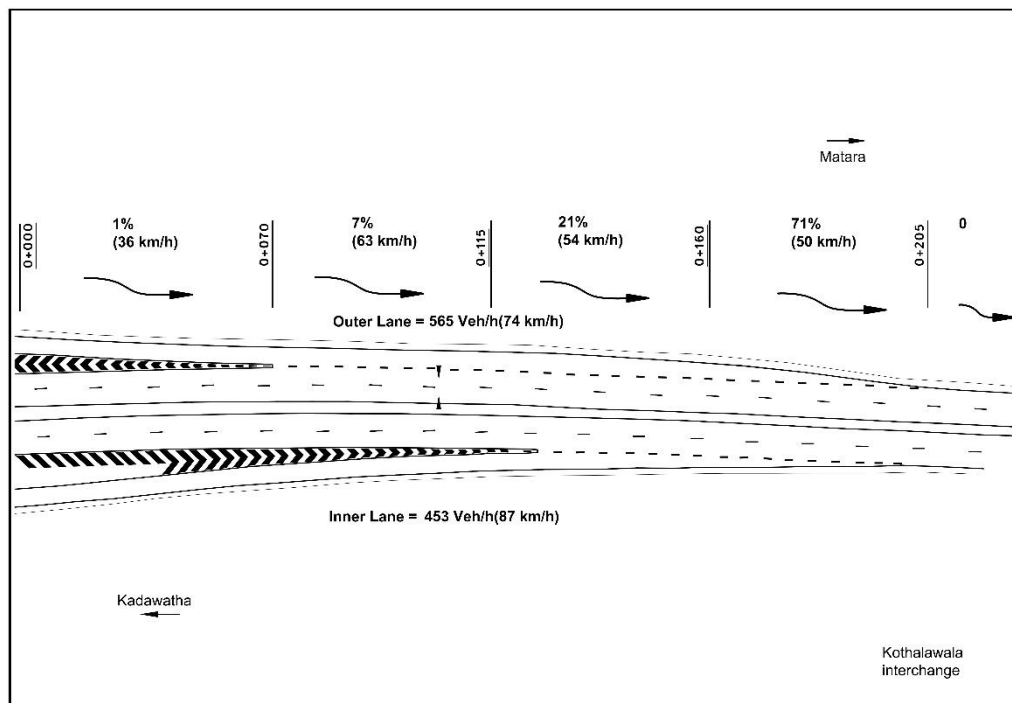


Figure 4.2 Entry Zone, Ramp Speed and Through Lane Flow Rate of Kothalawala Interchange

Kothalawala Interchange for southbound traffic was the second acceleration ramp terminal studied. This ramp terminal is of the parallel-type. The majority of acceleration lane vehicles, 71%, merged into the through lane at an average speed of 50kmph within Zone 4 same as Kerawalapitiya Interchnage entrance ramp. This again justify that the majority of drivers did not use the acceleration lane as intended. The following highest percentage, 21%, entered the through lane at an average speed of 54kmph within Zone 3. Then the 7% of vehicles entered the through lane within Zone 2 at the speed of 63kmph. The remaining small portion of vehicles, 1%, entered the through lane at an average speed of 36kmph within Zone 1. Despite the fact that this Figure was lower, it again indicates poor diver behaviour at the entrance ramp terminal.

The average speed of the vehicles passing through the entrance ramp was 51kmph. Within the conflict area, the average speed of the outer through lane traffic was 74kmph. In this area, the speed difference between ramp traffic and through lane traffic was 23kmph (74-51). This difference is substantial.

The outer lane traffic flow rate was 565veh/hr, while the inner lane traffic flow rate was 453veh/hr. The average speeds of the two lanes were 74 and 87kmph, respectively.

#### **4.1.3 Kottawa Interchange**

Kottawa Interchange for northbound traffic was the third acceleration ramp terminal studied. This ramp terminal is of the parallel-type. The majority of acceleration lane vehicles, 42%, merged into the through lane at an average speed of 51kmph within Zone 4 same as Kothalawala Interchange entrance ramp. This again confirm that the majority of drivers did not use the acceleration lane as intended. The following highest percentage, 26%, entered the through lane at an average speed of 57kmph within Zone 3. Then the 12% of vehicles entered the through lane within Zone 2 at the speed of 46kmph. Surprisingly, the remaining significant portion of vehicles, 20%, entered the through lane at an average speed of 56kmph within Zone 5, which is outside the allowable entrance area. In other words, nearly 20% of drivers enter the expressway through the expressway shoulder.

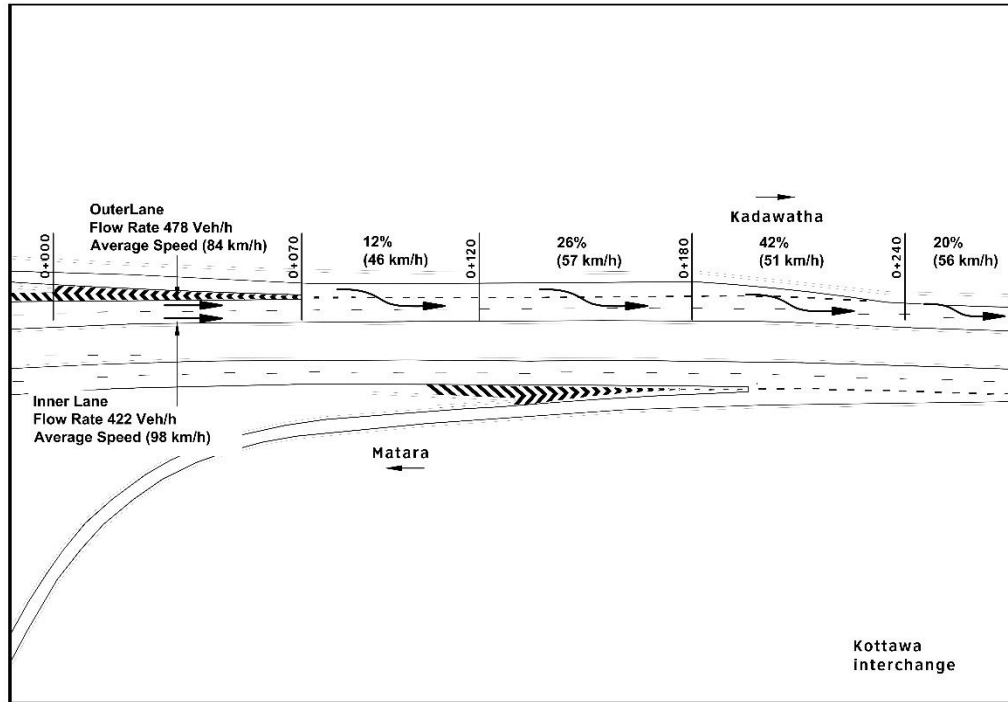


Figure 4.3 Entry Zone, Ramp Speed and Through Lane Flow Rate of Kottawa Interchange

Kottawa Interchange for northbound traffic was the third acceleration ramp terminal studied. This ramp terminal is of the parallel-type. The majority of acceleration lane vehicles, 42%, merged into the through lane at an average speed of 51kmph within Zone 4 same as Kothalawala Interchange entrance ramp. This again confirm that the majority of drivers did not use the acceleration lane as intended. The following highest percentage, 26%, entered the through lane at an average speed of 57kmph within Zone 3. Then the 12% of vehicles entered the through lane within Zone 2 at the speed of 46kmph. Surprisingly, the remaining significant portion of vehicles, 20%, entered the through lane at an average speed of 56kmph within Zone 5, which is outside the allowable entrance area. In other words, nearly 20% of drivers enter the expressway through the expressway shoulder.

The average speed of the vehicles passing through the entrance ramp was 54kmph. Within the conflict area, the average speed of the outer through lane traffic was 84kmph. In this area, the speed difference between ramp traffic and through lane traffic was 30kmph (84-54). The difference is substantial.

The outer lane traffic flow rate was 478veh/hr, while the inner lane traffic flow rate was 422veh/hr. The average speeds of the two lanes were 84 and 97kmph, respectively.

#### 4.1.4 Gelanigama Interchange

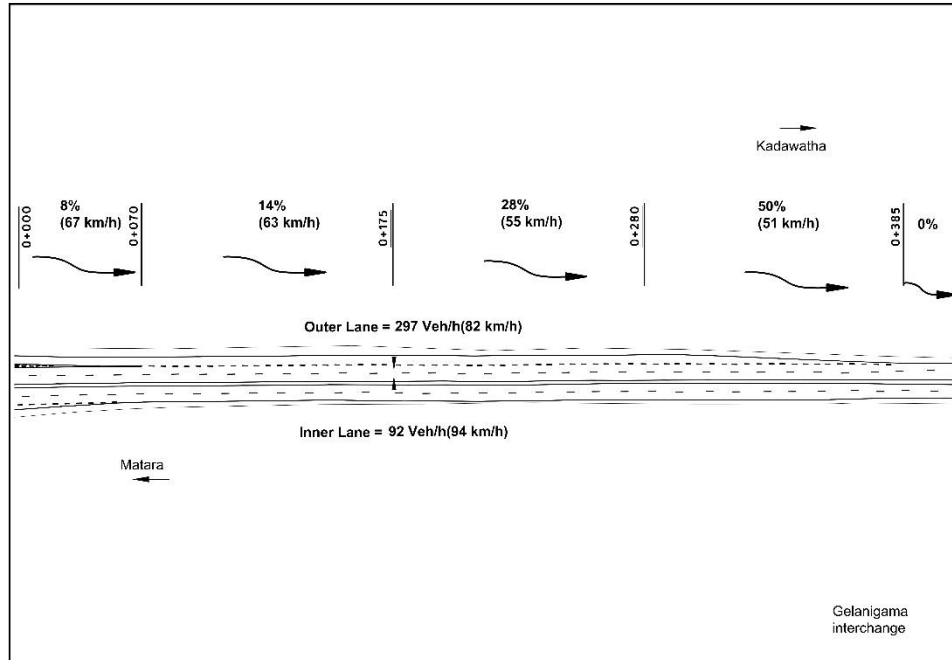


Figure 4.4 Entry Zone, Ramp Speed and Through Lane Flow Rate of Gelanigama Interchange

Gelanigama Interchange for northbound traffic was the fourth acceleration ramp terminal studied. This ramp terminal is of the parallel-type. The majority of acceleration lane vehicles, 50%, merged into the through lane at an average speed of 51kmph within Zone 4 same as Kottawa Interchange entrance ramp. This again justify that the majority of drivers did not use the acceleration lane as intended. The following highest percentage, 28%, entered the through lane at an average speed of 55kmph within Zone 3. Then the 14% of vehicles entered the through lane within Zone 2 at the speed of 63kmph. The remaining significant portion of vehicles, 8%, entered the through lane at an average speed of 67kmph within Zone 1. Because this Figure was significant, it confirms the poor diver behaviour at the entrance ramp terminal. The average speed of the vehicles passing through the entrance ramp was 55kmph. Within the conflict area, the average speed of the outer through lane traffic was 82kmph. In this area, the speed difference between ramp traffic and through lane traffic was 27kmph (82-55). The difference is substantial.

The outer lane traffic flow rate was 297veh/hr, while the inner lane traffic flow rate was 92veh/hr. The average speeds of the two lanes were 82 and 94kmph, respectively.

#### 4.1.5 Pinnaduwa Interchange

Pinnaduwa Interchange for northbound traffic was the fifth acceleration ramp terminal studied. This ramp terminal is of the taper type. The majority of acceleration lane vehicles, 61%, merged into the through lane at an average speed of 67kmph within Zone 3. The following highest percentage, 36%, entered the through lane at an average speed of 66kmph within Zone 2. The remaining small portion of vehicles, 3%, entered the through lane at an average speed of 79kmph within Zone 4. When considering the entry zone, this implies that the majority of drivers used the acceleration lane as intended at the Pinnaduwa Interchange northbound entrance ramp.

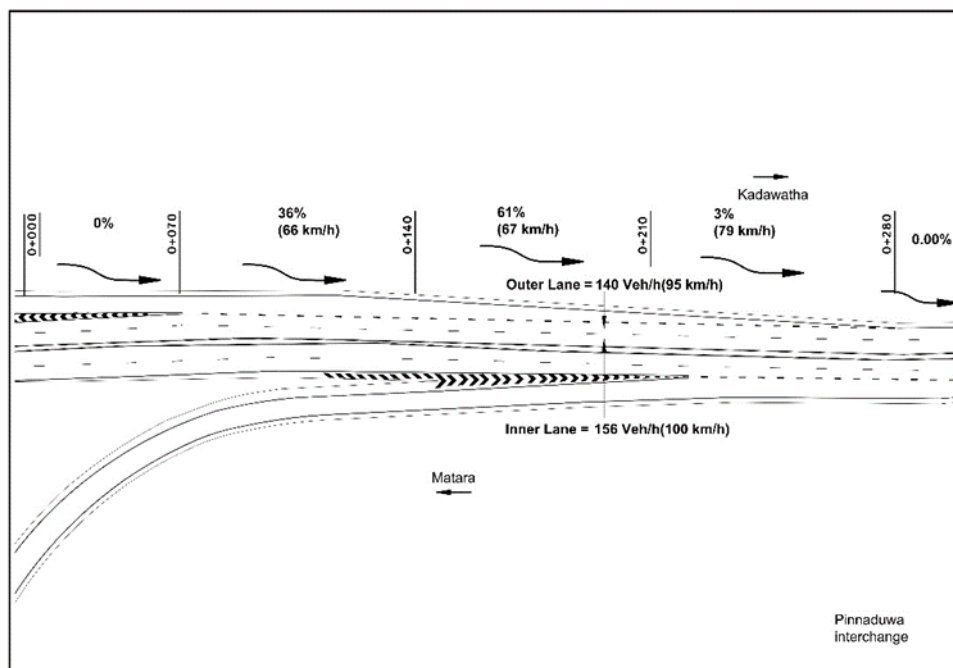


Figure 4.5 Entry Zone, Ramp Speed and Through Lane Flow Rate of Pinnaduwa Interchange

The average speed of vehicles passing through the entrance ramp was 67kmph, which was faster than any other entry speed considered. Within the conflict area, the average speed of the outer through lane traffic was 95kmph. In this area, the speed difference between ramp traffic and through lane traffic was 28kmph (95-67). The difference is substantial. The outer lane traffic flow rate was 140veh/hr, while the inner lane traffic

flow rate was 156veh/hr. The average speeds of the two lanes were 95 and 100kmph, respectively. These flow rate values differed from the through lane flow rates considered in other interchanges because the outside lane flow rate is higher than the inside flow rate in other locations. This could be because the drivers give way to vehicles coming through the ramps by changing their lanes from outside to inside. The Figure 8 shows the percentage entries at each zone with other details.

#### 4.1.6 Godagama Interchange

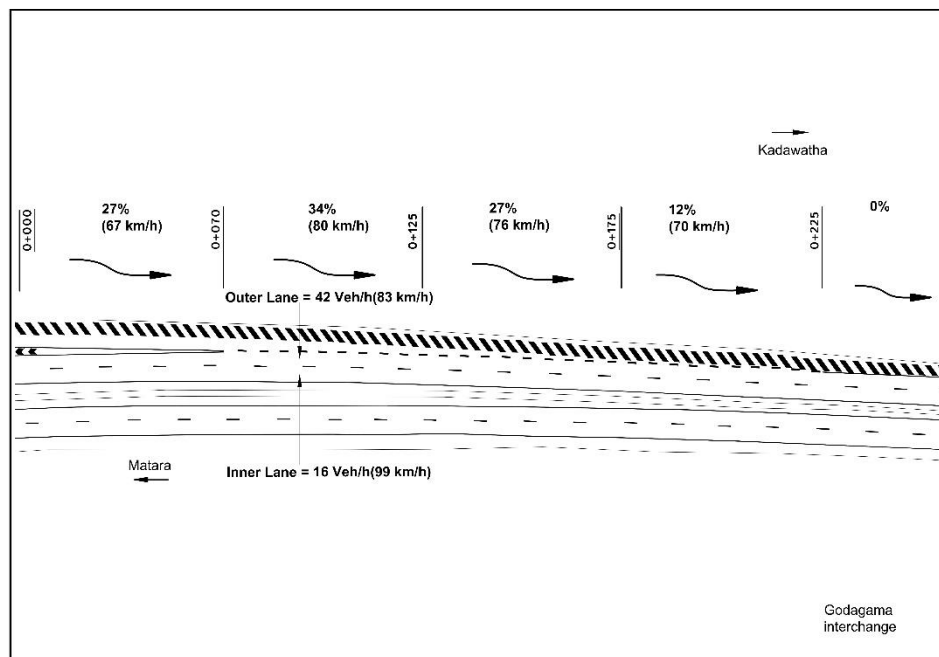


Figure 4.6 Entry Zone, Ramp Speed and Through Lane Flow Rate of Godagama Interchange

Godagama Interchange for northbound traffic was the sixth acceleration ramp terminal studied. This ramp terminal is of the taper type. The majority of acceleration lane vehicles, 34%, merged into the through lane at an average speed of 80kmph within Zone 2. The following highest percentage, 27%, entered the through lane at an average speed of 76kmph within Zone 3. Then the equal portion 27% of vehicles entered the through lane within Zone 1 at the speed of 67kmph. The remaining significant portion of vehicles, 12%, entered the through lane at an average speed of 70kmph within Zone 4. When considering the entry zone, this implies that the majority of drivers (61%) used the acceleration lane as intended at the Godagama Interchange Northbound entrance ramp.

The average speed of the vehicles passing through the entrance ramp was 78kmph. Within the conflict area, the average speed of the outer through lane traffic was 83kmph. In this area, the speed difference between ramp traffic and through lane traffic was 5kmph (83-78). The difference is substantial with compared to other interchanges. However, fastest entrance ramp speed was recorded at Godagama Interchange. The outer lane traffic flow rate was 42veh/hr, while the inner lane traffic flow rate was 16veh/hr. The average speeds of the two lanes were 83 and 99kmph, respectively. The highest ramp entry speed was recorded in this interchange, which could be attributed to the low traffic flow rate.

## 4.2 Entry Zone and Percentage Entry at Interchanges

Table 4.2 The percentage of Ramp Traffic Entering the Expressway via Different Zones at each Interchange.

Interchange Name	Percentage Entry to Expressway				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Kerawalapitiya (E02-1)	0	15	22	63	0
Kothalawala (E 02-3)	1	7	21	72	0
Kottawa (E 01-1)	0	12	26	42	20
Gelanigama (E 01-3)	8	14	28	50	0
Pinnaduwa (E 01-8)	0	36	62	3	0
Godagama (E 01-11)	27	33	27	12	0
Total %	6	19.5	31.1	40.2	3.2

According to Table 4.2, the percentages of vehicles entering the expressway from Zone 1 to Zone 5 were 6, 20, 31, 40, and 3, respectively. When considering individual zones the majority of vehicles (40%) enter the expressway via Zone 4, which is the taper length of the acceleration lane. This situation could be caused by a number of factors, including: 1) Due to the high traffic volume on the expressway, there were insufficient gaps to enter; 2) Drivers waiting to enter the expressway until they see the end of the acceleration lane; and 3) A lack of knowledge of how to properly use an expressway ramp terminal.

However, when the overall entry percentages are considered, 51% of the vehicles enter the expressway through Zones 2 and 3, which are the expressway's designated entry zones.

Interestingly, 9% of vehicles enter the expressway through undesigned or undesirable zones, with Zone 1 accounting for 6% and Zone 5 accounting for 3%. This demonstrates drivers' inability to use expressway ramp terminals appropriately.

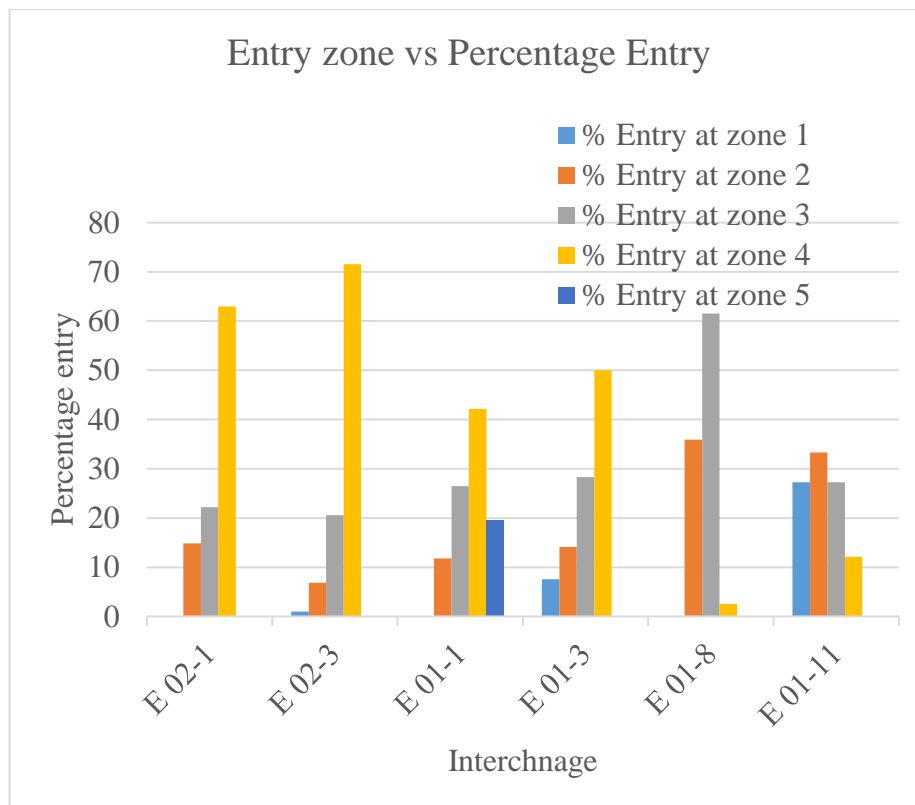


Figure 4.7 Entry Zone with the Percentage of Entry at each Interchnage

### 4.3 Vehicle Flow Rate at Interchanges

The highest flow rate of the outer lane is observed at the Kothalawala interchange, 565veh/hr, followed by the Kottawa Interchange, 478veh/hr. However, the entry ramp flow rate at Kottawa is significantly higher than at the other interchanges. The relationship between vehicle flow rates at different lanes in each interchange is shown in Table 4.3 and Figure 4.8.

Table 4.3 Summary of Vehicle Flow Rates

Interchange Name	Vehicle Flow Rate (Veh/hr)		
	Outer Lane	Inner Lane	Entry Ramp Ramp
Kerawalapitiya (E02-1)	194	33	270
Kothalawala (E 02-3)	565	453	176
Kottawa (E 01-1)	478	427	517
Gelanigama (E 01-3)	297	92	204
Pinnaduwa (E 01-8)	140	156	144
Godagama (E 01-11)	42	16	120

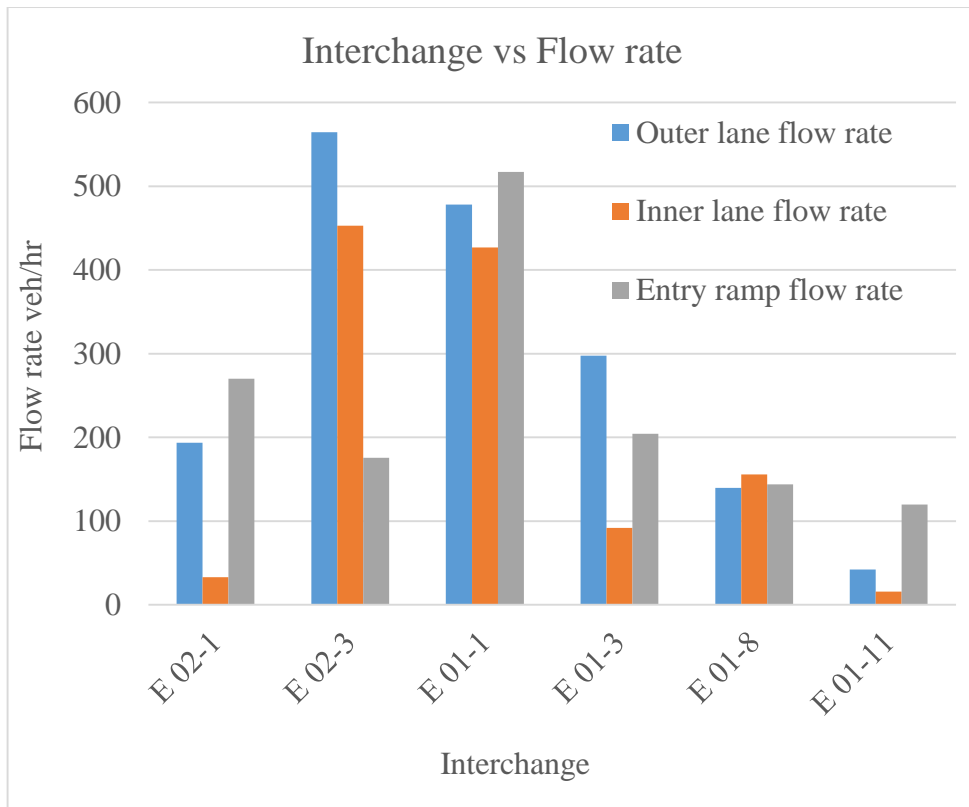


Figure 4.8 Vehicle Flow Rate at each Interchange

#### 4.4 Entry Speed and Length of the Acceleration Lane

The entry speed to the expressway should ideally increase as the acceleration length increases because drivers have more space to increase their speed. However, as

illustrated in Table 4.4 and Figure 4.9, no such relationship can be identified. This also demonstrates poor diver behaviour as they approach the expressway.

Table 4.4 Summary of Acceleration Lane Lengths and Entry Speed

Interchange Name	Entry Speed (kmph)	Length of Acceleration Lane (m)
Kerawalapitiya (E02-1)	55	200
Kothalawala (E 02-3)	51	210
Kottawa (E 01-1)	54	240
Gelanigama (E 01-3)	55	410
Pinnaduwa (E 01-8)	67	368
Godagama (E 01-11)	78	225

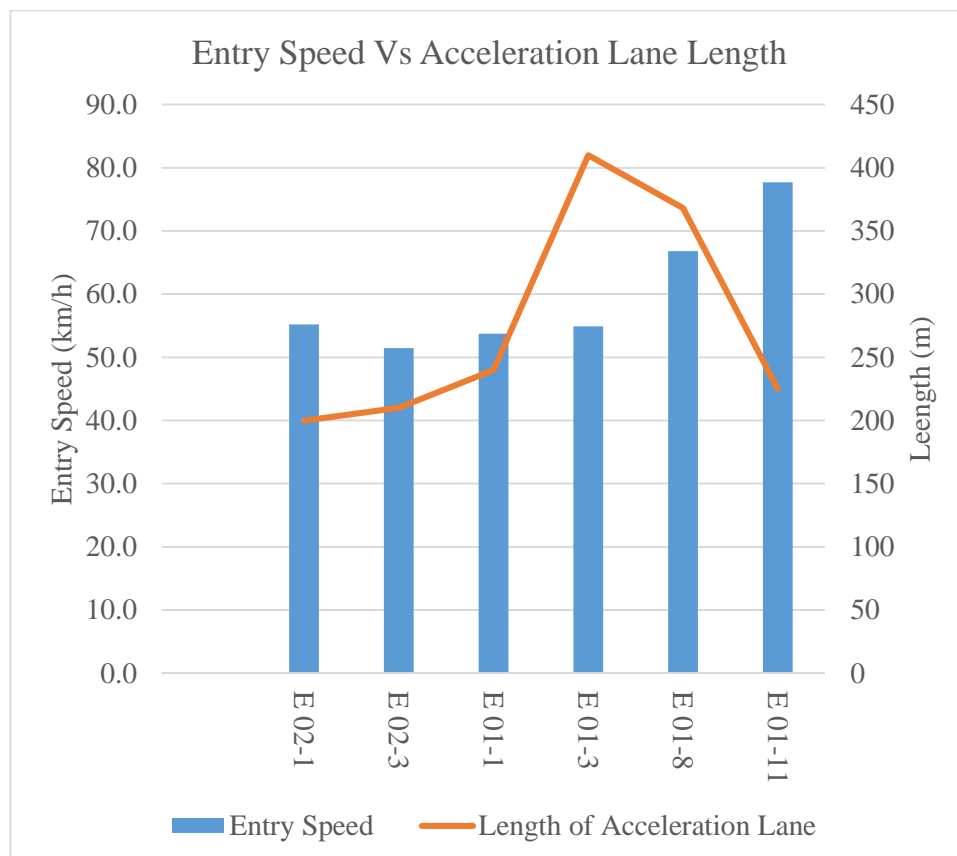


Figure 4.9 Entry Speed with the Acceleration Lane Length at each Interchange

## 4.5 Entry Speed and Expressway Outer Lane Speed

Ideally, the speed of the vehicles entering the expressway through the ramp should be somewhat similar to the speed of vehicles traveling in the expressway's outer lane. However, Graph 4.10 demonstrates that, with the exception of the Godagama interchange, there are significant variations in entry speed and outer lane's speed of the expressway.

Table 4.5 Summary of Acceleration Lane Lengths and Entry Speed

Interchange Name	Entry Speed (kmph)	Expressway Outer Lane Speed (kmph)
Kerawalapitiya (E02-1)	55	86
Kothalawala (E 02-3)	51	74
Kottawa (E 01-1)	54	84
Gelanigama (E 01-3)	55	82
Pinnaduwa (E 01-8)	67	95
Godagama (E 01-11)	78	83

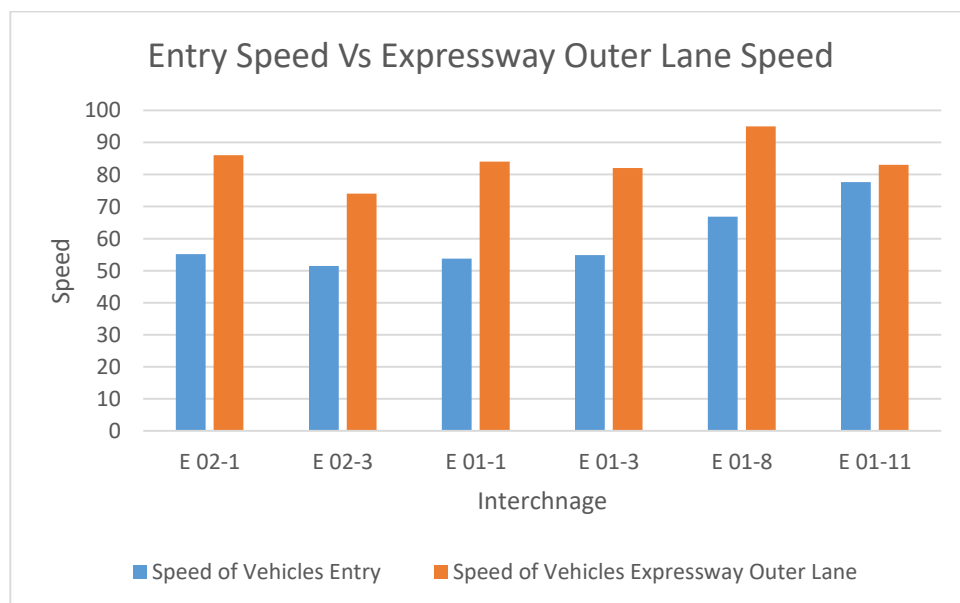


Figure 4.10 Entry Speed with the Acceleration Lane Length at each Interchange

## 4.6 Headway Distribution of the Expressway Outer Lane

The time headway of the expressway's outer lane at the nose point was calculated and plotted against the expressway's entry speed to determine the relationship between traffic volume and expressway entry speed. As shown in Table 4.6 and Figure 4.11, there is no clear relationship between outer through lane traffic and expressway entry speed. When the headway is increased, i.e. there is less traffic, the entry speed should be increased as well. However, the absence of the expected relationship in the study reveals that the drivers did not behave as expected.

Table 4.6 Average Headway and Entry Speed at each Interchange

Interchange Name	Average Headway (s)	Entry Speed (kmph)
Kerawalapitiya (E02-1)	19	78
Kothalawala (E 02-3)	6	67
Kottawa (E 01-1)	7	55
Gelanigama (E 01-3)	12	55
Pinnaduwa (E 01-8)	26	51
Godagama (E 01-11)	91	54

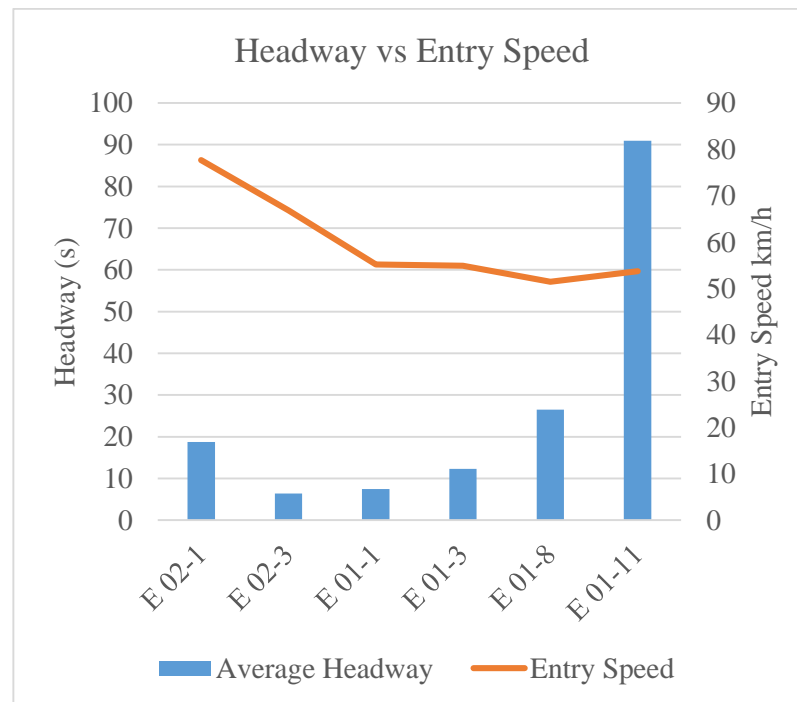


Figure 4.11 Headway with the Entry Speed at each Interchange

## 4.7 Speed of Vehicles based on Vehicle Categories

The average speed for each vehicle category is shown in Table 4.7 along with the speeds of the various vehicle categories at each interchange.

Table 4.7 Speed of Vehicles based on Condition of the Vehicle

Vehicle Category	Average Speed (kmph)
Bowser	52
Bus	58
Cab	54
Car	62
Container	65
Jeep	62
Lorry (B)	49
Lorry (M)	57
Lorry (S)	56
Van	58

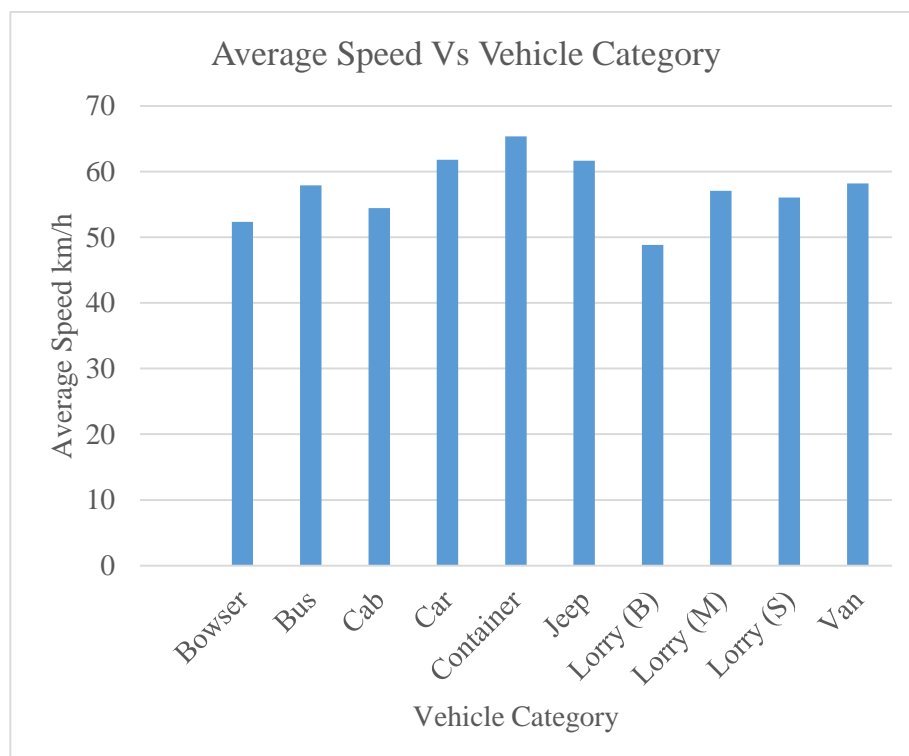


Figure 4.12 Average Speed with Vehicle Category

The Figure 4.12 shows the average speed for various types of vehicles, with cars, containers, and jeeps reaching the highest speeds.

## 4.8 Speed of Vehicles based on the Condition of the Vehicle

Vehicle was categorized in to new and old based visual observation. The speed of new vehicles was higher than the speed of old vehicles at all interchanges except Godagama, as shown in the Table 4.8 and Figure 4.13. This scenario is expected. The old vehicles, however, were traveling faster than the new ones at the Godagama interchange.

Table 4.8 Speed of Vehicles based on Condition of the Vehicle

Interchange/Condition of Vehicles	Speed of Vehicles	
	New	Old
Kerawalapitiya (E02-1)	57	49
Kothalawala (E 02-3)	52	51
Kottawa (E 01-1)	55	50
Gelanigama (E 01-3)	56	52
Pinnaduwa (E 01-8)	69	48
Godagama (E 01-11)	77	83

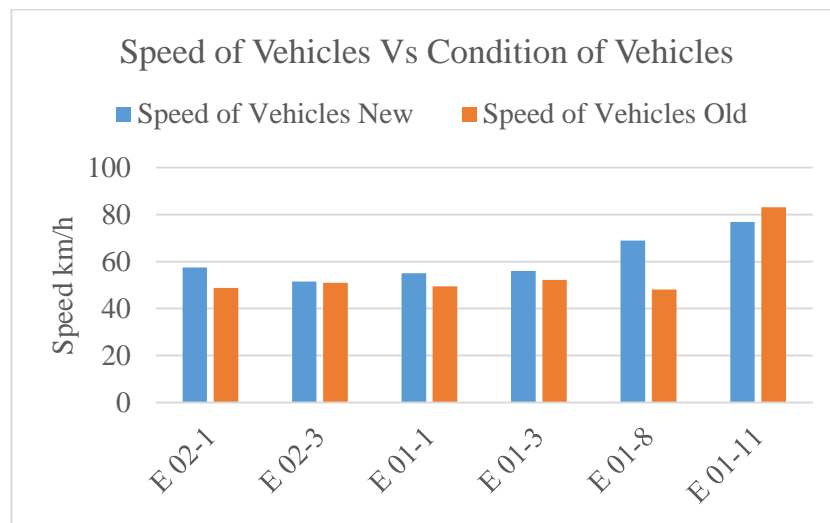


Figure 4.13 Speed with Condition of Vehicles

## 4.9 Questionnaire Surveys

Two questionnaire surveys were carried out, the first to enhance the performance of entrance ramp terminal usage, and the second to investigate drivers' knowledge of the expressway's entry speed and entry zone.

#### **4.9.1 Questionnaire Survey 1 – To Enhance the Performance of Entrance Ramp Terminal**

Traffic-flow theories among speed, flow, and headway describe the interactions among vehicles, drivers, and the infrastructure. It was identified that driver behaviour in the acceleration lane of the expressway can be describes on; (1) Acceleration length vs entry speed; (2) Headway vs entry speed; and (3) entry location. Drivers' decision made at different traffic conditions do not follow the traffic behaviour models in the selected interchanges.

In order to address the low speed of entrance vehicles and inconsistent use of acceleration lane to enter the expressway, a survey was conducted among the design engineers who are involving in the field of geometric design of roads in Sri Lanka to choose the appropriate sign board.

"Prepare for Expressway Speed" was considered the most suitable phrase for the signboard by the majority of the Design Engineers (40%) who participated in the survey.

Further, the majority (80%) suggested that speed variation signboards to be implemented. According to the survey's recommendations, the signboard configuration shown in Figure 5.1 has been suggested for implementation. The 100kmph signboard is already in place at the merge point. According to the available space, another two sign boards carrying 80kmph and 60kmph are proposed to be installed 60m apart. The questionnaire with the results is attached as Annexure 1.

#### **4.9.2 Questionnaire Survey 2 – Drivers Knowledge of Entry Zone and Speed**

The second questionnaire survey was conducted to investigate drivers' knowledge of the expressway's entry speed and entry zone.

##### **Entry Speed**

The drivers are entering at different speeds to the expressway as per the main study. According to the results obtained from the second questionnaire survey, it was confirmed that the drivers are preferred to enter the expressway at different speeds, which are not appropriate to enter an expressway. Figure 4.13 depicts the speeds at which drivers prefer to enter the expressway.

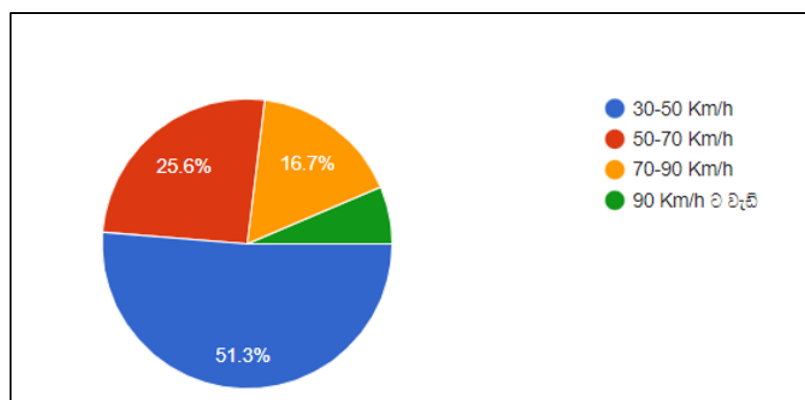


Figure 4.13 Entry Speeds to the Expressway According to the Second Questionnaire Survey

In Table 4.8, the results were tabulated against the results of the main study (video analysis results) for comparison.

Table 4.8 Percentage of Vehicles Enter Through Ramp Terminal with Different Speed Categories

Speed Range (kmph)	Percentage of Vehicles (%)	
	Main Study	Questionnaire Survey
Morethan 90	3	6
70-90	12	17
50-70	50	25
30-50	35	52

According to Table 4.8, the majority of drivers, 85% from the main study and 77% from the questionnaire survey, enter the expressway through the ramp terminal at speeds less than 70kmph, which is significantly lower than the desired speed range. The percentages of entrance speeds greater than 90kmph are only 3% and 6% in the main study and questionnaire survey, respectively, which is significantly lower than the expected value.

In contrast, in both the main study and the questionnaire survey, significantly higher percentages of vehicles (35% and 52%, respectively) entered the expressway at very low speeds of 30 to 50kmph, which is unacceptable. These statistics unequivocally

demonstrate that drivers did not understand how to enter the expressway when entry speed was taken into account.

### Entry Zone

The drivers are entering in different zones to the expressway as per the main study. According to the results obtained from the second questionnaire survey, it was confirmed that the drivers are preferred to enter the expressway at different zones, which are not appropriate to enter an expressway. Figure 4.14 depicts the zones at which drivers prefer to enter the expressway.

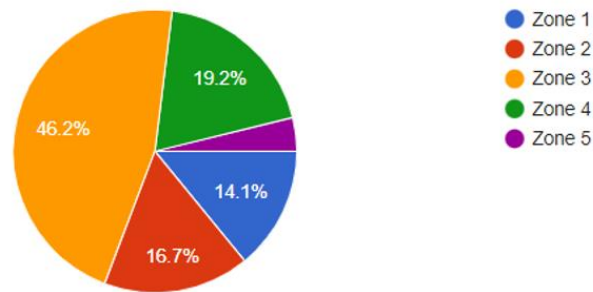


Figure 4.14 Entry Zones to the Expressway According to the Second Questionnaire Survey

In Table 4.9, the results were tabulated against the results of the main study (video analysis results) for comparison.

Table 4.9 Percentage Entry of Vehicles at each Zone

Entry Zone	Percentage of Vehicles (%)	
	Main Study	Questionnaire Survey
Zone 1	6	14
Zone 2	20	16
Zone 3	31	47
Zone 4	40	20
Zone 5	3	4

According to the Table 4.9, the percentage of vehicles entering the expressway in the proper zones, i.e. Zones 2 and 3, was 51% in the main study and 63% in the questionnaire survey. The 12% difference was substantial. The reason may be that, despite the fact that drivers would prefer to enter the expressway through these zones,

the expressway's existing traffic conditions prevent it. When both studies were considered, the entry percentages at the appropriate zones were significantly lower than the expected percentages, implying that drivers' lack of knowledge to enter the expressway through the ramp terminal.

Furthermore, the Table 4.9 shows that the zones that are not appropriate for expressway entry, namely Zones 1 and 5, had higher percentages, 9% and 18% in the main study and questionnaire survey, respectively. This confirms that the drivers were not fully aware of how to use the expressway ramp terminal properly.

## CHAPTER 5

### CONCLUSION AND RECOMMENDATIONS

According to the results of video analysis, the majority of drivers did not use the entrance ramp terminal as expected by the Design Engineers at the six interchanges where the study was conducted. A significant number of drivers did not use the designated location to enter the expressway at the ramp terminal, but instead entered through the entire length of the entrance ramp terminal as well as the expressway shoulder.

Furthermore, the speed of drivers entering the expressway through the entrance ramp was significantly lower than the expressway through lane speed. This was also not expected by the Designers. As a result, it can be concluded that a significant number of drivers did not understand the proper way to enter the expressway via the entrance ramp terminal.

The results of the research demonstrate that drivers' speeds, trajectories, and accelerations are not significantly affected by the acceleration lane length. Additionally, there is no correlation between the length of the acceleration lane and the zone where drivers enter the expressway.

The results of questionnaire survey 2 confirm that a substantial percentage of drivers do not know how to enter the expressway through an entrance ramp terminal.

The design engineers who participated in the questionnaire survey 1 recommended that additional signboards be installed to improve the performance of the entrance ramp terminal, as shown in Figure 5.1. Furthermore, it is recommended that television programs or printed media campaigns be conducted to improve drivers' knowledge of the proper entrance to the expressway via the ramp terminal.

It recommends carrying out further research to determine whether or not there has been an improvement in driver behaviour following the installation of the sign board arrangement depicted in Figure 5.1.



Figure 5.1 Proposed Sign Board Arrangement at Kottawa Interchange

## Appendix A – Questionnaire 1

### Selection of Suitable Sign Board for Entrance Ramp in Expressways in SriLanka

I am, Dhammika Ratiyala who is MEng student of University of Moratuwa. I am currently doing a research under the supervision of Prof. W. K. Mampearachchi regarding design consideration of entrance ramp of Expressways. Our initial investigation reveals that the speed of the vehicles when entering the expressway is very much less than the speed of expressway vehicles. This requires more gap between expressway vehicles and entering vehicles who enter from the acceleration lane to the Expressway. As such the drivers are not used the Ramp, Acceleration lane and merging area effectively as expected by the design engineers.

In order to address this problem, we have decided to educate the drivers at the entrance ramp by using suitable signboard as a first step. and monitor the performance after installation of the sign. Therefore, this survey is conducted among the Design Engineers and Experts who are involving in the field of Geometric Design of roads in Sri Lanka to choose the appropriate sign board from the listed wordings below. New wordings are also welcomed (if any). |

1. Please select the most appropriate signboard from the below five signboards.

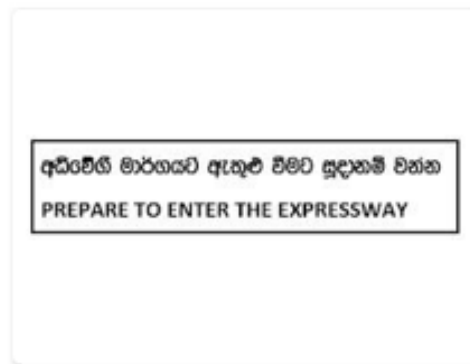
*Check all that apply.*



Option 1



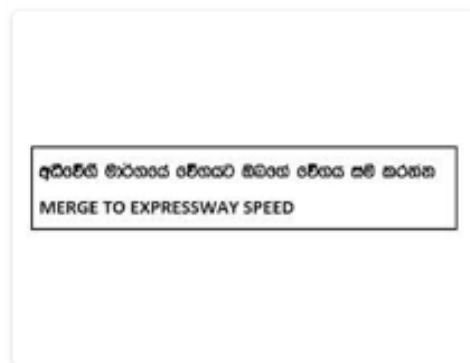
Option 2



Option 3



Option 4



Option 5

Other: \_\_\_\_\_

2. Are variable speed signboards required to place along the entrance ramp in order to inform the drivers to increase their speed gradually before entrance to the expressway such as 40kmph, 60kmph and 80kmph?

Mark *only one oval*.

No

Yes

3. What shall be the distance between two speed sign boards? Please note that following distances are recommended between two sign boards according to the Traffic Control Devices Part 1 which was published by the RDA in 2007 for general road applications

Travel Speed (km/h)	Clear visibility distance (m)	Distance from sign to hazard (m)
30	60	45
40	60	45
50	60	60
60	60	100
80	75	180

Mark *only one oval*.

40-50

50-60

60-70

70-80

80-100

Other: \_\_\_\_\_

4. Any suggestions?

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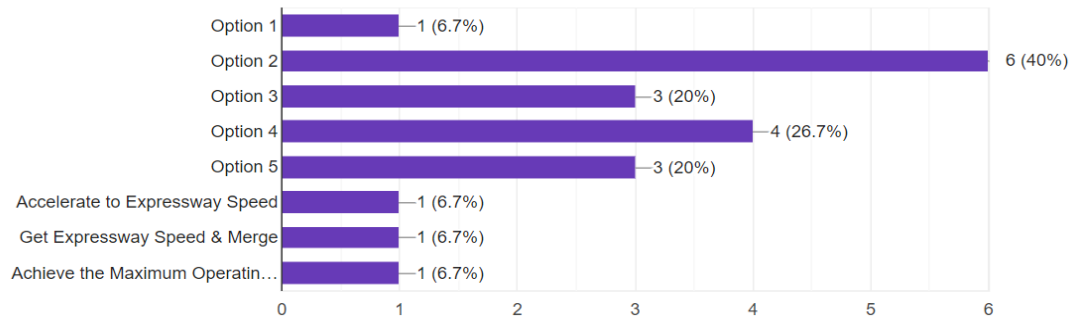
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Google Forms

## Appendix B – Answers for Questionnaire 1

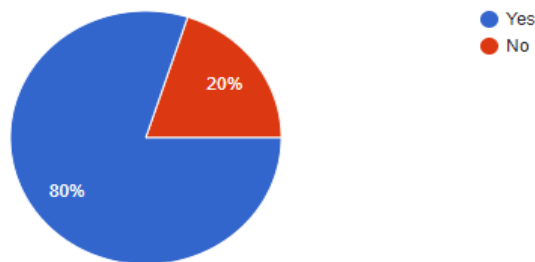
1. Please select the most appropriate sign board from the below 5 sign boards.

15 responses



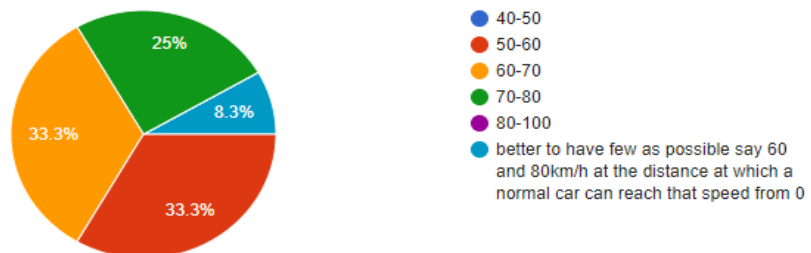
2. Are variable speed sign boards required to place along the entrance ramp in order to inform the drivers to increase their speed gradually before entrance to the expressway such as 40kmph, 60kmph and 80kmph?

15 responses



3. What shall be the distance between two speed sign boards? Please note that following distances are recommended between two sign boards according to the Traffic Control Devices Part 1 which was published by the RDA in 2007 for general road applications

12 responses



4. Any suggestions ? 9 responses

Another way is to install a speed gun and display the current speed, and flash speed up if it is lower and slow down if it is too fast.

Repeat the sign on ramp

1. Majority of vehicles in SL is old difficult to gain quick speed and most older drivers have slower reaction time, weak eye sight, difficulty to read signs, loss of confidence to accelerate, etc. Therefore, the length of the acceleration lane should be given prominence over ramp and determined using the higher side of the standards of RDA or AASHTO. OR even non-standard longer lengths of the acceleration lane as per the designers' engineering judgment for example; shorter ramp entrance.

2. Sign board with minimum amount of texts would be better given the fact that people reluctant to read text based sign board

Good luck! Better to add a question to get info on the background of the respondent. Experience in highway sector. Educational qualifications etc., so that you can gauge his responses.

Two Information Sign boards are proposed to place very close to toll booths and before end the entry ramp in order to read easily to the drivers.

Some drivers enter their vehicle to the expressway lane even at the beginning of acceleration lane (as soon they exit from ramp). This may they do not have idea about acceleration lane and entry speed to the expressway. Better educate drivers to utilize acceleration lane to develop required speed and then enter to expressway. Our people try to enter the expressway first and then try to achieve speed. "USE ACCELERATION LANE TO SPEED UP" to be educated.

This is a behavior issue of the drivers. Adding signboards to control the drivers behavior is not good. Improve the driver's knowledge rather than adding signboards would be the best option.

it is suggested to provide varying speed boards within acceleration region to provide smooth entering to the mainline from ramp. varying speed boards may help driver to direct accelerate the vehicle with specific rate which may make easy to enter mainline with the acceptable gap.

Implementation of such a education is very important for the drivers in Sri Lanka who are maintaining low discipline in driving. Also the Grade of the ramp and Type and Conditions play major role in the decision when setting the values for the parameters.

**Appendix C – Questionnaire 2**

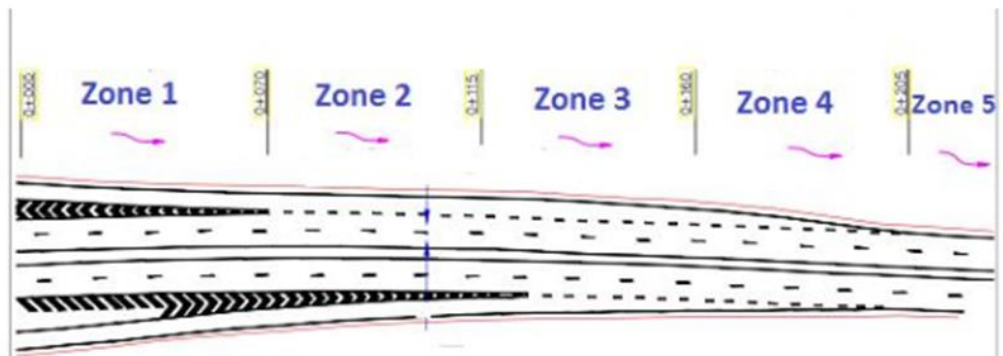
**ඔබ අධිවේගී මාර්ගයට පිවිසෙන්නේ කෙසේද?**

1. 01. අධිවේගී මාර්ගයට පිවිසීමේදී ඔබ ලබා ගන්නා වේගය කුමක්ද?

Mark only one oval.

- 30-50 Km/h
- 50-70 Km/h
- 70-90 Km/h
- 90 Km/h ට වැඩි

2. 02. සාමාන්‍යයෙන් අධිවේගී මාර්ගයට පිවිසීමේදී ඔබ පිවිසෙන්නේ රූපයේ කිනම් ස්ථානයකින්ද?



Mark only one oval.

- Zone 1
- Zone 2
- Zone 3
- Zone 4
- Zone 5

3. 03.අධිවේගී මාර්ගයට පිවිසීමට පෙර ඔබ වේගය වැඩි කිරීමේ මං තීරුව, වේගය වැඩි කිරීම සඳහා භාවිත කරනවා ද?

Mark only one oval.

- ඔවු
- නැත

4. 04.වේගය වැඩි කර ගැනීමේ මං තීරුවේ දිග ඔබට අවශ්‍යය වේගය ලබා ගැනීමට ප්‍රමාණවත්ද?

Mark only one oval.

- ඔවු
- නැත

5. 05.ඔබගේ පිය පැදවීමේ පලපුරුද්ද වසර වලින්

Mark only one oval.

- 0-5
- 5-10
- 10-15
- 15 ට වැඩි

6. 06.ඔබ ලබා ඇති අධ්‍යාපන මට්ටම

Mark only one oval.

- අ.පො.ස සා/පෙළ
- අ.පො.ස උසස් පෙළ
- උපාධි
- උපාධියට වඩා වැඩි

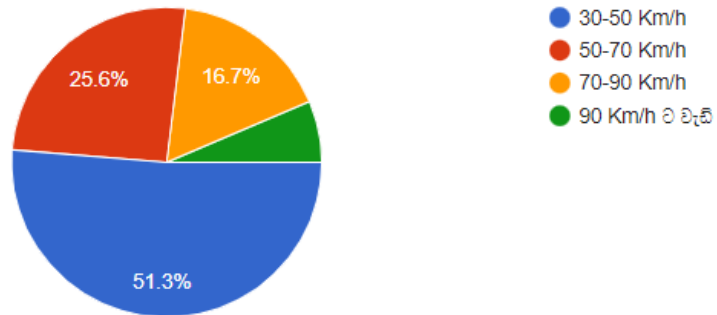
7. 07.ඔබගේ වයස කීයද?

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## Appendix D –Answers for Questionnaire 2

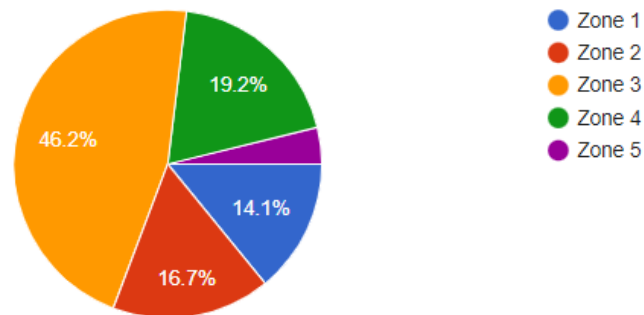
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78 responses



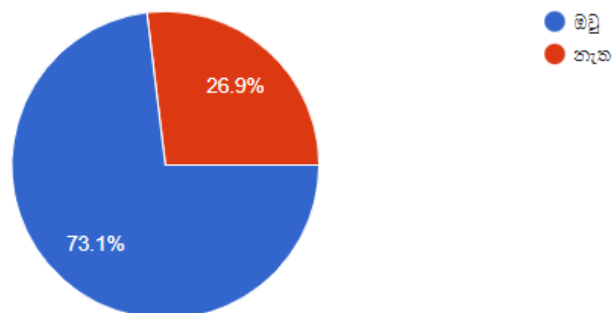
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78 responses



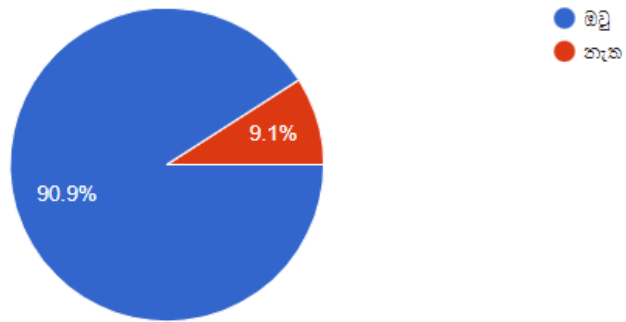
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78 responses



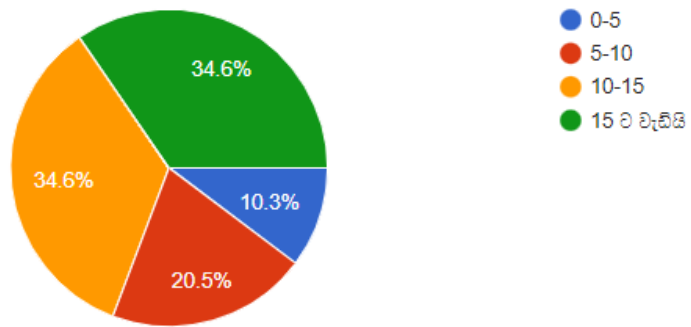
04. වේගය වැඩි කර ගැනීමේ මං තීරුවේ දිග ඔබට අවශ්‍යය වේගය ලබා ගැනීමට ප්‍රමාණවත්ද?

77 responses



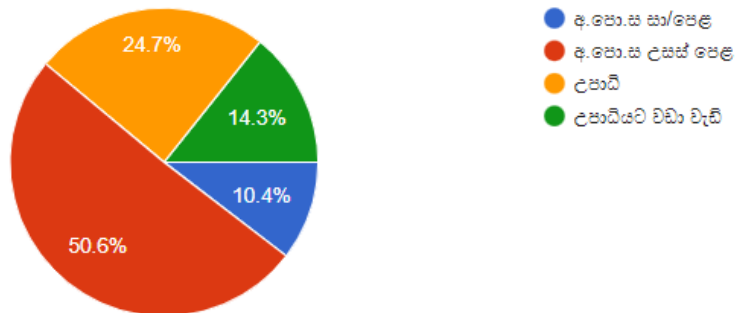
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78 responses



06. ඔබ ලබා ඇති අධ්‍යාපන මට්ටම

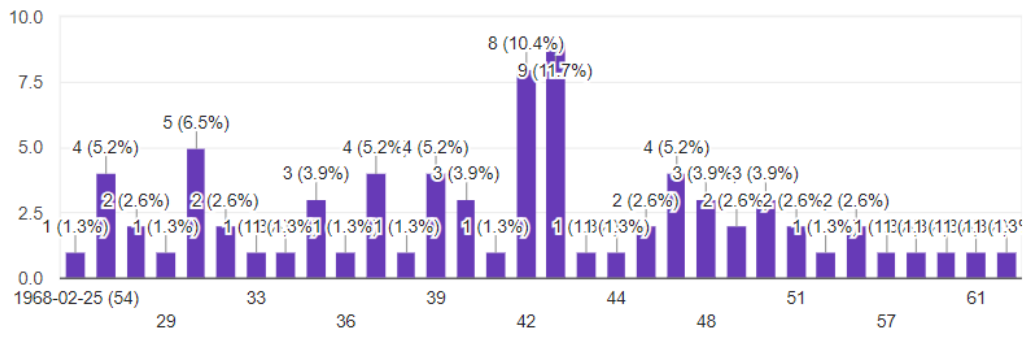
77 responses



07.ඔබගේ වයස කීයද?



77 responses



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