CRITERIA TO IDENTIFY OPTIMUM SPACING FOR SERVICE AREAS ON SOUTHERN EXPRESSWAY EXTENSION

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DECLARATION

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ABSTRACT

Southern Expressway is the first E class highway in Sri Lanka currently spanning from Kottawa to Godagama. This expressway is 126.1 kilometers long from Kottawa to Godagama. In most expressway projects, service area which will serve passengers is common. From Kottawa to Godagama there is one service area located at Welipenna. Southern Expressway extension will extend the expressway from Matara to Hambanthota including Expressway link to Mattala. From Welipenna to Hambanthota, there is approximately 177 km. So, it is evident that there needs to be additional rest areas located in the southern extension project.

Service area is an integral part of a long expressways. Purpose of the service area in an expressway is to provide services to the passengers and provide a resting place for the drivers in their long journey. Placing of the service area is very important because it will affect the accident rate in expressways.

In this research using traffic data collected which include the vehicle entrance time and date to the expressway, exit time and date from the expressway, vehicle type, entered interchange and exit interchange from existing southern expressway, location for a service area is proposed by calculating the optimum distance between the service areas. Quantitative data gathered from the expressway is analyzed to obtain a criteria for deciding the optimum location for the service area of the expressway extension. According to the findings 60km was proposed for distance between service areas and 30km was proposed as the distance between the rest areas.

Keywords – Service area, Sothern expressway extension, traffic analysis

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1. INTRODUCTION

1.1 BACKGROUND

The expressway network in Sri Lanka is comprised of three expressways namely Southern Expressway-E01 from Kottawa to Godagma, (123 km) Katunayaka Expressway E 02 from Peliyagoda to Katunayaka (25.8 km) and Outer Circular Highway (OCH) from Kottawa to Kadawatha (18.9 km) which are in operation now. Construction is underway for the extension of Southern Expressway from Matara to Hambantota (96 km) via Beliatta, Wetiya, Sooriyawewa and Andarawewa and expected to be in operation by end 2019. Central Expressway from Kadawatha to Kandy of 118.6 km length is also under construction and expected to be in operation in 2021. OCH Phase III from Kadawatha to Kerawalapitiya on Katunayaka Expressway (9.63 km) is expected to be completed in mid-2019. Land acquisition and feasibility study is being carried out for Ruwanpura Expressway from Kahatuduwa to Pelmadulla comprising of 73.9 km length. Upon completion of all the expressways, length of expressway network in Sri Lanka will be 378.8 km in total.

Phase 1 of the Southern Expressway became operational from Kottawa - Pinnaduwa (95.3 km) on 27th November 2011 as first access controlled expressway in Sri Lanka and expressway from Pinnaduwa - Godagama (30.8 km) wascompleted on 15th March 2014. In 2014 Southern Expressway became operational from Pinnaduwa to Godagama extending to a total length of 126.1 km.

Due to dilapidated condition of existing road network, substandard road alignment, road congestion and rapid growth of vehicle population in Sri Lanka ensued the Road Development Authority and the Ministry of Highways to develop expressways to cater for the increasing traffic demand. The concept of expressway in Sri Lanka was first introduced four decades ago. The University of Moratuwa had commenced initially the feasibility of construction of expressways in Sri Lanka and the Environment Impact Assessment in 1996 and a report had submitted in 1997. Construction of the expressway had commenced in 2006. First expressway from Kottawa to Galle was completed in November 2011. Extension of this expressway from Galle to Matara was commissioned in Nov 2014.

The financial support for the construction of Southern expressway from Kottawa to Kurundugahahetekma (65 km) was provided by the Japan Bank for International Cooperation (JICA), the section from Kurundugahahetekma to Pinnaduwa (27.7 km) was

funded by the Asian Development Bank (ADB) and the China Exim Bank has funded the 30.8 km section of expressway from Pinnaduwa to Godagama.

Southern Expressway from Kottawa to Matara consists of eleven interchanges and has two lanes in both travel direction separated by 1.5 m center median. The posted speed limit is 100 km/h. Construction of this expressway has reduced the travel time from 5 hours to one and half hours.

Benefits of construction of this expressway are:

- Reduced travel time for passengers from Godagama to Kottawa
- Enhanced land and property values for land adjoining the expressway specifically at 11 interchanges.
- Create number of jobs related to the expressway
- Contributes to the economic development of the country in many ways
- Decrease the traffic congestion in the main Matara - Colombo A2 road
- Enhance the infrastructure of the towns where interchanges are located
- Increase the tourism which is now concentrated in the coastal belt

Southern Expressway has separate Service Areas for both directions in Welipenna at 44^{th} km. This service area consists of supermarkets, assorted shops, restaurants, automated Teller Machines, wash rooms, fuel stations etc. After entered the southern expressway, it is legally prohibited to stop at edges of the expressway unless for an emergency requirement. Sometimes drivers felt tired tend to stop vehicles after entering the expressway. Map of the southern expressway is depicted in Figure 1.

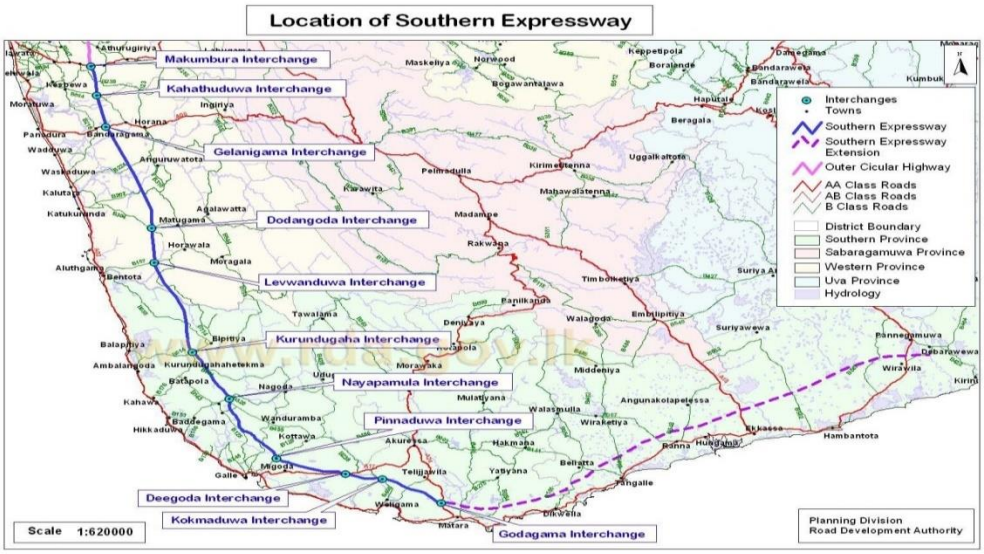


Figure 1 Map of the Southern Expressway

Extension of the Southern expressway to Hambanthota was commenced on 24th January 2016. The extension of expressway from Godagama in Matara to Hambanthota will be constructed to four lane capacity with possibility to add two more lanes in the future. This project is funded by Exim Bank of China and the forecasted project cost is LKR 250 bn.

Length of the expressway extension is 96 km. This section of expressway has been divided in to four sections where Section 1 spans from Matara to Beliatta and has a length of 30 km, Section 2 spans from Beliatta to Wetiya having 26km expressway section. Third section starts from Wetiya to Andarawewa which has a length of 15km and section 4 connects to Mattala air port and Hambantota port via Andarawewa which has total length of approximately 25 km.

After construction Southern Expressway and Southern Expressway Extension will have a total length of 227 km from Kottawa to Hambanthota.

Up to now the only service area is located at Welipenna. Welipenna is located around 46km away from Kottawa and 80km away from Godagama in Matara. After the construction of southern expressway extension it is important to construct another service area in the extended section of the expressway from Godagama to Hambantota. The second service area should be ideally located on the extended section of the expressway. In this research identification of an optimum location for the service area is carried out using the traffic data collected during the operation of southern expressway. Service area located at Welipenna is depicted in Figure 2.

Figure 2 Service area located at Welipenna

1.2 OBJECTIVES

Objectives of the research study are to:

- Identify the optimum spacing for the Service areas for Extension of Southern Expressway Project
- Find requirement for mini service areas or rest areas for Extension of Southern Expressway

1.3 METHODOLOGY

Following steps were carried out to achieve the aforementioned objectives of the research**.** Traffic data including of vehicle entrance time and date entering the expressway, exit time and date leaving the expressway, vehicle type, and entering and exit interchanges, have been collected. Travel speed of vehicles stopped at the service area was calculated and traffic survey using radar speed measured devices was carried out at a selected location to verify the travel speed of vehicles. Results were analyzed to find the optimum distance between the rest areas. Detailed methodology is described in Chapter 3.

2. LITERATURE REVIEW

2.1 SERVICE AREAS AND REST AREAS ON EXPRESSWAYS

Long drives can take mental and physical toll on drivers, which has become the major cause for accidents**.** Service areas and parking areas have been established on expressways so that the drivers could take break during the journey. In general a service area is comprised of resting facilities, restaurants, gas station, vehicle repair facilities and facility for vehicle parking. Other facilities may include a snack corner, gift shop, parking spaces, and toilets. Predominantly the business travelers on a business trip might stop in a service area to attend urgent business matters by calling his business place or to a customer, or to relax for a moment, while other drivers travelling with the families or group stop to enjoy the trip in service area for meals, or to buy provisions and gifts. Container trucks and vehicles carrying cargo for long distance might stop to rest, dine or take a nap.

Functional requirements of an expressway service area may include the facilities established to ensure vehicle safety requirements. Improvement of the driver behavior and psychological barriers are important for driving safely on the expressway. Passengers travelling long distance on the expressway require aesthetically pleasing environment to overcome the travelling fatigue. Facilities in the service area shall include the amenities such as clean public toilet facilities, a play area, convenience store, food courts, accommodation for road users, vehicle parking, refueling facilities, facility to repair vehicles, etc. As a developing country with rapid economic growth and spectrum of needs of the people, the facilities provided in service area should be able to expand its functions to fulfill the increasing road user demand. Expansion of service functions is an inevitable requirement with rapid development of the society. In addition to the basic functions provided, the service area should have multilevel other services including restaurants with variety of food (Chinese, Italian, Korean etc.), supermarkets, leisure and entertainment facilities (cinema), information centers for tourists, and cargo logistics facilities such as warehouses, passenger transit points, services for tourists and large parking area within the expressway resting facility.

Typically, a parking area is smaller than a service area. All parking areas generally have limited space for few vehicles and toilet facilities. Certain parking areas have a snack corner and gift shop. There are also parking areas with restaurants and gas stations. Generally if a

given expressway has a service area on one side, it should include another on the opposite side as well.

Muramatsu & Oguchi (2017) conducted a survey in service area and observed that the road users park vehicles in service area during mealtime where they spend more time, so the main purpose of vehicle drop-by in a service area would be to consume food. The overall usage average of the rest areas is approximately 10% of mainline traffic entering the rest area. (Al-Kaisy, Church, Veneziano, & Dorrington, 2012)

Minnesota Department of Transportation (2009) has done a research to find out the amenities that should be provided inside a rest area. Those are the direct access from expressway, clean toilets, vehicle parking, signs shown on expressway before entering the rest area list of amenities and services offered, video surveillance, travel information for sightseeing, lodging and food during 24-hour operation of service area, rest area buildings with indoor tables and facilities etc.

Construction and development of freeways in China consider 3 types of service areas namely, central service areas, general service areas and parking areas as shown in Table 1. (Lindi, Xiyuan, & Wang, 2011)

Table 1 Types of service areas and the services offered (Lindi, Xiyuan, & Wang, 2011)

Service area type	parking	garage	meals and drinking	accommodation	maintenance	supermarket	public toilets	rest areas	medical treatment
Central	*	*	*	*	*	*	*	*	*
General	*	*	*		*	*	*	*	
Parking	*						*	*	

(a) Central Service Area:

Central service areas provide comprehensive service functions for the road users. Central service area occupies approximately 8~20 hectares for basic amenities. The central service area must have basic facilities described in Table 1. Central service areas are mainly located

on the national freeways/expressways which are carrying large traffic volumes with provision for at least 50 parking spaces for one way.

(b) General Service area:

General Service areas provide basic service functions for the road users. General Service area shall be located between two central service areas or for regional highways. Generally this type of service area occupies 4~8 hectares with 20 parking spaces for one side. Generally, there is no medical treatment facility in this type of service area.

(c) Parking Area:

Parking area is a small scale service area which only has limited facilities and functions. The service facilities of a parking area is comprised of parking bays without vehicle repair facility, public toilets in general. Parking area has land space of 1~2.67 hectares with no more than 20 parking bays on either side.

Jung, Joo, & Oh (2017) has categorized the main types of freeway rest areas in Korea as shown in Figure 3.

Those are:

(1) Service area (regular rest area)

(2) Service area for trucks

(3) Simplified service area

(4) Supplemental rest area (a small-sized rest area for 1-2 vehicles especially for tired drivers)

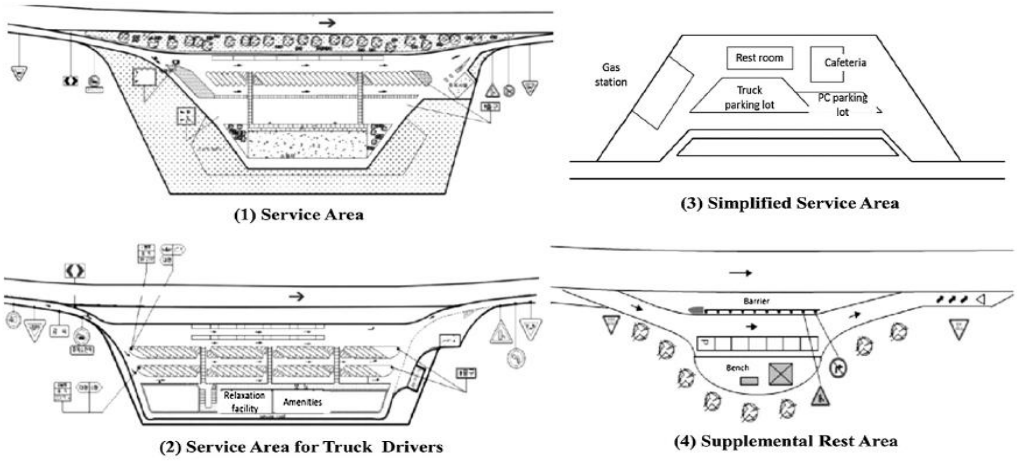


Figure 3 Main types of freeway rest areas in Korea Jung, Joo, & Oh (2017)

2.2 ISSUES RELEVANT TO REST AREAS AND PARKING AREAS

(Muramatsu & Oguchi, 2017) has pointed out the issue of lack of parking areas in rest areas of expressways in Japan. Also he has stressed that the number of parking lots required should be calculated based on the average daily traffic volume of the highway or expressway. A large number of parking bays are required for service areas with heavily trafficked highways. Another issue which has become significant is that as the number of parking bays increases, the operation of parking area will become complex and perhaps the allocation of parking spots could be inefficient.

In theory the distance between expressway service areas, size of service area, and the economic benefits derived from establishing the service areas are related to pause rate (Chen and Wang, 2012). In the planning stage, service area layout to a scale, the predicted traffic volume and pause rates (how frequently vehicles stop at a rest area) are needed to determine the number parking lots and to establish the layout of service areas of an expressway network. The pause rate directly related to the size, scale and contributes to the operational requirements of the service area.

The determination of pause rates is difficult in the planning and design stage of a rest area. However, it is extremely difficult to accurately predict the pause rate in the design stage and that will affect the placement and design of the service areas lay out of an expressway.

Jiang & Hou (2010) states that when designing a service area following factors are need to be taken in to account.

- Distance between Service Areas
- Service area functions
- The location of service area
- Expressway traffic volume, traffic composition and driving-in rate

A suitable land adjoining highway to build the service area is generally encounter with difficulty in acquiring utilities such as electricity, sewer disposal and water supply. Service area located in an urban area has limited land space to build the service area for heavy traffic volumes. Difficulty in solid waste management is a major problem in an urban area. Alternative solutions should be focused in the design stage but the cost could be significantly high and the initial investment may become expensive. The landscape of service area should be designed considering safety aspects for pleasure and to provide

aesthetically pleasing environment. The restriction to build or expand a rest area is the limited funding and impediment to acquire land.

According to Lindi, Xiyuan, & Wang (2011) the service area layout depends on the distance between two service areas and the service level that are to be provided in a service area will have direct relationship for the type of service area established for an expressway.

2.3 PLACEMENT OF REST AREAS IN AN EXPRESSWAY

N. P. Ornatskiy (1974, 1978) has derived a formula to calculate the distances between simplified rest areas as follows:

$$X_{av} = \frac{66.4\ q\ V_d}{f.N_{day}}$$

q — number of parking spaces provided for parking

V_d — design speed of vehicle category designed for an expressway

f — period of stay at the parking, (Generally considered as 15 minutes or 0.25 hours)

N_{day} — average daily traffic flow on the expressway (existing or prospective)

Okorokov in his research published in 1973 has determined the distance between simplified rest areas considering the following conditions,

- Capacity of simplified rest areas for three motor cars maximum
- Engagement coefficient of 1.5
- Intensity of daily traffic has been considered for the period of maximum occupancy of rest areas on expressways

Table 1 Distance between service areas with Traffic Volume Okorokov(1973)

Traffic volume (cars per day)	Distance between the service area in flat terrain (km)	Distance between the service areas in hilly terrain (km)
Less than 1000	50	25
1000 to 2000	50 – 30	25–13
2000 to 3000	30 – 22	13–10
3000 to 4000	22 – 16	10–8

4000 to 5000	16 – 13	8–7
5000 to 6000	13 – 11	7–6
6000 to 7000	11 – 10	6–5
7000 to 8000	10 – 9	5–4
8000 to 9000	9 – 8	-

The maximum distance recommended by the United States National Transport Commissions in 2016 for the positioning of service area facilities is 60km for simplified rest areas, 110km for large rest areas, and 40km for heavy vehicle parking along the highway. A deviation of 5 km has been allowed to ascertain suitable locations. Jiang & Hou (2010) states that the average distance between two service areas shall be limited to 30-50 km as appropriate.

The distance recommended for the establishment of rest areas by the Russian Ministry of Regional Development in 2012 is as below:

a) rest areas shall be provided at every 15–20 km on highways of categories I–II,
b) rest areas shall be provided at every 25–35 km on highways of category III, and
c) rest areas shall be provided at every 45–55 km on highways of category IV.

The capacity of rest areas shall not be less than for 20–50 cars at a time for highways of category I which will have the traffic volume up to 30,000 transport units per day. The capacity of rest areas shall not be less than for 10–15 cars at a time for highways of categories II–III. The capacity of rest areas shall not be less than for 10 cars at a time for highways of category IV. The road categories are the criteria for characterizing the importance of a highway in the country's transport network and the determination of service area capacity based on the traffic intensity.

Optimum quantum of rest area facilities to be provided for the road users, drivers and vehicles requiring various service needs, and the travel safety are expected to be at maximum service levels. The road user aspirations have become a multi criterion optimization problem as published in a paper by Borshchenko, Vasilyev, Lizunov, & Sharypov, in 2017.

N. P. Ornatskiy in 1986 has proposed a theoretical model for optimum placement of traffic service area constructions, which is expressed by the following functional parameters:

$$P = f\ (L, N, D_a, Z_t, \bar{\vartheta}, A, t, n)$$

where L — length of the road, km;

N — traffic volume in vehicles per day;

D_a — density of population centers in the highway area;

Z_t — trip zone;

ϑ — average travel speed of the expressway, km/h;

A — attraction of service facilities and the respective profitability;

t — duration of stay of drivers and passengers at the service facilities in hours;

n — number of road users using the type of service area.

Jiang & Lu (2011) state that the determination of the distance between service areas should consider the following additional requirements in addition to the basic requirements.

a) The demand for safe driving by the road users and vehicles

Driving safety is essential for the driver and considered best if a rest taken for 5 ~10min after a spell of continuous driving at high speed on an expressway for 1~1.5h. At the travel speed of 60~100km/h calculation show that the corresponding distance is considered to be 60~150km. In addition within the service area networks, vehicles need to be refueled at particular distances depending on the remaining fuel in the tank. Service areas need to be constructed to ensure that the vehicles can be refueled before warning lights show promptly the running out of fuel in the vehicle. Usually the distance requirements for the refueling is 30~50km after the warning lights indicate the running out of fuel. Furthermore, human behavior is such that at intervals of 1.5~3h in average people have physical needs such as usage of the toilet and other requirements. At 60~100 km / h design speed calculation show that the corresponding distance as of 90~300km. The service areas should be positioned on the freeway to fulfil these needs. Therefore, the spacing between the service areas should not be excessive.

b) Freeway travel trend

Travel trend, generation of traffic pattern, and the quantum of vehicle which influence the setting up of and the extent of the service area facilities including parking lots should be

determined considering the distance between the service areas. Traffic trend and vehicle growth rate are factors deciding the service area layout configuration specifically the parking spaces during the design phase taking in to account of category of vehicles. For large vehicles and small cars the interval of service area and the distance requirements vary and the distance between service areas for large vehicles should be established at close intervals than for the small vehicles in general. These factors should be treated differently in determining the service areas at fixed intervals.

Zheng, Sun, Wang in 2014 has presented that the layout of a service area should not be decided by simple means mechanically by fixed interval method, but consideration should also be given to the regional road network, roads connecting the cities, traffic patterns, natural landscape, the location of interchanges, and other localized factors.

Zheng et al. in 2014 published that following factors are needed to be taken in to account when designing a rest area on an expressway.

a) The natural environment conditions

Natural landscape such as lakes, mountains and rivers in the vicinity is an important aspect for the development of a service area and such localities should be incorporated when planning is done.

The importance of construction of a service facilities is to provide road users to take rest, reduce travel fatigue from continuous driving and consumption of food. Elimination of physical and psychological fatigue is essential for safe driving. The service facilities constructed in a beautiful environment has more advantage to attract road users to rest frequently.

b) Construction conditions

Construction features are important factors for a service area to be attractive for the road users. The service area should be provided with adequate water supply and drainage facilities. Supplies for the service area for its operational needs should also be established. Service area lay out should consider the symmetry to reduce downlink service area spacing to save management and operational costs

c) Traffic conditions

The construction of service area should be based on the present condition of service area and its operation in the long run with the ability for future expansion. In order to ensure road safety, service area should be properly designed with access roads from the

expressway and unfavorable construction with small radius of curves should be avoided while keeping a safe distance from tunnels and interchanges.

d) Service area requirements

Road user demand is the important factor that influences the service area layout. Studies have shown that when the road condition is at higher service level, traffic flow increases and vehicle travel distance is larger, and the demand for service area is higher.

Zheng et al. in his publication in 2014 describes the steps that require to locate the rest areas on the expressways based on the experience and a theoretical model. The steps are:

a) Investigation and analysis.

Collect the information of cities along the highway, traffic flow, and the position of highway bus stations, and natural landscapes and scenic locations, availability of water & power supply, geology, topography, land and other relevant information.

b) Formulate alternatives.

Analyze the information, measure the results according to the size of the service area, find all those that meet the requirements as a service area by empirical comparison

c) Scheme optimization.

In order to get maximum benefit from the service area, calculations should be done to identify, best alternative site that will meet the basic requirement.

Tai, Cailiang, Qiong in 2011 has listed out the basic requirements of a layout and location-selection for a highway service area.

d) Heavier traffic flow

Establish the service area at close proximity to the highway section with heavy traffic flow as more vehicles requiring the serves and road users of higher economic capacity and social benefits could be attracted. For locations with extra heavy traffic flow, sometimes parking cannot be provided for all the vehicles, but should be considered a narrow strip configuration for the service area

e) Larger cities nearby

The service areas located near major cities are the passageways established as a service area which will be advantageous to provide the services such as parking, refueling, resting and dining for the road users and vehicles coming in or getting out from the interchanges.

A city that originate or end travel has significantly less dining demand in the service area. Under certain travel circumstances, drivers will require refueling in the service area to avoid the trouble to search for a fuel station in downtown area when they drive in congested city areas. Accordingly, a service area needs to be established at the exit of a highway to a city with a fuel station with adequate parking lots.

f) Transport hub location

A transportation hub is considered to be integrated with most of the transportation modes, where a service area for parking should be set up where the number of roads are linked to the intersection to ensure facilitation for the transportation hub.

g) Suitable terrain and road section

When a location is chosen to set up a service area, it is necessary to consider natural environment and scenic appearance so that the location has the best features for construction, maintenance and management of the facility. Avoid land requiring high fill and deep excavation, construction interference such as bridges, interchanges, passageways, culverts, overpass and underpass bridges should not exist within the distance of 700 to 800 meters away from service area as much as possible. Acceleration and deceleration lanes merging with the expressway, ramps connected to service are, distance for uplink and downlink acceleration lanes on both side of expressway is 270 meters each totaling 540 meters for both ends. Consider that the ramp length of over 60 meters from the endpoint of acceleration and deceleration lanes to the service area where the parking length is commonly around 200 to 250 meters, so that the distance free from structures along the expressway is around 700 to 800 meters, to set up the service area.

h) Meeting the requirements of Maintenance and management

When layout and location for selecting a service area is established, sewerage & drainage system of the service area should comply with the rules and regulations. Select the location where easy access for power, & water supply and drainage paths, and materials supply are readily available.

i) Transportation conditions

Avoid placing the rest facilities on road sections where the radius of curve is less or in road sections where steep slope exists. It is best that the rest facilities are not affected by the

vicinity of rest facilities where easy access to come in and get out could be provided. In principle, the access for a service area should not be closer to an overpass, where the distance between an overpass and the service area should be over three Kilometers to prevent lack of visibility to traffic and enhance road safety.

Tai, Cailiang, Qiong (2011), has suggested basic requirements for planning of highway service area layout. Designer may adopt the basic layout requirements listed below when planning a service area.

1. Completely analyze the highway network in the area, travel demand and trend, forecast daily the number of road users and vehicle expected to arrive in the service area for the implementing period with traffic trends of all planned routes. Analyze present traffic status, functions and relationship of all travel routes

2. Survey traffic flow of each route, investigate traffic flow pattern of road network with OD survey, requirements of road users in service area and service area interval with details of incoming and outgoing traffic within the existing service area.

3. Determine the gross traffic demand for the service area for different operational periods on the basis of basic requirements, highway network planning and studying the available information.

4. Observe social and economic characteristics of the location, size and properties of nearby cities and traffic characteristics along highway;

5. Analyze and forecast the trend of transportation demand for existing and future planning of highway network.

6. Find the traffic demand for the service areas from various highways on the basis of distribution model of service area.

7. Consider various constraints and favorable conditions separately which influences the setting up of service area. Determine the suitability of service area initially, and find alternative locations for service area on the basis of general requirements of a service area.

8. Consider key factors such as traffic in the location of service area, transpiration needs and geographic factors to devise a location selecting optimization model. Compute location selecting optimization model to determine area position selection program for

the service area, traffic driving in rate, type and functional division requirements. Then develop the master plan for service area for the highway network.

9. Measure and calculate the perspective scale of service area, dynamically adjust according to position relationship model with different service area locations, and determine functional and type of service area required on the basis of transportation trend of the highways under consideration..

Girder in 2002 has carried out a questionnaire survey regarding the service areas. Most of the drivers stated that 55 miles between rest areas is a reasonable distance. According to Cho (2008) distance between rest areas specified in accordance with the requirements of different countries are given in Table 3.

Table 2 Spacing standards between service areas and rest areas in different countries Cho (2008)

Country	Type	Spacing Standard (km)
U.S.	Service Area Safety Rest Area	100 40 –50
Japan	Service Area Parking Area	50 15
U.K.	Service Area	48
Australia	Service Area Simplified Service Area Parking Area	100 50 30

2.4 DRIVER SAFETY AND REST AREAS

Freeways are characterized according to the road geometry, and drivers usually travel on freeways for long distances at high speeds. Therefore, freeway driving is likely to cause travel fatigue which will reduce driver attention and recognition capabilities resulting in fatal accidents. (Rogé, Pébayle, Hannachi, Muzet, 2003)

Borshchenko, Vasilyev, Lizunov, & Sharypov (2017) have indicated that installation of service area facilities for different purposes serves as one way to improve traffic safety, specifically travelling long distances.

Minnesota Department of Transportation (2009) has carried out a research using numerous respondents to identify a relationship between driving safety on the highway and the availability of rest areas. Firstly, the respondents were asked about their feeling when stopping at rest areas informing the personal safety of the drivers on the highway. Researchers have used a 10 point scale, where 10 represented 'Strong agreement' and 1 meant 'Strong disagreement'. Respondents have scored an average 7.7 implying that there is a positive correlation between safety of the drivers on the expressways and the interval of rest areas.

Hongjun, Kongjie, Quan, Xiaobao (2009) emphasize that service areas reduce accident rates on expressways, eliminate driver long-distance travel fatigue, facilitate vehicle maintenance and refueling which are significant to safe operation of expressways. Authors further argue that the pause rate, which is the ratio of vehicles entering the service area and expressway traffic is basically influenced by the driver behavior and human psychology of drivers, the condition of vehicles, road traffic congestion and the distance between the service areas.

Service area facilities should reduce driver fatigue, with potential to reduce driver fatigue-related accidents on expressways. (Al-Kaisy et al., 2012). The rest areas have become remarkably effective on freeways with on and off access ramps on a natural environment as the provision of rest areas reduce accidents caused due to driver fatigue by 36%. (Jung et al., 2017)

2.5 DESIGN ASPECTS OF REST AREAS

a) Safety

Traffic safety within the rest areas should be resolved by the application of three E's concept of Engineering, Education and Enforcement. Another aspect of road safety in service area is the provision of safe distance for deceleration/acceleration lanes and introduction of traffic calming devices so that vehicles traveling at 100km/h will be able to reduce the speed sufficiently to 5 to 10 km/h on the deceleration lane to reach parking lots or vice versa on the acceleration lane to reach 100 km/h speed as required to enter the expressway. Speed reducing methods include properly designed speed humps and protected pedestrian crossings/barriers for public safety in the parking lots from vehicles. Provision of natural curves with gradually decreasing radii may be the preferred design method for access ramps.

Accessibility for disable people is a mandatory requirement for public areas which should be considered during the planning and design stage. Solutions which are not optimal may create unacceptable safety concerns specifically for people with visual or mobility impairments.

b) Wastewater Management & Water Conservation

Wastewater management is an important facet of rest area design, maintenance and long term operation. Survey results show that 56.7% of visitors stop at service area are primarily use the restroom. Wastewater, solid waste and sewer management system in the service area shall be properly designed to handle waste disposal system. Water supply system shall also be designed adequately designed to meet the water consumption demand of the service area.

c) Building Design

The building facilities should have easily accessible restrooms to the public at all times, and the facility ought to be opened for 24 hours daily. Separate public toilet facilities shall be provided even if the main buildings are closed. Certain rest areas have provided three restrooms in order to provide service when one toiled is closed for cleaning. At least two toilets should be in service when cleaning is rotationally done to serve large groups vising by buses. Another solution is to recruit male and female custodians for male and female restrooms respectively, who are allowed to enter restrooms and clean without closure to public.

d) Lighting

Properly designed lighting in the service area is important to enhance safety of pedestrians and motorists and also to deter undesirable activities. Lighting systems shall be designed to provide sufficient lighting levels, while minimizing night time glare and by elimination of fugitive light escaping from the sites. Fully cutoff type light fixtures shall be used. Solar and other energy conserving lighting devices should be considered in the lighting design. All parking lots shall be lit during nighttime and for security reasons.

e) Grading and Drainage

Grading of service area should be adequately designed to accommodate and integrate the required facilities without disturbance of the land as much as possible. Grading and

drainage should be in harmony with the natural landscape and should follow the direction of existing slopes and drainage patterns. Cut and fill areas should be shaped to blend with existing landscape and to prevent erosion. Service area terrain development and layout of parking areas and sidewalks should be in conducive with the natural environment.

3. RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter of the thesis describes the details of research methodology adopted, and data collection from the representative samples.

3.2 RESEARCH DESIGN

Research design is the blueprint of the methodology outlined for conducting the research study in a manner that maximum control could be exercised over the factors that may influence the validity of the research results. This research has been used for quantitative exploration of descriptive design analysis of the traffic data collected and to identify a pattern to determine the optimum spacing requirement for service areas for expressways.

3.2.1 QUANTITATIVE RESEARCH

Quantitative data can be transposed into numbers adopting a formal objectively systematic process to obtain information and describe variable parameters and to find relationships. Quantitative research has the following characteristics,

a) There is a single reality that can be defined by careful measurement.
b) It is usually concise.
c) It describes, and examines relationships, and determines causality among variables, where possible.
d) Statistical analysis is conducted to reduce and organize data, determine significant relationships and identify differences and/or similarities within and between different categories of data.
e) The sample should be representative for a large data population.
f) Reliability and validity of the measuring instruments are crucial.
g) Comprehensive data collected by adoption of different methods and/or instruments should provide a complete description of the variable of the population studied.

h) It provides an accurate account of characteristics of particular individuals, situations, or groups

This research has most of the characteristics listed above and hence can be categorized as quantitative research. Using traffic data on the expressway, quantitative analysis is done to obtain a relationship to identify the spacing of service area requirement.

3.3 RESEARCH SETTING

The research setting refers to the place where the data is collected. In this study vehicle entry time and date of entering the expressway and interchange entered, vehicle exit time, date and exit interchange have been collected from following interchanges.

Kottawa, Kahathuduwa, Gelenigama, Dodangoda, Welipenna, Kurundugahahathakma, Baddegama, Pinnaduwa, Imaduwa, Kokmaduwa, Godagama, Aturugiriya, Kaduwela, Kadawatha

(Kothalawala interchange was not established when the data was collected)

The data collected has been used to calculate the number of vehicles passing between two particular interchanges to calculate the travel speed limit for vehicles passing and entering the rest area. Vehicles passing and entering rest area can be differentiated.

3.4 Methodology

a) A detailed literature review has been carried out to investigate the design aspects and related case studies for service areas on expressways
b) Traffic data consisting of vehicle entry and exit date and time to and from the expressway, vehicle type, entry and exit interchanges have been collected.
c) Following steps have been carried out to calculate the speed limit to estimate the number of vehicles stopped at the service area.
d) Traffic data consisting of vehicle entry and exit date and time to and from the expressway, vehicle type, entry and exit interchange have been analyzed and a matrix has been developed for all vehicle categories.
e) Critical interchanges with heavy traffic demand have been identified by analyzing the matrix.

f) Trips between critical interchanges which are passing and entering the service area have been sorted out to identify the relationships between vehicle trips between interchanges and vehicle trips passing and entering service area at Welipenna.
g) Frequency distribution of speed graphs have been developed to identify the difference between expressway trips of passing and entering vehicle trips of service area.
h) Using the frequency distribution of speed graphs, a speed limit has been derived to identify the number of vehicles stopping at the service area.
i) Identified speed limit has been verified by conducting the traffic survey.
j) Following steps have been carried out to analyze the suitability of existing service area for extension of southern expressway project
k) Based on literature review, different criteria which influence the driver behavior to use the service area have been studied.
l) A relationship between the distance to service area and percentage of stopped vehicles has been developed.
m) A graph to identify the optimum distance between service areas and rest areas have been developed.
n) Ideal location of the service area for extension of southern expressway project has been identified by research methods.

4. DATA ANALYSIS

Traffic data has been collected from Southern Expressway and OCH which are in operation for data analysis. Traffic data for 10 days has been collected including a weekend and data collection during the spell of obstructions such as rain, accidents etc. have been omitted. The data collection consisted of entry date, entry time, exit date and exit time, vehicle category of all vehicles on the expressway. There are 15 interchanges from Kadawatha to Godagama in operation and entry and exit data from all the interchanges have been collected.

Collected data has been arranged in a matrix as shown in Table 4. Calculation has been done using the original data. First column and row consist of interchanges. Each item in the matrix consists of five rows. Those five rows are the Population comprising of number of vehicles enter from interchanges & exit from a different interchange, total ravel distance, average speed, median speed and standard deviation of speed of population.

Using this matrix critical or highly demanded interchanges have been identified with population higher than 3000. Analysis of matrix indicate that certain interchanges have low population while other interchanges have significantly a higher population. So population more than 3000 has been considered a reasonable population for the analysis. Other interchanges have been omitted as the population decreased when the pattern of vehicle movements between interchanges have been increased. Critical interchanges are listed below.

- Kottawa
- Gelanigama
- Dodangoda
- Athurugiriya
- Kaduwela
- Kadawatha
- Kurundugahahethekma
- Godagama
- Pinnaduwa

Then the trips between those selected critical interchanges have been analysed in two different ways.

1. Trips between interchanges which have passed the service area.
2. Trips between interchanges which have entered the service area.

This differentiation was done to identify the impact of rest area for the average vehicle speed. Those trips have also been differentiated with respect to the average speed of vehicles in trips in between the interchanges. This analysis provide the details of vehicles in case any vehicle passes the service area and had a chance of stopping elsewhere thereby reducing the average speed of the vehicle. This analysis of vehcle data is given in Table 5 and Table 6.

The keywords of Matrix data has been set as follows

1. Population

2. Total distance (km)
3. Ave. speed (km/h)
4. Median speed (km/h)
5. Standard deviation of speeds (km/h)

Table 3 Matrix developed using traffic data between interchanges

EXIT

ENTRANCE

		Godagama	Kokmaduwa	Imaduwa	Pinnaduwa	Baddegama	Kurundugaha hetekma	Welipenna	SERVICE AREA	Dodangoda	Gelanigama	Kahatuduwa	Kottawa	Aturugiriya	Kaduwela	Kadawatha
		1	**2**	**3**	**4**	**5**	**6**	**7**		**8**	**9**	**10**	**11**	**12**	**13**	**14**
	Chainage	*0*	*10.9*	*18.6*	*30.8*	*46.3*	*58.5*	*80.1*	*82.1*	*91.3*	*112.4*	*120.2*	*126.1*	*131.2*	*138*	*145*
Godagama 1	0	1	704	1082	11112	1295	1926	1038		1273	3164	1828	11644	618	575	2250
		2	10.90	18.60	30.80	46.30	58.50	80.10	82.10	135.30	156.40	164.20	170.10	175.20	182.00	189.00
		3	78.78	76.21	82.10	80.35	81.05	81.47		77.52	78.60	78.92	81.05	76.47	75.37	74.08
		4	81.75	79.71	84.00	81.71	81.63	84.32		80.56	81.25	81.95	85.01	81.15	78.11	76.32
		5	16.89	13.85	12.94	15.98	14.31	16.84		17.47	18.14	18.19	18.05	20.83	20.45	19.96
Kokmaduwa 2	10.9	644	1	138	915	182	177	165		152	308	189	1123	53	119	252
		10.90	2	7.70	19.90	35.40	47.60	69.20	71.20	124.40	145.50	153.30	159.20	164.30	171.10	178.10
		77.60	3	59.23	73.35	76.24	80.76	81.98		75.61	74.57	75.77	78.78	82.36	80.30	74.39
		81.75	4	57.75	74.63	78.67	81.60	83.04		77.19	78.08	79.01	81.32	84.92	84.73	78.12
		17.98	5	14.22	14.23	15.29	13.25	13.85		19.84	20.08	20.35	16.99	13.99	20.27	20.15
Imaduwa 3	18.6	1034	173	1	2401	254	353	136		169	447	280	1416	81	85	287
		18.60	7.70	2	12.20	27.70	39.90	61.50	63.50	116.70	137.80	145.60	151.50	156.60	163.40	170.40
		76.80	64.30	3	71.21	74.01	74.65	77.85		77.01	75.50	73.18	75.87	75.03	72.71	73.01
		79.71	66.00	4	73.20	75.55	74.81	80.22		79.31	78.17	73.45	78.66	80.43	75.41	74.35
		15.90	16.73	5	13.26	17.69	15.04	18.22		16.28	16.30	19.52	18.36	23.37	21.48	19.22
Pinnaduwa 4	30.8	10956	915	2169	1	775	3377	1378		1507	3204	1561	11767	548	905	2314
		30.80	19.90	12.20	2	15.50	27.70	49.30	51.30	104.50	125.60	133.40	139.30	144.40	151.20	158.20
		80.26	73.51	66.14	3	73.41	75.84	81.16		76.93	77.88	78.72	80.72	77.89	78.52	75.30
		80.35	74.63	66.55	4	71.54	75.55	82.17		78.91	80.26	81.27	84.09	82.52	84.63	78.76
		13.07	13.80	11.55	5	14.22	13.51	14.28		15.71	17.51	17.42	16.83	19.59	21.43	19.47
Baddegama 5	46.3	1201	167	227	810	1	1254	365		474	1112	579	3216	198	250	663
		46.30	35.40	27.70	15.50	2	12.20	33.80	35.80	89.00	110.10	117.90	123.80	128.90	135.70	142.70
		81.64	79.16	75.10	71.52	3	71.51	75.10		76.41	77.32	78.32	78.58	79.44	79.38	74.80
		84.18	81.69	75.55	71.54	4	73.20	78.00		77.14	80.94	80.62	81.15	83.51	82.12	77.92
		14.66	14.67	15.35	13.64	5	13.52	19.03		16.37	18.34	16.82	17.03	19.17	17.86	18.04
Kurundugahah etekma 6	58.5	1870	193	356	3484	1143	1	756		800	1733	995	5852	314	366	1038
		58.50	47.60	39.90	27.70	12.20	2	21.60	23.60	76.80	97.90	105.70	111.60	116.70	123.50	130.50
		81.77	78.05	74.59	73.27	68.98	3	74.48		74.28	76.58	77.87	78.08	79.04	76.95	75.41
		81.63	79.33	74.81	75.55	66.55	4	0.00		75.69	77.00	78.77	79.53	80.78	76.94	76.32
		14.02	14.51	14.40	12.11	13.21	5	14.63		16.19	15.85	15.81	14.83	15.40	15.16	13.82
Welipenna 7	80.1	1076	179	120	1176	307	590	1		918	1359	775	4612	374	550	1306
		80.10	69.20	61.50	49.30	33.80	21.60	2	2.00	55.20	76.30	84.10	90.00	95.10	101.90	108.90
		81.84	81.73	78.41	80.39	75.55	70.43	3		64.22	74.11	76.78	77.43	78.15	79.46	77.02
		82.86	84.73	80.22	82.17	75.11	72.00	4		67.20	77.52	80.20	81.18	80.68	82.71	81.13
		15.27	15.63	14.23	13.84	16.37	13.36	5		21.19	18.28	17.58	15.83	17.65	18.54	16.25
SERVICE AREA	82.1															
Dodangoda 8	91.3	1414	151	197	1340	527	777	822		1	2665	1521	8711	533	665	1622
		135.30	124.40	116.70	104.50	89.00	76.80	55.20	9.20	2	21.10	28.90	34.80	39.90	46.70	53.70
		78.87	78.67	73.48	77.25	74.47	71.31	60.47		3	76.89	76.67	76.57	78.45	76.16	76.37
		80.56	80.40	76.53	78.91	77.14	72.89	67.20		4	79.13	78.82	77.33	79.80	77.83	78.59
		15.96	19.39	17.53	15.55	17.75	16.03	22.24		5	13.72	13.64	12.51	13.97	15.99	15.00
Gelanigama 9	112.4	3364	337	449	3049	1147	1810	1573		2629	1	1673	19001	1750	1866	4495
		156.40	145.50	137.80	125.60	110.10	97.90	76.30	30.30	21.10	2	7.80	13.70	18.80	25.60	32.60
		79.46	78.78	73.68	77.84	75.62	74.53	73.15		75.29	3	62.11	64.53	72.03	75.47	72.52
		81.25	81.20	76.05	80.26	77.76	75.21	77.52		74.47	4	58.50	63.23	75.20	76.80	75.23
		17.43	17.78	17.91	17.35	17.59	16.07	18.82		13.61	5	11.34	9.96	11.57	13.36	13.36
Kahatuduwa 10	120.2	2084	226	294	1589	676	1140	823		1577	2182	1	3829	590	885	2822
		164.20	153.30	145.60	133.40	117.90	105.70	84.10	38.10	28.90	7.80	2	5.90	11.00	17.80	24.80
		79.95	80.42	76.95	78.61	77.55	76.31	75.45		76.55	61.39	3	53.41	69.62	78.25	72.72
		82.90	83.01	77.16	81.27	80.62	78.77	77.61		78.82	58.50	4	50.57	73.33	82.15	74.40
		18.50	19.03	17.27	17.04	17.42	15.42	18.15		14.52	11.05	5	10.01	12.21	13.42	13.40
Kottawa 11	126.1	11196	1270	1545	11369	3192	5977	5203		8597	18756	3796	1	919	2661	11171
		170.10	159.20	151.50	139.30	123.80	111.60	90.00	44.00	34.80	13.70	5.90	2	5.10	11.90	18.90
		81.92	78.78	75.33	80.26	77.43	76.79	76.44		76.81	65.47	56.81	3	54.99	72.38	68.04
		85.98	83.28	77.71	84.09	81.15	79.53	81.18		77.33	68.50	59.00	4	51.00	71.40	70.88
		18.42	20.81	19.33	16.81	17.64	15.29	17.51		13.21	10.67	10.69	5	10.33	12.36	12.48
Aturugiriya 12	131.2	464	50	98	396	146	246	241		396	1376	497	1030	1	1187	6050
		175.20	164.30	156.60	144.40	128.90	116.70	95.10	49.10	39.90	18.80	11.00	5.10	2	6.80	13.80
		80.76	79.19	73.05	79.02	76.99	75.00	75.76		76.84	70.86	67.42	59.08	3	70.16	66.20
		83.74	82.02	76.77	82.52	80.86	76.53	78.62		77.23	70.50	66.00	61.20	4	68.00	69.00
		17.92	18.11	20.51	17.37	19.94	15.89	19.47		14.06	12.18	12.71	12.47	5	13.23	12.89
Kaduwela 13	138	1316	190	190	1504	438	682	986		1013	2736	1273	3361	1728	1	8472
		182.00	171.10	163.40	151.20	135.70	123.50	101.90	55.90	46.70	25.60	17.80	11.90	6.80	2	7.00
		76.82	77.64	73.16	78.11	76.77	74.06	79.54		76.21	73.69	75.24	74.12	65.77	3	57.67
		81.18	79.44	75.02	82.46	79.74	75.71	84.73		77.83	76.80	76.29	71.40	68.00	4	0.00
		21.70	19.55	19.14	19.26	20.79	15.55	17.78		16.15	13.52	13.12	12.64	13.20	5	13.76
Kadawatha 14	145	2267	233	285	2052	648	998	1393		1578	4114	2948	10108	7342	7228	1
		189.00	178.10	170.40	158.20	142.70	130.50	108.90	62.90	53.70	32.60	24.80	18.90	13.80	7.00	2
		73.96	73.34	70.93	74.40	74.90	72.69	75.36		77.67	73.86	74.05	72.46	67.03	62.38	3
		76.99	77.37	72.23	77.86	74.96	74.14	79.47		80.55	75.23	74.40	0.00	69.00	60.00	4
		21.82	21.15	20.62	19.85	15.75	15.41	18.45		15.39	13.31	13.08	12.63	12.03	11.94	5

Table 4 Trips between interchanges which are passing the service area

Average speed ranges	Trips between interchanges which are passing the service area													
	14 to 1	1 to 14	14 to 6	6 to 14	14 to 4	4 to 14	11 to 1	1 to 11	11 to 6	6 to 11	11 to 4	4 to 11	9 to 1	1 to 9
<15	0	0	0	0	0	0	0	0	1	1	1	3	0	0
15-20	2	0	0	0	0	0	6	11	3	4	4	4	3	1
20-25	0	1	1	0	3	2	5	11	5	2	2	3	1	0
25-30	2	1	2	1	3	5	7	13	6	8	12	5	7	1
30-35	1	6	7	1	5	2	18	18	21	16	22	14	6	8
35-40	9	9	7	5	14	3	27	33	41	44	42	54	5	20
40-45	14	18	23	11	24	22	54	67	87	61	99	97	19	39
45-50	43	45	43	22	58	58	141	157	167	117	177	187	67	70
50-55	105	82	61	34	94	98	273	354	254	203	340	334	113	137
55-60	170	143	71	86	147	115	459	561	340	285	490	424	152	164
60-65	210	238	103	92	172	200	710	728	390	355	765	656	240	228
65-70	227	240	90	99	212	223	739	832	573	548	724	708	257	246
70-75	261	296	114	116	188	208	952	1077	473	475	792	773	326	300
75-80	228	235	143	157	200	277	935	1002	826	820	1095	1269	347	276
80-85	210	232	76	118	219	285	1007	1022	851	878	1335	1401	362	344
85-90	240	253	125	166	235	270	1258	1336	672	663	2024	2165	470	426
90-95	227	222	79	65	252	280	2016	2088	803	829	1630	1778	444	409
95-100	203	151	33	47	147	184	1443	1413	259	313	994	1114	289	242
> 100	115	79	18	18	79	82	1146	1020	205	229	821	778	256	252

In Table 5 and Table 6 interchange numbers stand for following interchanges.

- 1- Godagama
- 4- Pinnaduwa
- 6- Kurundugahahethekma
- 8- Dodangoda
- 9- Gelanigama
- 11- Kottawa
- 12- Athurugiriya
- 13- Kaduwela
- 14- Kadawatha

Table 5 Trips between interchanges which are not passing the service area

Average speed ranges	Trips between interchanges which are not passing the service area													
	14 to 13	**13 to 14**	**14 to 12**	**12 to 14**	**14 to 11**	**11 to 14**	**14 to 9**	**9 to 14**	**13 to 11**	**11 to 13**	**11 to 9**	**9 to 11**	**11 to 8**	**8 to 11**
<15	9	12	2	1	12	1	2	0	2	0	6	26	70	1
15-20	12	74	2	1	24	3	2	2	0	0	1	25	36	4
20-25	8	93	4	7	24	6	4	2	0	1	6	32	30	2
25-30	10	129	13	42	41	15	13	1	1	0	11	57	51	3
30-35	17	172	14	48	81	69	14	3	0	2	34	132	47	4
35-40	105	339	30	73	230	93	30	18	7	14	92	275	113	14
40-45	174	399	91	140	461	153	91	39	24	23	235	666	179	32
45-50	456	797	269	276	1264	432	269	59	33	27	814	1590	343	92
50-55	1213	1560	330	305	2500	699	330	172	197	188	2474	4053	729	232
55-60	1827	1800	1407	1088	5212	1358	1407	304	273	235	2364	4949	1194	469
60-65	390	440	1209	889	3774	1194	1209	373	501	425	3207	6231	1766	481
65-70	321	293	1520	1128	4848	1475	1520	835	0	0	4081	8171	2807	1238
70-75	1972	1856	0	0	5653	1679	0	393	718	641	3637	8393	3560	1279
75-80	0	0	1373	1147	5365	1814	1373	934	904	669	0	4722	2897	764
80-85	683	492	848	697	5350	1420	848	481	0	0	1503	5650	4164	1923
85-90	0	0	0	0	3297	567	0	676	587	382	0	3439	2645	884
90-95	0	0	197	189	1857	151	197	133	0	0	252	2571	2413	1062
95-100	0	0	0	0	663	0	0	52	0	0	0	1145	1085	138
> 100	30	16	33	19	538	42	33	18	114	54	39	982	588	89

Trips which have passed the service area have been analyzed and percentage of vehicles corresponding to different speed range have been calculated. Cumulative percentage of vehicles have been calculated as shown in Table 7. Difference of the cumulative percentage has been calculated for two interchanges in order to find the relationship between number of vehicles corresponding to trips which have passed the service areas and have entered the service area for a given speed range. Details for the critical interchanges are given in Appendix (1).

Table 6 Specimen table for difference between cumulative percentages of vehicles which are passing and not passing the Service area

	Passing trip			Not Passing trip			
Speed ranges	**12 to 1 (Number of vehicles)**	**Percentage number of vehicles corresponding to speed range**	**Cumulative % (A)**	**4 to 1 (Number of vehicles)**	**Percentage number of vehicles corresponding to speed range**	**Cumulative % (B)**	**(B) – (A)**
<15	0	0.00	0.00	0	0.00	0.00	0.00
15-20	0	0.00	0.00	0	0.00	0.00	0.00
20-25	0	0.00	0.00	0	0.00	0.00	0.00
25-30	0	0.00	0.00	0	0.00	0.00	0.00
30-35	0	0.00	0.00	2	0.28	0.28	0.28
35-40	0	0.00	0.00	1	0.14	0.43	0.43
40-45	2	0.32	0.32	0	0.00	0.43	0.11
45-50	11	1.75	2.06	4	0.57	1.00	-1.07
50-55	6	0.95	3.02	9	1.28	2.28	-0.74
55-60	25	3.97	6.98	33	4.69	6.97	-0.01
60-65	23	3.65	10.63	48	6.83	13.80	3.16
65-70	45	7.14	17.78	95	13.51	27.31	9.53
70-75	60	9.52	27.30	116	16.50	43.81	16.51
75-80	54	8.57	35.87	66	9.39	53.20	17.33
80-85	50	7.94	43.81	144	20.48	73.68	29.87
85-90	65	10.32	54.13	82	11.66	85.35	31.22
90-95	118	18.73	72.86	82	11.66	97.01	24.16
95-100	113	17.94	90.79	16	2.28	99.29	8.50
> 100	58	9.21	100.00	5	0.71	100.00	0.00
Sum	630			703			

Then a graph has been drawn for the difference of cumulative percentage values of not passing trip and passing trip as shown in Figure 3

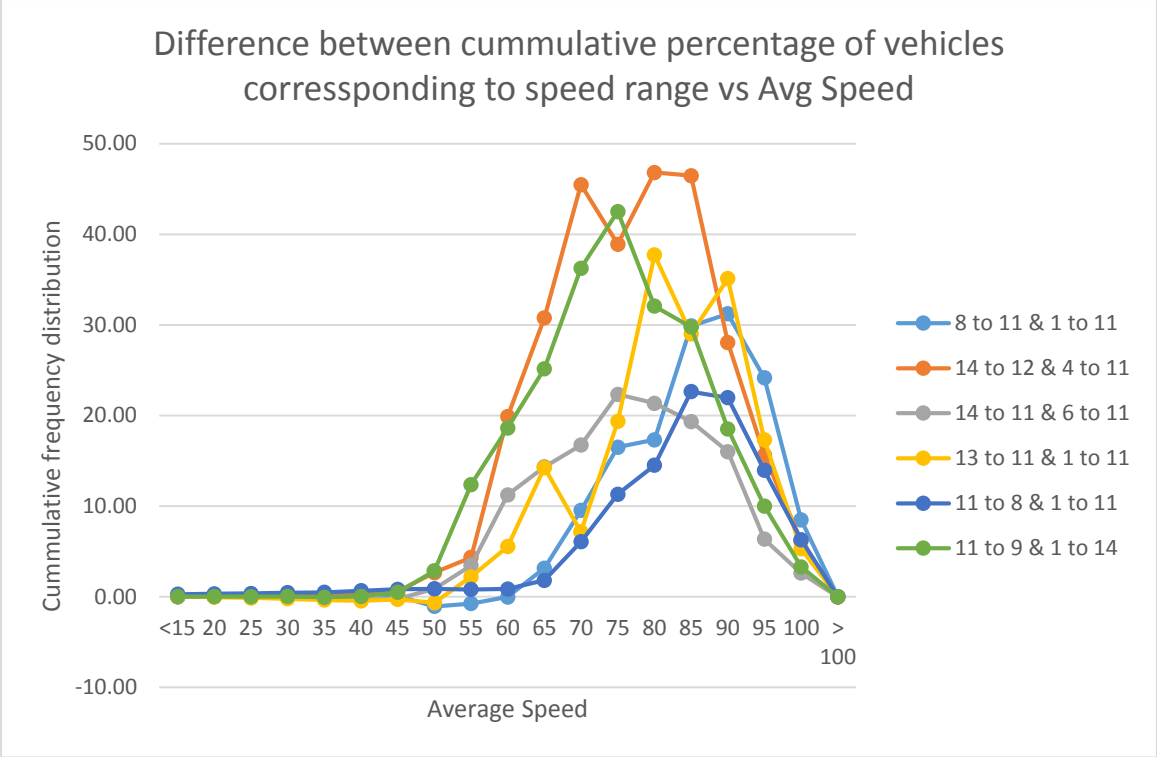


Figure 1 Cumulative frequency distribution between trips which are not passing & passing the Service area

Analysis of this graph show that cumulative frequency distribution (difference between cumulative percentage of vehicles corresponding to speed range of not passing trips and passing trips) suddenly increases between the speeds range of 55km/h to 85km/h. That means prior to the speed range from 55km/h to 85km/h, vehicles passing the service area is high compared with the vehicles entering the service area. It implies that most of the vehicles which have passed the service area have an average speed from 55km/h to 85km/h compared with the vehicles passed the service area. For average speed of more than 85km/h cumulative frequency distribution drops sharply. It implies that the vehicles which have passed the service area is comparatively higher than the vehicles entered the service area. Most of the vehicles which have passed the service area have an average speed of more than 85km/h compared with the vehicles which have not passed the service area. In order to clarify further, the gradients of those graphs has been analyzed against the average speed.

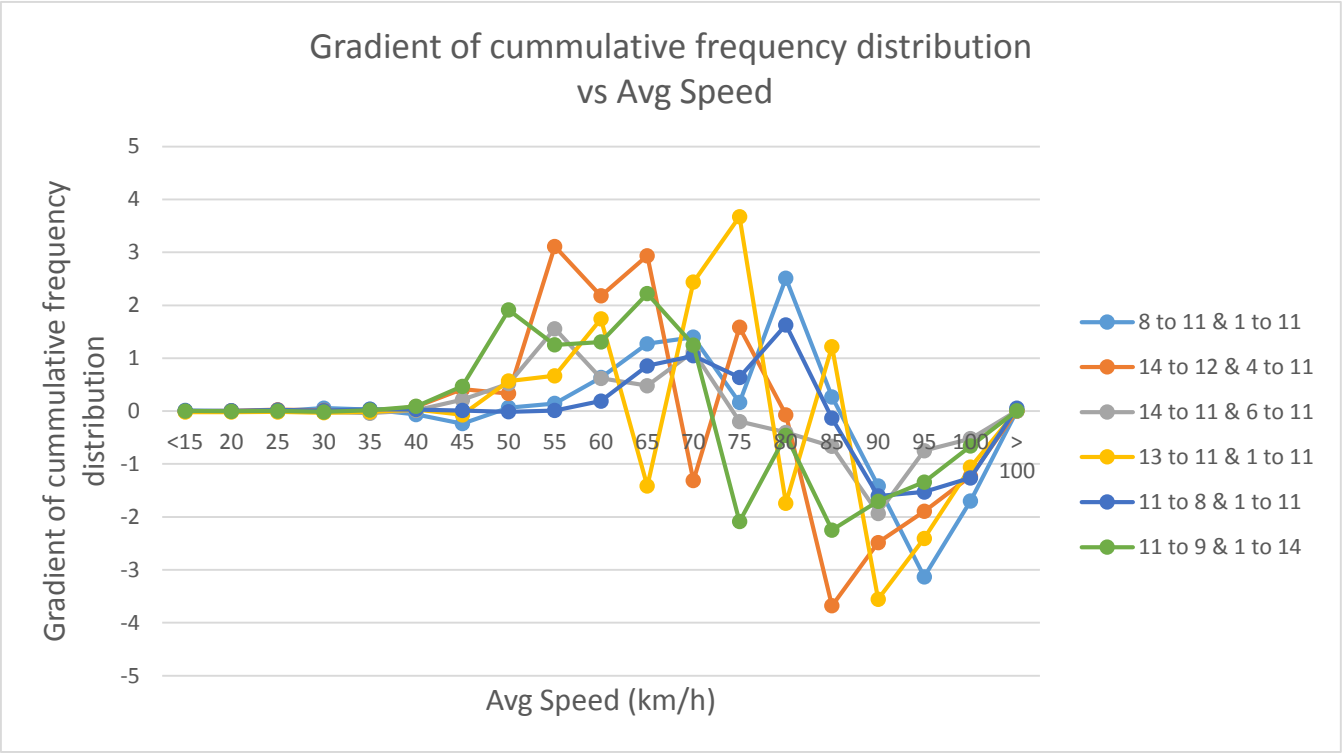


Figure 2 Gradient of cumulative frequency distribution vs. Average speed graph

From the above figure, maximum positive and negative gradient has been analyzed and mean speed has been calculated as follows.

Table 7 Mean speed for Positive & Negative maximum gradients

Series	Trip	Average speed corresponding to positive maximum gradient (km/h)	Average speed corresponding to negative maximum gradient (km/h)
01	8 to 11 & 1 to 11	80	95
02	14 to 12 & 4 to 11	55	85
03	14 to 11 & 6 to 11	55	90
04	13 to 11 & 1 to 11	75	90
05	11 to 8 & 1 to 11	80	90
06	11 to 9 & 1 to 14	65	85
	Mean speed	**68**	**89**

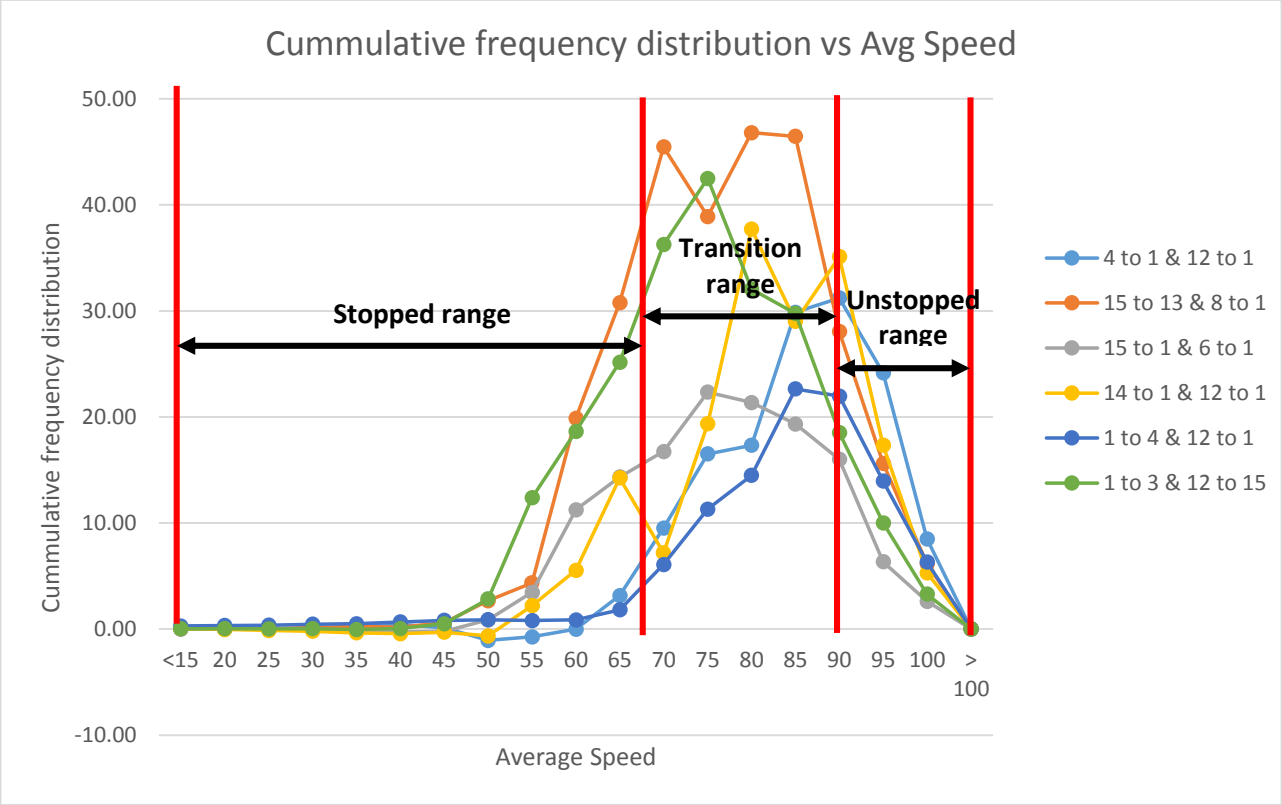


Figure 3 Graphical representation of speed ranges

- When average speed fall below 68km/h, number of vehicles which have passed the area are comparatively higher than the number of vehicles which have entered the service area because those vehicles have stopped at the service area. So their average speeds have been dropped to around 60km/h - 70km/h.
- Between average speeds of 68km/h to 89km/h, number of vehicles which have passed the service area varies comparative to the number of vehicles which have not passed the service area because certain vehicles may have stopped for a moment in the service area while others may have driven at 80km/h – 90km/h speed without stopping at the rest area. So the behavior of such vehicles are difficult to predict to say whether those had stopped or not.
- When average speed falls above 89km/h, again number of vehicles which have passed the service area is high comparative to the number of vehicles which have not passed the service area because those vehicles have continued the trip without stopping at the service area. Average speed of those vehicles are comparatively high.

The summary of the conclusions derived are as below,

- Maximum mean speed of vehicles which have been stopped at the service area is 68km/h
- Minimum mean speed of vehicles which have not been stopped at the service area is 89km/h
- Speed range of vehicles which have stopped or not at the service area is from 68km/h to 89km/h

A survey has been carried out at Godagama Interchange to verify the speed limits. Three time slots have been selected taking account of peak and off peak hours.

- Peak hours – 8.00a.m – 10.00a.m & 6.00p.m – 8.00p.m
- Off peak hour – 12.00p.m – 2.00p.m

Vehicles which have passed the service area have been analyzed in Appendix (2) and summarized below

Table 8 No. of vehicles & the Average speed of vehicles which have passed the service area

Exit	Entry	No. of vehicles stopped at the Service area	Avg speed km/h	No. of vehicles not stopped at the Service area	Avg speed km/h
Godagama	Dodangoda	5	65.40	16	82.25
	Gelanigama	12	66.58	46	82.23
	Kahathuduwa	22	67.59	39	82.53
	Kottawa	65	69.29	111	88.42
	Athurugiriya	12	66.58	30	88.26
	Kothalawala	6	65.66	11	87.90
	Kaduwela	36	69.27	38	84.18
	Kadawatha	71	67.35	67	82.37
Total			**67.21**		**84.76**
		229		**358**	

From the table it can be clearly seen that the average speed of vehicles which have stopped at the service area is below 68km/h.

Analysis concludes that the speed derived from the traffic data analysis is compatible with the analysis of survey data. Therefore, those speed limits are acceptable.

Cumulative trips up to an average speed of 68 km/h have been calculated for critical interchanges identified previously. For those analyzed trips, the distance from the interchange entered to the service area and distance from the service area to the exit interchange have been calculated. The results are given in Table 10.

Table 9 cumulative trips up to an average speed of 68 km/h

Average speed ranges (km/h)	Trips between interchanges																		
	14 to 1	1 to 14	14 to 6	6 to 14	14 to 4	4 to 14	11 to 1	1 to 11	11 to 6	6 to 11	11 to 4	4 to 11	9 to 1	1 to 9	4 to 9	9 to 4	6 to 9	9 to 6	
<15	0	0	0	0	0	0	0	0	1	1	1	3	0	0	2	0	1	2	
15-20	2	0	0	0	0	0	6	11	3	4	4	4	3	1	0	3	1	4	
20-25	0	1	1	0	3	2	5	11	5	2	2	3	1	0	3	2	5	3	
25-30	2	1	2	1	3	5	7	13	6	8	12	5	7	1	5	3	1	8	
30-35	1	6	7	1	5	2	18	18	21	16	22	14	6	8	9	2	9	11	
35-40	9	9	7	5	14	3	27	33	41	44	42	54	5	20	23	19	10	25	
40-45	14	18	23	11	24	22	54	67	87	61	99	97	19	39	62	34	35	32	
45-50	43	45	43	22	58	58	141	157	167	117	177	187	67	70	87	60	46	49	
50-55	105	82	61	34	94	98	273	354	254	203	340	334	113	137	96	74	69	78	
55-60	170	143	71	86	147	115	459	561	340	285	490	424	152	164	161	164	86	119	
60-65	210	238	103	92	172	200	710	728	390	355	765	656	240	228	183	226	128	152	
65-70	227	240	90	99	212	223	739	832	573	548	724	708	257	246	287	262	133	144	
70-75	261	296	114	116	188	208	952	1077	473	475	792	773	326	300	244	268	211	213	
75-80	228	235	143	157	200	277	935	1002	826	820	1095	1269	347	276	363	311	224	238	
80-85	210	232	76	118	219	285	1007	1022	851	878	1335	1401	362	344	417	452	145	181	
85-90	240	253	125	166	235	270	1258	1336	672	663	2024	2165	470	426	420	418	316	281	
90-95	227	222	79	65	252	280	2016	2088	803	829	1630	1778	444	409	439	402	83	93	
95-100	203	151	33	47	147	184	1443	1413	259	313	994	1114	289	242	245	220	143	118	
> 100	115	79	18	18	79	82	1146	1020	205	229	821	778	256	252	158	129	87	58	
																			Total
Total number of vehicles	2267	2251	1255	1038	2052	2314	11196	11743	5977	5851	11369	11767	3364	3163	3204	3049	1733	1809	**85143**
Cumulative number of vehicles for speed up to 68km/h	556	543	274	252	520	505	1700	1953	1205	1096	1954	1781	613	668	631	587	391	380	**15609**
Cumulative percentage of vehicles for speed up to 68km/h	24.53	24.12	31.93	24.28	25.34	21.82	15.18	16.63	22.00	18.73	17.19	15.14	18.22	21.12	19.69	19.25	22.56	26.70	**18.33**
Distance gone to Service area from Entrance IC	62.9	82.1	62.9	23.6	62.9	51.3	44	82.1	44	23.6	44	51.3	30.3	82.1	51.3	30.3	23.6	30.3	
Distance to be gone to Service area to Exit IC	82.1	62.9	23.6	62.9	51.3	62.9	82.1	44	23.6	44	51.3	44	82.1	30.3	30.3	51.3	30.3	23.6	

The cumulative percentage of vehicles stopped have been calculated for different trips between the critical interchanges with respect to the distance travelled to the service area from Entrance IC and distance to be travelled from service area to Exit IC. The results are given in Tables 11 & 12 respectively.

Table 10 Total percentage of vehicles stopped at Service area compared with distance gone to Service area from Entrance IC

Distance gone to Service area from Entrance IC	Average speed ranges (km/h)	Total number of vehicles	Cumulative number of vehicles for speed up to 68km/h	Cumulative percentage of vehicles for speed up to 68km/h (A)	Distance to be gone to Service area to Exit IC (B)	Total % of stopped vehicles (A/B)	Average % of stopped vehicles
23.6	6 to 14	1038	252	24.28	62.9	38.60	51.87
	6 to 11	5851	1096	18.73	44	42.57	
	6 to 9	1733	391	22.56	30.3	74.46	
30.3	9 to 1	3364	613	18.22	82.1	22.19	57.62
	9 to 4	3049	587	19.25	51.3	37.52	
	9 to 6	1809	380	26.7	23.6	113.14	
44	11 to 1	11196	1700	15.18	82.1	18.49	48.41
	11 to 6	5977	1205	22	23.6	93.22	
	11 to 4	11369	1954	17.19	51.3	33.51	
51.3	4 to 14	2314	505	21.82	62.9	34.69	44.69
	4 to 11	11767	1781	15.14	44	34.41	
	4 to 9	3204	631	19.69	30.3	64.98	
62.9	14 to 1	2267	556	24.53	82.1	29.88	71.52
	14 to 6	1255	274	31.93	23.6	135.30	
	14 to 4	2052	520	25.34	51.3	49.40	
82.1	1 to 14	2251	543	24.12	62.9	38.35	48.62
	1 to 11	11743	1953	16.63	44	37.80	
	1 to 9	3163	668	21.12	30.3	69.70	

Table 11 Total percentage of vehicles stopped at Service area compared with distance to be gone from Service area to Exit IC

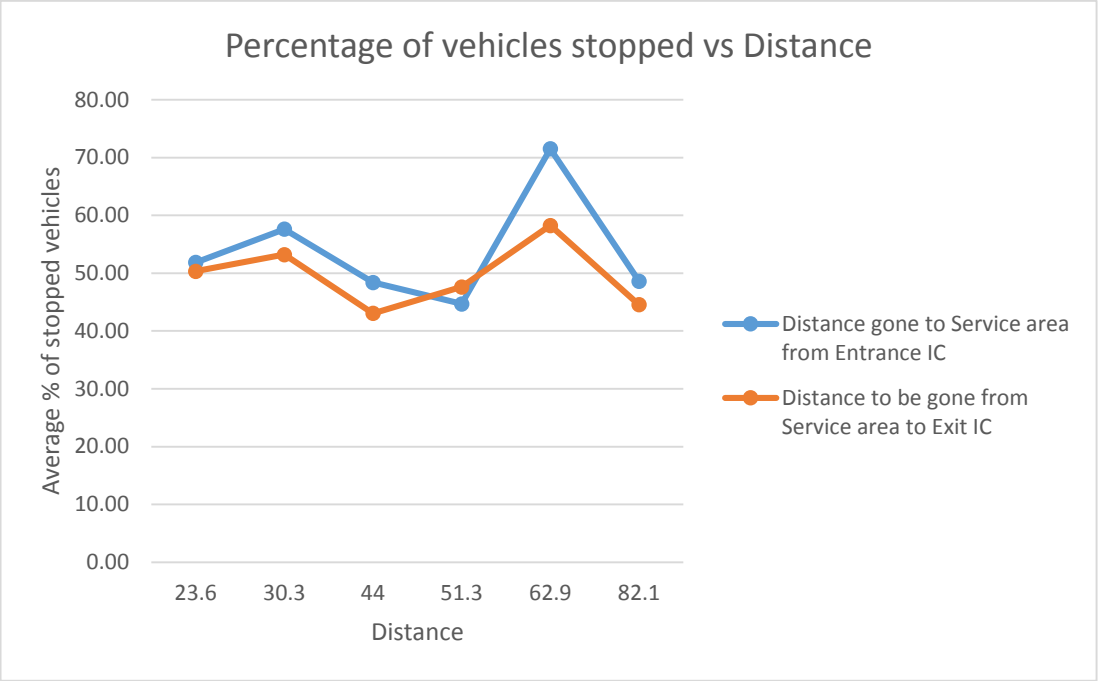
Distance to be gone to Service area to Exit IC	Average speed ranges (km/h)	Total number of vehicles	Cumulative number of vehicles for speed up to 68km/h	Cumulative percentage of vehicles for speed up to 68km/h (A)	Distance gone to Service area from Entrance IC (B)	Total % of stopped vehicles (A/B)	Average % of stopped vehicles
23.6	9 to 6	1809	380	21.01	30.3	69.34	50.33
	11 to 6	5977	1205	21.83	44	49.61	
	14 to 6	1255	274	20.16	62.9	32.05	
30.3	6 to 9	1733	391	22.56	23.6	95.59	53.23
	4 to 9	3204	631	19.69	51.3	38.38	
	1 to 9	3163	668	21.12	82.1	25.72	
44	6 to 11	5851	1096	18.73	23.6	79.36	43.04
	4 to 11	11767	1781	15.14	51.3	29.51	
	1 to 11	11743	1953	16.63	82.1	20.26	
51.3	9 to 4	3049	587	19.25	30.3	63.53	47.63
	11 to 4	11369	1954	17.19	44	39.07	
	14 to 4	2052	520	25.34	62.9	40.29	
62.9	6 to 14	1038	252	24.28	23.6	102.88	58.26
	4 to 14	2314	505	21.82	51.3	42.53	
	1 to 14	2251	543	24.12	82.1	29.38	
82.1	9 to 1	3364	613	18.22	30.3	60.13	44.54
	11 to 1	11196	1700	15.18	44	34.50	
	14 to 1	2267	556	24.53	62.9	39.00	

5. RESULTS AND DISCUSSION

From the data analysis of graph plotted for the differences of cumulative percentage of vehicles which have not passed and have passed the Service area against the average speed of vehicles *(Refer figure 3)*, show that the cumulative frequency distribution suddenly increases for the speeds ranges from 55km/h to 85km/h and for the average speed of more than 85km/h, cumulative frequency distribution falls immediately. Further analysis using the gradient of the graphs average speed with maximum positive gradient is at 68km/h while average speed of maximum negative gradient is at 89km/h. So this means that vehicles which have an average speed below 68km/h could be considered stopped at the service area, whereas the vehicles with average speed from 68km/h to 89km/h could be considered either stopped or unstopped at the service area. Average speed of above 89km/h, could be considered unstopped at the service area. So, it is concluded that 68 km/h speed is the speed limit at which the vehicle trips could be identified whether they have stopped or not stopped at the service area. Therefore vehicles which have an average speed below 68 km/h, can be considered as the vehicles stopped at the service area.

Using the analyzed data, a graph has been drawn for the total percentage of stopped vehicles against the distance to travel to the service area from Entrance IC. It can be seen from the graph that drivers tend to get a break when they have driven about 30 km while the majority of drivers tend to get a break when they have driven about 60-70km distance. The percentage of stopped vehicles around 60-70km is higher because drivers may have felt the fatigue too. The graph plotted for the total percentage of stopped vehicles against the distance to be travelled from the service area to Exit IC, the results have been similar. Drivers tend to get a break when they have to travel around 30km while high percentage of drivers tend to break the journey when they have to travel around 60-70km. This can be be clearly seen from Figure 6.

Figure 4 Frequency of vehicles stopped vs. distance



6. CONCLUSION

In this research method to identify the optimum distance between service areas for the southern expressway extension has been identified analyzing the traffic data collected from the Southern Expressway between interchanges. First the data has been analyzed to identify the critical interchanges that will generate more trips between interchanges. Then those interchanges have been divided in to two categories. The first category is for trips between interchanges where the vehicle have passed the service area and the second category is for trips between interchanges where the vehicle have entered the service area.

There is a correlation between the trips which have passed and entered the service area. It is concluded that 68 km/h is the cutoff speed at which the vehicles could be recognized as those have stopped at the service area or not. If the average speed of the vehicles is less than 68 km/h it can be concluded that the vehicle have stopped at the service area.

From the graphs drawn for the cumulative percentage of vehicles stopped and the distance to travel to the service area from Entrance IC and the distance to be travel from the service area to Exit IC, it is concluded that the drivers tend to stop when they have driven or should have driven about 30km and 60 km distance respectively. So, it is concluded that optimum spacing for service areas is 60 km and 30 km for rest areas. So drivers can take a rest at 30km interval. This findings are coherent with the international guidelines established for the spacing requirements for rest areas and service areas.

Also, using these results, proposed service and rest areas for the southern expressway extension project can be established. It can be clearly seen from Fig c, that service areas should be located at 60 km interval and rest areas should be established at 40 km interval concluding the research paper.

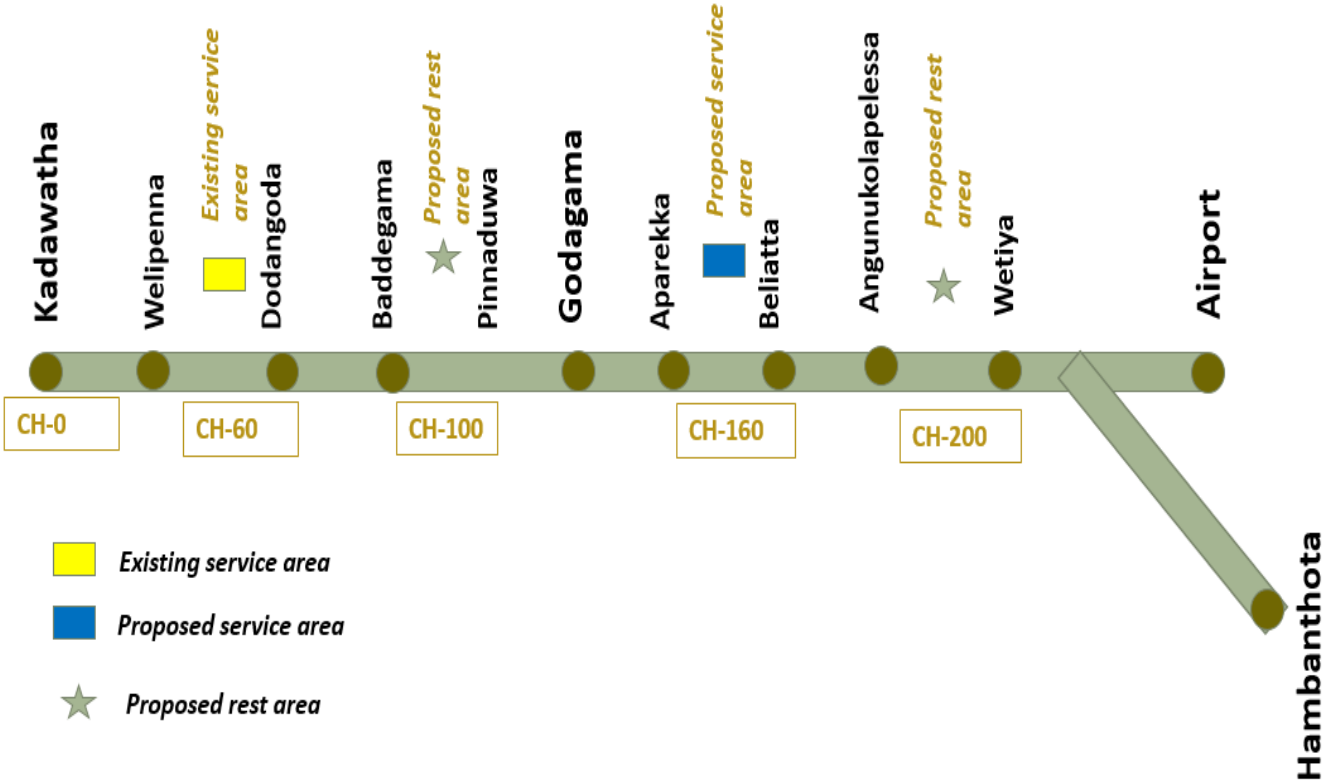


Figure 5 Proposed locations for Service and rest areas

7. REFERENCES

Al-Kaisy, A., Church, B., Veneziano, D., & Dorrington, C. (2012). Investigation of Parking Dwell Time at Rest Areas on Rural Highways. *Transportation Research Record: Journal of the Transportation Research Board*, *2255*(1), 156–164. https://doi.org/10.3141/2255-17

Borshchenko, Y., Vasilyev, V., Lizunov, A., & Sharypov, A. (2017). Solutions of a Multicriteria Problem of Optimum Placement of Short-term Rest Areas on Highways. *Transportation Research Procedia*, *20*(September 2016), 87–93. https://doi.org/10.1016/j.trpro.2017.01.020

Jiang, Y., & Hou, W. (2010). Research on expressway service area planning. *2010 2nd Conference on Environmental Science and Information Application Technology, ESIAT 2010*, *3*, 1–3. https://doi.org/10.1109/ESIAT.2010.5568946

Jiang, Y., & Lu, J. (2011). Functional analysis of freeway service area based on user demand. *2011 International Conference on Remote Sensing, Environment and Transportation Engineering, RSETE 2011 - Proceedings*, 8285–8287. https://doi.org/10.1109/RSETE.2011.5964084

Jung, S., Joo, S., & Oh, C. (2017). Evaluating the effects of supplemental rest areas on freeway crashes caused by drowsy driving. *Accident Analysis and Prevention*, *99*, 356–363. https://doi.org/10.1016/j.aap.2016.12.021

Lindi, D., Xiyuan, H., & Wang, H. (2011). Optimized Model for the Layout Planning of Freeway Service Areas. *Asce*, 1–8. https://doi.org/10.1061/41177(415)1

Muramatsu, T., & Oguchi, T. (2017). Methodology to Measure the Parking Area Performance of Inter-city Expressways. *Transportation Research Procedia*, *25*, 639–651. https://doi.org/10.1016/j.trpro.2017.05.448

Wang, S., Zhao, J., Wang, K., & Liu, Y. (2018). Green Intelligent Transportation Systems, *419*. https://doi.org/10.1007/978-981-10-3551-7

Okorokov, Ye.M. (1972). Design principles of short-term rest areas [Principy proektirovanija mest kratkovremennogo otdyha]. PhD thesis in Engineering Science. Moscow: Moscow Automobile and Road Construction State Technical University (MADI), 121 p.

Ornatskiy, N.P. (1974). Design of improvement of highways ,Vysshaya Shkola, Moscow, 136 p.

Ornatskiy, N.P. (1986). Improvement of highways Moscow: Transport, 136 p.

Policy and Guidelines for Rest Areas (2016) the National Transport Commission, Australia

Ministry of Regional Development (2012). Set of Rules 34.13330.2012 Automobile roads. Revised edition of Construction Rules and Regulations

Minnesota Department of Transportation (2009). Rest Area Amenities Study, New York

Hongjun, C., Kongjie, L., Quan, Y., Xiaobao, S. (2009) Pause Rate Of Motorway Service Area Base On Vehicle Continuous Travel Time. International Conference on

Transportation Engineering

W. Q. Zheng et al., "Study on Layout Methods and Location-Selecting Model for Highway Service Area", Applied Mechanics and Materials, Vols. 505-506, pp. 520-523, 2014

Tai, W., Cailiang, J., Qiong, S. (2011) Layout Methods And Location-Selecting Optimization For Highway Service Area, Third International Conference on Transportation Engineering, July 23-25, 2011 , Chengdu, China

Chen, Y., Wang, J., (2012) A Study on Forecast Method of Pause Rate in Expressway Service Area, The Twelfth COTA International Conference of Transportation Professionals August 3-6, 2012 , Beijing, China

Gårder, P.E, (2002) Quantifying Roadside Rest Area Usage, New England Transportation Consortium, Storrs

Rogé, J., Pébayle, T., Hannachi, S.E., Muzet, A., (2003). Effect of sleep deprivation anddriving duration on the useful visual field in younger and older subjects duringsimulator driving. Vis. Res. 43 (13), 1465–1472.

Cho, N., 2008. Strategic plan of freeway service area installation for highway safetyimprovement. Krihs Policy Brief 164, 1–4.

Aworemi, J.R., Abdul-Azeez, I.A., Oyedokun, A.J. & Adewoye, J.O. (2010). Efficacy of Drivers' Fatigue on Road Accident in Selected Southwestern States of Nigeria. International Business Research Vol. 3, No. 3; July 2010

Nippon Expressway Company. (2015). Service Areas. Roadside Rest Stops Becoming Leisure Destinations. Retrieved from https://www.nippon.com/en/features/jg00002/

8. APPENDIX

1. Tables for Difference between Cumulative percentage of vehicles which are passing and not passing the service area.

	Not passing			Passing			NP - P
	8 to 11	%	cum %	1 to 11	%	cum %	
<15	0	0.00	0.00	0	0.00	0.00	0.00
20	0	0.00	0.00	0	0.00	0.00	0.00
25	0	0.00	0.00	0	0.00	0.00	0.00
30	0	0.00	0.00	0	0.00	0.00	0.00
35	2	0.28	0.28	0	0.00	0.00	0.28
40	1	0.14	0.43	0	0.00	0.00	0.43
45	0	0.00	0.43	2	0.32	0.32	0.11
50	4	0.57	1.00	11	1.75	2.06	-1.07
55	9	1.28	2.28	6	0.95	3.02	-0.74
60	33	4.69	6.97	25	3.97	6.98	-0.01
65	48	6.83	13.80	23	3.65	10.63	3.16
70	95	13.51	27.31	45	7.14	17.78	9.53
75	116	16.50	43.81	60	9.52	27.30	16.51
80	66	9.39	53.20	54	8.57	35.87	17.33
85	144	20.48	73.68	50	7.94	43.81	29.87
90	82	11.66	85.35	65	10.32	54.13	31.22
95	82	11.66	97.01	118	18.73	72.86	24.16
100	16	2.28	99.29	113	17.94	90.79	8.50
> 100	5	0.71	100.00	58	9.21	100.00	0.00
sum	703			630			

	Not passing			Passing			NP - P
	14 to 12	%	cum %	4 to 11	%	cum %	
<15	2	0.03	0.03	3	0.03	0.03	0.00
15-20	2	0.03	0.06	4	0.03	0.06	0.00
20-25	4	0.05	0.11	3	0.03	0.08	0.03
25-30	13	0.18	0.29	5	0.04	0.13	0.16
30-35	14	0.19	0.48	14	0.12	0.25	0.23
35-40	30	0.41	0.89	54	0.46	0.71	0.18
40-45	91	1.24	2.13	97	0.82	1.53	0.60
45-50	269	3.66	5.79	187	1.59	3.12	2.67
50-55	330	4.49	10.29	334	2.84	5.96	4.33
55-60	1407	19.16	29.45	424	3.60	9.56	19.89
60-65	1209	16.47	45.92	656	5.57	15.14	30.78
65-70	1520	20.70	66.62	708	6.02	21.15	45.47
70-75	0	0.00	66.62	773	6.57	27.72	38.90
75-80	1373	18.70	85.32	1269	10.78	38.51	46.81
80-85	848	11.55	96.87	1401	11.91	50.41	46.46
85-90	0	0.00	96.87	2165	18.40	68.81	28.06
90-95	197	2.68	99.55	1778	15.11	83.92	15.63
95-100	0	0.00	99.55	1114	9.47	93.39	6.17
> 100	33	0.45	100.00	778	6.61	100.00	0.00
sum	7342			11767			

	Not passing			Passing			NP - P
	14 to 11	%	cum %	6 to 11	%	cum %	
<15	12	0.03	0.03	1	0.02	0.02	0.01
15-20	24	0.06	0.09	4	0.07	0.09	0.00
20-25	24	0.06	0.15	2	0.03	0.12	0.03
25-30	41	0.10	0.25	8	0.14	0.26	-0.01
30-35	81	0.20	0.44	16	0.27	0.53	-0.09
35-40	230	0.56	1.00	44	0.75	1.28	-0.28
40-45	461	1.12	2.12	61	1.04	2.32	-0.21
45-50	1264	3.07	5.19	117	2.00	4.32	0.86
50-55	2500	6.07	11.26	203	3.47	7.79	3.46
55-60	5212	12.65	23.91	285	4.87	12.66	11.24
60-65	3774	9.16	33.07	355	6.07	18.73	14.34
65-70	4848	11.77	44.84	548	9.37	28.10	16.74
70-75	5653	13.72	58.56	475	8.12	36.22	22.35
75-80	5365	13.02	71.59	820	14.01	50.23	21.35
80-85	5350	12.99	84.57	878	15.01	65.24	19.34
85-90	3297	8.00	92.58	663	11.33	76.57	16.01
90-95	1857	4.51	97.08	829	14.17	90.74	6.35
95-100	663	1.61	98.69	313	5.35	96.09	2.61
> 100	538	1.31	100.00	229	3.91	100.00	0.00
sum	41194			5851			

	Not passing			Passing			NP - P
	13 to 11	%	cum %	1 to 11	%	cum %	
<15	2	0.059506	0.059506	0	0	0	0.059506
15-20	0	0	0.059506	11	0.093673	0.093673	-0.03417
20-25	0	0	0.059506	11	0.093673	0.187346	-0.12784
25-30	1	0.029753	0.089259	13	0.110704	0.29805	-0.20879
30-35	0	0	0.089259	18	0.153283	0.451333	-0.36207
35-40	7	0.208271	0.29753	33	0.281018	0.732351	-0.43482
40-45	24	0.714073	1.011604	67	0.570553	1.302904	-0.2913
45-50	33	0.981851	1.993454	157	1.336967	2.639871	-0.64642
50-55	197	5.861351	7.854805	354	3.014562	5.654432	2.200373
55-60	273	8.122583	15.97739	561	4.777314	10.43175	5.545641
60-65	501	14.90628	30.88367	728	6.199438	16.63118	14.25248
65-70	0	0	30.88367	832	7.085072	23.71626	7.167409
70-75	718	21.36269	52.24636	1077	9.171421	32.88768	19.35868
75-80	904	26.89676	79.14311	1002	8.532743	41.42042	37.72269
80-85	0	0	79.14311	1022	8.703057	50.12348	29.01963
85-90	587	17.46504	96.60815	1336	11.37699	61.50047	35.10768
90-95	0	0	96.60815	2088	17.78081	79.28127	17.32688
95-100	0	0	96.60815	1413	12.0327	91.31397	5.294178
> 100	114	3.391848	100	1020	8.686026	100	0
sum	3361			11743			

Tables for gradient of difference between Cumulative percentage of vehicles which are passing and not passing the service area

	Not passing			Passing			NP - P	Gradient
	8 to 11	%	cum %	1 to 11	%	cum %		
<15	0	0.00	0.00	0	0.00	0.00	0.00	0
20	0	0.00	0.00	0	0.00	0.00	0.00	0.00
25	0	0.00	0.00	0	0.00	0.00	0.00	0.00
30	0	0.00	0.00	0	0.00	0.00	0.00	0.00
35	2	0.28	0.28	0	0.00	0.00	0.28	0.28
40	1	0.14	0.43	0	0.00	0.00	0.43	0.14
45	0	0.00	0.43	2	0.32	0.32	0.11	-0.32
50	4	0.57	1.00	11	1.75	2.06	-1.07	-1.18
55	9	1.28	2.28	6	0.95	3.02	-0.74	0.33
60	33	4.69	6.97	25	3.97	6.98	-0.01	0.73
65	48	6.83	13.80	23	3.65	10.63	3.16	3.18
70	95	13.51	27.31	45	7.14	17.78	9.53	6.37
75	116	16.50	43.81	60	9.52	27.30	16.51	6.98
80	66	9.39	53.20	54	8.57	35.87	17.33	0.82
85	144	20.48	73.68	50	7.94	43.81	29.87	12.55
90	82	11.66	85.35	65	10.32	54.13	31.22	1.35
95	82	11.66	97.01	118	18.73	72.86	24.16	-7.07
100	16	2.28	99.29	113	17.94	90.79	8.50	-15.66
> 100	5	0.71	100.00	58	9.21	100.00	0.00	-8.50
sum	703			630				

	Not passing			Passing			NP - P	Gradient
	14 to 12	%	cum %	4 to 11	%	cum %		
<15	2	0.03	0.03	3	0.03	0.03	0.00	0.00
15-20	2	0.03	0.06	4	0.03	0.06	0.00	-0.01
20-25	4	0.05	0.11	3	0.03	0.08	0.03	0.03
25-30	13	0.18	0.29	5	0.04	0.13	0.16	0.13
30-35	14	0.19	0.48	14	0.12	0.25	0.23	0.07
35-40	30	0.41	0.89	54	0.46	0.71	0.18	-0.05
40-45	91	1.24	2.13	97	0.82	1.53	0.60	0.42
45-50	269	3.66	5.79	187	1.59	3.12	2.67	2.07
50-55	330	4.49	10.29	334	2.84	5.96	4.33	1.66
55-60	1407	19.16	29.45	424	3.60	9.56	19.89	15.56
60-65	1209	16.47	45.92	656	5.57	15.14	30.78	10.89
65-70	1520	20.70	66.62	708	6.02	21.15	45.47	14.69
70-75	0	0.00	66.62	773	6.57	27.72	38.90	-6.57
75-80	1373	18.70	85.32	1269	10.78	38.51	46.81	7.92
80-85	848	11.55	96.87	1401	11.91	50.41	46.46	-0.36
85-90	0	0.00	96.87	2165	18.40	68.81	28.06	-18.40
90-95	197	2.68	99.55	1778	15.11	83.92	15.63	-12.43
95-100	0	0.00	99.55	1114	9.47	93.39	6.17	-9.47
> 100	33	0.45	100.00	778	6.61	100.00	0.00	-6.16
sum	7342			11767				

2. Survey data of speed of vehicles which have passed the service area.

In	Avg Speed	Stop or not	In	Avg Speed	Stop or not	In	Avg Speed	Stop or not
8.00-10.00			**12.00-2.00**			**6.00-8.00**		
Kadawatha	69	Yes	Kaduwela	97	No	Kottawa	95	No
Athurugiriya	80	No	Kottawa	57	Yes	Kaduwela	95	No
Kahathuduwa	77	Yes	Dodangoda	88	No	Kaduwela	94	No
Kahathuduwa	78	No	Kottawa	61	Yes	Kottawa	80	No
Kottawa	98	No	Gelanigama	91	No	Gelanigama	96	No
Kaduwela	92	No	Kadawatha	89	No	Gelanigama	92	No
Gelanigama	56	Yes	Kadawatha	81	No	Kadawatha	63	Yes
Kottawa	56	Yes	Athurugiriya	58	Yes	Athurugiriya	76	Yes
Gelanigama	52	Yes	Kottawa	113	No	Kottawa	46	Yes
Kaduwela	66	Yes	Dodangoda	72	Yes	Kahathuduwa	88	No
Kadawatha	88	No	Gelanigama	54	Yes	Kaduwela	85	Yes
Kadawatha	75	Yes	Kottawa	95	No	Gelanigama	61	Yes
Kaduwela	77	Yes	Kaduwela	75	No	Kottawa	76	Yes
Kadawatha	77	Yes	Kadawatha	94	No	Kadawatha	100	No
Kadawatha	82	Yes	Kottawa	92	No	Kottawa	80	Yes
Gelanigama	100	No	Kottawa	80	Yes	Kaduwela	75	Yes
Kadawatha	59	Yes	Kottawa	55	Yes	Kadawatha	73	No
Kottawa	85	No	Kothalawala	91	No	Gelanigama	71	Yes
Kadawatha	91	No	Kothalawala	91	No	Kottawa	96	No
Kottawa	91	No	Kadawatha	76	No	Kahathuduwa	69	No
Kadawatha	55	Yes	Kottawa	89	No	Kottawa	86	No
Kadawatha	83	Yes	Kaduwela	80	Yes	Athurugiriya	94	No
Kottawa	82	No	Kottawa	81	No	Kottawa	65	Yes
Kahathuduwa	91	No	Kadawatha	79	Yes	Kottawa	90	No
Kaduwela	80	No	Kadawatha	74	Yes	Gelanigama	91	No
Kottawa	85	No	Kottawa	60	Yes	Kadawatha	90	No
Kottawa	90	No	Kahathuduwa	104	No	Kottawa	81	Yes
Kaduwela	99	No	Kahathuduwa	84	Yes	Kottawa	80	No
Kahathuduwa	88	No	Kothalawala	97	No	Kottawa	96	No
Kottawa	88	No	Kottawa	93	No	Kottawa	56	Yes
Kadawatha	71	Yes	Kaduwela	77	Yes	Kaduwela	92	No
Gelanigama	62	Yes	Kadawatha	71	No	Kaduwela	92	No
Gelanigama	61	No	Kottawa	73	Yes	Kottawa	82	No
Gelanigama	97	No	Kottawa	97	No	Athurugiriya	89	No
Kottawa	96	No	Kottawa	98	No	Kaduwela	78	Yes
Kadawatha	78	No	Dodangoda	70	No	Kottawa	102	No
Kottawa	82	Yes	Gelanigama	76	Yes	Athurugiriya	92	No
Kadawatha	80	Yes	Kadawatha	121	No	Kottawa	73	No

Kahathuduwa	73	Yes	Kottawa	106	No	Kaduwela	45	No
Kadawatha	56	Yes	Kottawa	59	No	Gelanigama	88	No
Kahathuduwa	91	No	Athurugiriya	93	No	Dodangoda	76	Yes
Athurugiriya	73	Yes	Kadawatha	67	No	Dodangoda	85	No
Kadawatha	59	Yes	Kahathuduwa	94	No	Athurugiriya	91	No
Athurugiriya	89	No	Athurugiriya	81	Yes	Kaduwela	99	No
Kottawa	56	Yes	Kottawa	69	Yes	Kottawa	95	No
Kottawa	86	No	Athurugiriya	77	No	Galanigama		No
Kottawa	67	Yes	Kahathuduwa	95	No	kaduwela	77	Yes
Kottawa	72	Yes	Kahathuduwa	73	Yes	Kahathuduwa	87	No
Kadawatha	68	Yes	Gelanigama	92	No	kaduwela	92	No
Kottawa	99	No	Kottawa	95	No	Kottawa	91	No
Kottawa	87	No	Kottawa	104	No	Galanigama	80	Yes
Kaduwela	75	Yes	Kahathuduwa	96	No	Kottawa	89	No
Kadawatha	74	Yes	Gelanigama	76	Yes	kaduwela	71	Yes
Kadawatha	61	Yes	Kahathuduwa	89	No	Dodangoda	72	No
Kaduwela	93	No	Kadawatha	72	No	kaduwela	85	No
Athurugiriya	91	No	Kahathuduwa	92	No	kaduwela	96	No
Kottawa	64	Yes	kaduwela	78	Yes	Kottawa	92	No
Kahathuduwa	88	No	Kadawatha	85	Yes	Kottawa	68	Yes
Kadawatha	63	Yes	Kadawatha	78	No	Athurugiriya	83	No
Kadawatha	63	Yes	Kottawa	85	Yes	Kottawa	90	No
Kottawa	93	No	Kadawatha	69	Yes	Kottawa	83	No
Kadawatha	65	Yes	Kottawa	81	No	Athurugiriya	84	Yes
Kadawatha	97	No	Galanigama	85	No	Athurugiriya	78	No
Kadawatha	106	No	Kadawatha	70	Yes	Kahathuduwa	94	No
Kahathuduwa	19	Yes	Kadawatha	66	No	kaduwela	53	No
Kahathuduwa	82	No	Kadawatha	76	Yes	Kottawa	60	Yes
Kottawa	65	Yes	Kottawa	99	No	Kahathuduwa	87	Yes
Kottawa	90	No	Kottawa	54	Yes	Kottawa	79	Yes
Gelanigama	77	No	Kottawa	80	Yes	Kadawatha	75	Yes
Kaduwela	80	No	kaduwela	80	Yes	Kahathuduwa	63	No
Kadawatha	63	Yes	Kahathuduwa	88	No	Kottawa	88	No
Dodangoda	83	No	Athurugiriya	68	Yes	Kothalawala	91	No
Kottawa	80	Yes	Kottawa	90	No	Athurugiriya	100	No
Kottawa	65	No	Kottawa	60	Yes	Kahathuduwa	68	Yes
Kottawa	68	Yes	Kahathuduwa	73	No	Galanigama	76	No
Kottawa	91	No	Galanigama	59	No	Kottawa	46	Yes
Gelanigama	80	No	Kadawatha	66	Yes	kaduwela	73	Yes
Gelanigama	108	No	Athurugiriya	84	No	Kahathuduwa	94	Yes
Kaduwela	61	Yes	Dodangoda	73	No	Kahathuduwa	106	No
Kadawatha	87	No	Kothalawala	83	No	Kottawa	81	No
Kaduwela	85	No	Kottawa	87	No	Kottawa	97	No
Kahathuduwa	65	Yes	Kadawatha	85	No	Kadawatha	60	Yes
Kahathuduwa	62	Yes	Galanigama	86	No	Kadawatha	85	No

Kahathuduwa	57	Yes	kaduwela	60	Yes	Kadawatha	65	No
Kadawatha	60	Yes	Kottawa	89	No	Kottawa	92	No
Kahathuduwa	71	No	Kottawa	69	Yes	Kadawatha	50	Yes
Kadawatha	71	No	Kottawa	90	No	Kottawa	91	No
Galanigama	67	No	Kottawa	80	Yes	Athurugiriya	61	No
Kottawa	60	Yes	Kottawa	90	No	Kottawa	73	No
kaduwela	57	No	Kottawa	94	No	kaduwela	58	Yes
Khathuduwa	50	Yes	Kothalawala	86	No	Kottawa	99	No
Kadawatha	64	No	kaduwela	96	No	Kottawa	87	No
kaduwela	80	Yes	Kottawa	88	No	kaduwela	97	No
Kottawa	79	Yes	Galanigama	90	No	Galanigama	100	No
Kottawa	60	Yes	Dodangoda	88	No	Kottawa	97	Yes
Kottawa	92	No	Kottawa	84	Yes	Kothalawala	62	Yes
Kadawatha	104	No	Kottawa	60	Yes	Kottawa	64	Yes
kaduwela	68	Yes	Kadawatha	93	No	kaduwela	77	No
Kottawa	97	No	kaduwela	63	No	Kadawatha	76	No
kaduwela	84	No	kaduwela	82	No	Kahathuduwa	79	Yes
Athurugiriya	94	No	kaduwela	70	No	Kahathuduwa	67	Yes
Kadawatha	54	Yes	Kahathuduwa	78	Yes	kaduwela	83	No
Athurugiriya	78	No	Athurugiriya	81	No	Kottawa	88	No
Kadawatha	102	No	Kottawa	73	No	Kahathuduwa	65	No
Kadawatha	52	Yes	Kottawa	94	No	Athurugiriya	95	No
Galanigama	76	No	Athurugiriya	96	No	Athurugiriya	83	No
Galanigama	68	Yes	Kadawatha	89	No	kaduwela	60	Yes
Kothalawala	80	Yes	Kottawa	74	No	Kottawa	82	No
Galanigama	91	No	Kadawatha	76	No	Kadawatha	55	Yes
kaduwela	70	Yes	Dodangoda	90	No	Galanigama	61	No
Kahathuduwa	62	No	Galanigama	64	No	Kaduwela	72	Yes
Athurugiriya	115	No	Kottawa	85	Yes	Galanigama	78	No
Athurugiriya	63	Yes	kaduwela	84	Yes	Kaduwela	88	Yes
Galanigama	97	No	Kottawa	80	Yes	Kottawa	85	No
Galanigama	53	No	Galanigama	62	No	Kaduwela	62	No
Kadawatha	86	No	Kottawa	73	Yes	Kottawa	73	Yes
Kothalawala	83	No	Kahathuduwa	51	No	Kaduwela	43	Yes
Kahathuduwa	70	No	kaduwela	64	Yes	Kottawa	78	Yes
Kottawa	71	No	Dodangoda	61	No	Kaduwela	49	Yes
Kottawa	78	No	Kadawatha	72	Yes	Kadawatha	87	No
Kottawa	70	Yes	Kottawa	76	No	Kottawa	65	Yes
Athurugiriya	72	Yes	kaduwela	109	No	Kothalawala	79	No
Galanigama	100	No	Kahathuduwa	111	No	Kadawatha	60	No
Galanigama	67	No	Kottawa	86	No	Athurugiriya	41	Yes
Kahathuduwa	72	No	Kadawatha	76	Yes	Kottawa	90	No
Athurugiriya	64	Yes	Kadawatha	58	Yes	Kottawa	84	No
Kadawatha	86	No	Kahathuduwa	79	Yes	Kadawatha	81	Yes
Kottawa	82	No	Kadawatha	91	No	Athurugiriya	95	No

Kahathuduwa	65	Yes	Kadawatha	66	Yes	Kadawatha	65	Yes
Kottawa	102	No	Dodangoda	88	No	Kadawatha	64	Yes
Galanigama	83	No	Athurugiriya	71	No	Kadawatha	72	No
Kadawatha	99	Yes	Dodangoda	59	No	Athurugiriya	86	No
Kadawatha	72	Yes	Kottawa	95	No	Kaduwela	90	No
Kadawatha	63	No	Kottawa	83	No	Kothalawala	68	Yes
Kadawatha	81	Yes	Kahathuduwa	65	No	Kadawatha	61	Yes
Kadawatha	63	Yes	Kahathuduwa	87	No	Kadawatha	60	Yes
Kottawa	84	No	Kadawatha	62	No	Kahathuduwa	73	Yes
Athurugiriya	58	Yes	Kaduwela	72	Yes	Kadawatha	74	Yes
Kadawatha	62	Yes	Kadawatha	92	No	Kahathuduwa	73	No
Kadawatha	76	Yes	Kadawatha	58	Yes	Kottawa	91	No
Kadawatha	95	No	Kottawa	66	Yes	Kadawatha	74	No
Kahathuduwa	61	No	Kottawa	91	No	Kottawa	96	No
Galanigama	79	No	Galanigama	82	No	Kottawa	89	No
Kottawa	84	No	Kothalawala	86	No	Kahathuduwa	77	No
Kottawa	91	No	Kadawatha	75	Yes	Kadawatha	64	Yes
Galanigama	88	No	Kahathuduwa	62	Yes	Kottawa	91	No
Athurugiriya	89	No	Kottawa	92	No	Kadawatha	74	Yes
Galanigama	89	No	Kottawa	53	Yes	Kaduwela	86	No
Kottawa	83	No	Kottawa	53	No	Kadawatha	89	No
Kottawa	53	Yes	Kadawatha	100	No	Kottawa	91	No
Kottawa	84	No	Kadawatha	76	Yes	Kaduwela	65	Yes
Kothalawala	95	Yes	Galanigama	88	No	Kadawatha	81	No
Kadawatha	66	Yes	Kothalawala	84	No	Galanigama	77	No
Kothalawala	44	Yes	Kadawatha	57	Yes	Kottawa	90	No
Kadawatha	62	Yes	Galanigama	90	No	Kottawa	101	No
Kadawatha	93	No	Kottawa	92	No	Kottawa	95	No
Kadawatha	66	Yes	Kaduwela	99	Yes	Kottawa	71	Yes
Kadawatha	91	No	Galanigama	65	No	Kottawa	95	No
Kadawatha	76	No	Kottawa	66	Yes	Kadawatha	92	No
Kadawatha	58	Yes	Kadawatha	59	Yes	Kahathuduwa	53	Yes
Kottawa	98	No	Kothalawala	96	No	Galanigama	76	No
Dodangoda	58	Yes	Kottawa	80	Yes	Kadawatha	83	No
Kottawa	89	No	Kottawa	80	Yes	Kothalawala	45	Yes
Galanigama	74	No	Kadawatha	78	No	Kaduwela	41	Yes
Athurugiriya	61	Yes	Kadawatha	58	Yes	Kottawa	90	No
Galanigama	88	No	Kahathuduwa	49	Yes	Kahathuduwa	75	No
Kadawatha	92	No	Galanigama	102	No	Kaduwela	70	Yes
Kadawatha	66	No	Kadawatha	80	Yes	Athurugiriya	103	No
Kaduwela	64	Yes	Kadawatha	97	No	Kottawa	79	Yes
Kaduwela	69	No	Kadawatha	97	No	Kahathuduwa	53	Yes
Kadawatha	67	No	Kadawatha	69	Yes	Galanigama	76	No
Galanigama	83	No	Kadawatha	91	No	Kadawatha	83	No
Kadawatha	61	Yes	Kadawatha	71	No	Kothalawala	45	Yes

Dodangoda	75	No	Kottawa	90	No	Galanigama	88	No
Kadawatha	56	No	Kaduwela	79	Yes	Kothalawala	84	No
Galanigama	71	Yes	Kadawatha	55	Yes	Kadawatha	57	Yes
Dodangoda	101	No	Dodangoda	61	Yes	Galanigama	90	No
Kadawatha	96	No	Kadawatha	85	No	Kadawatha	91	No
Kottawa	73	Yes	Kottawa	84	No	Kadawatha	76	No
Kottawa	60	Yes	Kadawatha	65	No	Kadawatha	58	Yes
Kottawa	84	Yes	Kaduwela	70	Yes	Kottawa	98	No
Kahathuduwa	75	No	Kottawa	91	No	Dodangoda	58	Yes
Kadawatha	84	Yes	Kaduwela	96	No	Kottawa	89	No
Kadawatha	66	Yes	Kadawatha	88	No	Kottawa	73	Yes
Kahathuduwa	97	No	Kaduwela	95	No	Kottawa	60	Yes
Kottawa	56	Yes	Kottawa	64	Yes	Kottawa	84	Yes
Kahathuduwa	73	Yes	Kadawatha	62	No	Kahathuduwa	75	No
Kadawatha	53	Yes	Kottawa	76	Yes	Kadawatha	84	Yes
Kadawatha	63	No	Kottawa	81	Yes	Kadawatha	66	Yes
Kaduwela	60	Yes	Kahathuduwa	84	No	Kottawa	97	Yes
Kadawatha	76	No	Kottawa	54	Yes	Kothalawala	62	Yes
Kadawatha	60	Yes	Kottawa	88	Yes	Kottawa	64	Yes
Kottawa	90	No	Kottawa	89	No	kaduwela	77	No
Athurugiriya	67	No	Kadawatha	107	No	Kadawatha	76	No
Athurugiriya	105	No	Kadawatha	62	Yes	Kahathuduwa	79	Yes
Galanigama	67	No	Total	195		Kahathuduwa	67	Yes
Dodangoda	91	No				Kadawatha	77	Yes
Kaduwela	93	No				Kadawatha	82	Yes
Kottawa	63	No				Gelanigama	100	No
Kottawa	99	No				Kadawatha	59	Yes
Kaduwela	77	No				Kottawa	85	No
Kottawa	88	No				Kadawatha	91	No
Kottawa	96	No				Kottawa	91	No
Kottawa	69	Yes				Total	202	
Dodangoda	96	No						
Galanigama	87	No						
Dodangoda	96	No						
Kaduwela	25	Yes						
Athurugiriya	95	No						
Kahathuduwa	82	No						
Athurugiriya	93	No						
Dodangoda	60	Yes						
Kaduwela	81	No						
Kadawatha	94	No						
Kottawa	66	No						
Kahathuduwa	78	No						
Kottawa	73	Yes						
Kaduwela	88	No						

Kahathuduwa	107	No
Kadawatha	78	Yes
Galanigama	80	No
Galanigama	72	Yes
Kottawa	76	No
Kadawatha	81	No
Kottawa	97	No
Total	225	