

**EVIDENCE BASED FUND ALLOCATION SYSTEM FOR  
PROVINCIAL ROAD NETWORKS IN SRI LANKA**

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168334V

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DECLARATION OF THE CANDIDATE AND THE SUPERVISOR

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...

## **ABSTRACT**

Sri Lanka has faced an unprecedented economic crisis during the year 2022 and the entire infrastructure development sector is now experiencing severe adverse effects. Under prevailing conditions, a cost-effective fund allocation system for all infrastructure development activities has become a mandatory requirement. Road infrastructure plays a pivotal role in sustainable development by providing required facilities for all other sectors. It can be shown that more benefits could be derived from the provincial and rural road improvement projects and road maintenance works if the funds are allocated in a scientific and logical manner.

Provincial road development planning needs more research and the main objective of this research paper is to fill at least part of the widening gap between economic aspects and the technical matters related to the development of the provincial roads. Unlike trunk roads and other high-mobility roads, provincial and local roads mainly serve a predefined population group living in the command area. However, those people living in the command area do not enjoy the benefits of a proper transport system mainly due to the substandard condition that prevailed on the roads. This can be directly attributed to the ineffective fund distribution among the provincial roads. The proposed fund allocation system is based on benefits-assets criteria.

Finally, it can be shown that net annual financial benefits derived from a single person living in the command area per km, is more than 500 LKR. In addition to trips generated by the people living in the command area, tourist destinations and industrial and agricultural areas are also served by the provincial roads. Part of provincial roads is used as shortcuts by minimizing the traffic congestion on the main roads.

Implementing Evidence-based fund allocation for provincial roads makes a strong foundation for sustainable economic development. This research deals with the development of a cost-effective fund allocation system for the provincial road system in Sri Lanka.

Key Words: Provincial, Roads, Evidence, Fund Allocation, Sustainable, development,

## **DEDICATION**

Who made every possible attempt to make my life successful specially my teachers,  
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## LIST OF ABBRIVIATINS

<b>Abbreviation</b>	<b>Description</b>
AADT	Average Annual Daily Traffic
ADB	Asian Development Bank
CBG	Criteria Based Grant
DVA	Direct Vehicle Access
FAO	Foods and Agriculture Organization
FPA	Foot Path Access
GND	Grama Niladari division
IMF	International Monetary Fund
IRI	International Roughness Index
IRR	Internal Rate of Return
JICA	Japan International Corporation Agency
KPI	Key performance Indicators
LGR	Local Government Road
LR	Local Road
NTC	National Transport Commission
PCU	Passenger Car Unit
PFC	Public Finance Commission
PSDG	Provincial Specific Development Grant
RDA	Road Development Authority
SDG	Sustainable Development Goals
SPC/SPMR	Sabaragamuwa Provincial Council/Ministry of Roads
RDA	Road Development Authority
TCAMP	Transport Connectivity Assets Management Project
UN	United Nations
VOT	Value of Time
WB	World Bank

## **CHAPTER 1: Introduction.**

### **1.1 General Background**

Provincial and rural roads play a pivotal role in facilitating connectivity for rural communities by providing access to health, education, markets, and other social needs. Provincial roads mainly serve the rural and suburban communities by connecting those beneficiaries to the National Road network. As far as Sri Lanka is concerned, the rural and suburban population is more than eighty percent (Finance Commission Annual report,2018).

Transport infrastructure development and management is one of the most important areas in the sustainable development process. Around 97% of freight movements are handled by road transport (NTC data book-2015). *United Nations* [UN] has already defined seventeen Sustainable Development Goals [SDG] so that the entire world community would be able to enjoy desired benefits in the year 2030 (United Nations SDG Policy document -2017).

United Nations SDG Goal-9 describes building resilient infrastructure, promoting inclusive and sustainable industrialization, and foster innovation while Goal-11- deals with making cities and human settlements inclusive, safe, resilient, and sustainable, and substantially dealing with road infrastructure development. All other development goals have a link with road infrastructure development. The Sri Lankan Government also acknowledged the UN resolution passed on July 06, 2017. The Ministry of Sustainable Development was established in the same year (2017) to safeguard the local and global needs of the country. Even though the Ministry of Sustainable Development no longer exists, SDGs are still applicable in Sri Lanka irrespective of the legal provisions.

SDG Goal 09 defines the term all season roads. According to the definition, all-season roads should be available for transport activities throughout the year without any interruption. Most of the developed nations enjoy the benefits of all-season roads. As far as Sri Lanka is concerned, part of the roads are vulnerable to frequent natural disasters. Provincial roads in the hilly terrains are more vulnerable for landslides while certain parts of provincial roads in the flat terrains inundate during the rainy seasons.

The concept of motorable roads is more applicable to Sri Lanka. As far as Sri Lanka is concerned most of the rural roads can be considered as all-season roads over ninety five percent of reliability.

The main indicator for all sub-goals defined under the main SDG goal nine is the proportion of the rural population who live within 2 km distance from an all-season road. A detailed study carried out in Sabaragamuwa Province under this research, reveals that more than 99 % of the population resides within the specified distance range. However, rural communities should be provided with easy access to the national road network and the main city centers by improving the secondary and local roads.

The other important factor is passenger and freight volumes by mode of transport. As far as the rural area of Sri Lanka is concerned, the most common transport mode is the road transport system. Navigation canals and railway lines provide transport facilities for very little rural population in Sri Lanka. Therefore provincial and local roads are considered as the most appropriate and technically feasible solutions available for rural transportation.

Donor agencies such as World Bank [WB], Asian Development Bank[ADB], International Monetary Fund [IMF]and other developed countries-based funding organizations grant soft loans for road infrastructure development projects in Sri Lanka and other developing countries. During the last two decades, Sabaragamuwa provincial road agencies were granted soft loans amounting to 200 million US\$.

The island-wide road network consists of a large number of provincial roads and local roads Under the following chapters, it can be shown that funds allocation to maintain different road segments are not proportional to the benefits derived.

RDA has carried out various research related to road infrastructure development with the help of local expertise and foreign funding agencies. However, very little research has been carried out regarding provincial roads.

United Nations Sustainable development goal 9.5 describes the enhancement of scientific research and upgrading of technological capacities in developing countries. The main indicator is defined as research and development expenditure as a proportion of GDP in-full time equivalent per million inhabitants. There are about 10 million citizens in Sri

Lanka, those who are served by the provincial roads (This result is verified under chapter 4).

As per the national transport policy drafted over the last 10-15 years, It is very important to discuss the economic policies, Social principles, and particularly transport facilities in rural and plantation areas. The government will have to take proactive steps to identify the quantity and quality of transport services that would adequately meet existing and potential demand for the movement of goods and passengers that would support a vibrant economy and a contented society. The government will have to take all possible steps to ensure that such services are made available to the users at the desired level of service and at the least cost to the government.

-Transport should not be considered purely as an economic commodity. It will have to be evaluated on its social impacts, particularly in terms of equity and equal accessibility for all people. Policy aiming at ensuring a minimum level of mobility required to meet the right of every citizen to have access to their basic needs is required. Furthermore, it is necessary to pursue the provision of transport services that will promote equitable socio economic growth across all geographical boundaries. (NTC data book-2012)

Rural Transport refers to transport infrastructure & services that link rural and estate areas to the nearest service center.

1. To fund the development and introduction of a suitable vehicle designed for the carriage of both goods and passengers exclusively on roads in remote areas.
2. To set up Community Based Transport Monitoring Committees to monitor and report the quality of services provided under the rural transport program.
3. To facilitate a regular system of mobile public consultations in rural areas to determine transport needs and to engage in facilitating the design and provision of services to satisfy such demands.

However, Covid -19 pandemic has created severe adverse effects on the sustainable development of Sri Lanka. (Central Bank Annual Report -2020) Public finance management plays a vital role under the prevailing condition and more funds must be utilized for the health sector. As such implementing evidence-based funds allocation systems for all infrastructure development has become a current need of the country in order to mitigate the burden on the national economy.

## **1.2 Research and Development work related to highway project planning**

South Korea is the country with the highest per capita research and development expenditure of US\$ 1936 (List of Countries by research and development spends- Wikipedia, 2022) and USA has been recognized the country with the highest per capita R&D expenditure in the field of highway construction.(Jayawickrama,2010). Research related to the highways planning, design and construction are very useful in the sustainable development process. In most of cases expenditure incurred for a research project can be recovered by means of output and outcomes within a very short time period. (Jayawickrama, 2010).

Research projects related to the Provincial road works are very limited in Sri Lanka and this research project can be considered as one of the few comprehensive research carried out in the field of fund allocation for provincial and local roads.

Finally, these research project outcomes may be useful for the formulation of general fund allocation criteria for the entire provincial road sector. However, this research project is carried out on an academic basis and research project outcomes will be very much useful to the Public Finance Commission[PFC], Sabaragamuwa Provincial Council[SPC] and other provincial and local roads authorities.

Class C Provincial roads are categorized under the highways while class D roads with single lane shall be treated as distribution roads. (National Thoroughfares Act No 40, 2008)

National Thoroughfare act also described the technical parameters related to both class C &D provincial roads even though the act mainly deals with national roads. Since there are no statutes passed by the most of provincial councils ,the Motor traffic act and National Thoroughfares act (2008) are empowered in the provincial councils. There are difference and similarities between the provincial roads and National roads. Low traffic volume and substandard design are the main differences between the national and local roads.

If daily traffic volume is less than 300 PCU, those roads are treated as low traffic volume roads. (Geometric Design Standard of Road Development Authority[RDA], 2008). During the last few years, low volume roads were improved without carrying out proper feasibility studies. This may be considered as a wastage of public money. There are some

provincial roads that belong to the low traffic volume category. However, middle level class C and D roads were partly neglected due to the lack of interest shown by the relevant authorities and the irrational method adopted.

As such it is necessary to pay more attention on Class C & D roads. PFC normally recommends an annual grant for provincial road development works, based on the request made by the provincial ministry of roads. Treasury release the funds based on the recommendation given by the PFC. During the year 2019, there was a request made by PFC to work out realistic fund allocation criteria based on the scientific research. The other important factor is PFC was interested about the technical matters related to the provincial roads like population percentage served by the provincial and local roads. This research paper substantially fulfills the requirements of the PFC, regarding the provincial roads. Research findings may be circulated to the other provinces and local authorities so that they will be able to maintain the provincial road network more efficiently. In order to achieve this goal current fund allocation system has to be reviewed.

### **1.3 Research Objectives**

The main objective of this study is to highlight the importance of provincial and local roads in Sri Lanka and formulate a more cost effective fund allocation criterion for the provincial and local road networks based on the scientific analysis.

### **1.4 Scope of the study**

This research projects mainly deals with formation of realistic and cost effective fund allocation criteria for the Sri Lankan provincial road network. However, scope of the case study is limited to the Class C and D roads in Sabaragamuwa province and the output of the research may be extended to the other provinces.

### **1.5 Research Problem**

Even though provincial roads serve a comparatively less number of people and traffic volume is less compared to National roads, the total length of provincial roads is nearly 150% of the RDA road length and the socio-economic impacts of both the provincial roads system and RDA roads network play a vital role in the sustainable economic development process

It can be shown that the costs incurred for provincial and rural road maintenance and improvement works are not sufficient when compared to the national roads. (Finance commission, 2000). As a result of aforesaid inequality, most of the secondary and tertiary level roads are not properly maintained which has resulted in active discrimination between provincial and urban road users, resulting in severe adverse effects on the quality of the life of the secondary level road users, ultimately creating a negative socio-economic impact on the entire country.

## **1.6 Research area**

This research is initially confined to the case study which involves the preparation of a fund allocation system for the provincial road network. There is a very sensitive economic indicator namely the population percentage served by the provincial and other roads, which will be determined by this research. The second part of this research deals with the formulation of general fund allocation criteria for all provincial roads.

## **1.7 Research Methodology**

Population percentage served by the provincial roads is determined by an interview, Google satellite images, and survey. In the second part of the research, the benefits derived and the asset values of all road segments are determined. A tentative fund allocation criterion is formulated based on the benefits derived and asset values. Fundamentally developed fund allocation criteria are verified by means of the case study and conclusions and recommendations are made accordingly.

## **1.8 Structure of the report**

Chapter 1: Introduction. This chapter describes the general background upon which this study is based.

Chapter 2: Literature Review. This chapter describes the present situation of the research area and further reviews available literature, PFC recommendations, pavement management theory, and IRI measurement in provincial roads.

Chapter 3: Methodology for the case study and Outline the case study

This chapter describes the practical application of the theory, related to the provincial roads. Network theory and basic economic theory are used to develop the basic fund allocation criteria. Tentative fund allocation criteria is developed at this stage.

Chapter 4: Case Study: Formulation of funds allocation criteria for Sabaragamuwa Province

In this chapter, data related to the large sample of data pertaining to the Sabaragamuwa provincial roads network was summarized and tabulated. Finally, results are analyzed to verify the funds allocation criteria.

Chapter 5: Interpretation of results and Formulation of general funds allocation criteria for Sabaragamuwa Provincial road network based on the statistical analysis. The results of this chapter are used to make necessary recommendations and conclusions.

Chapter 6: Conclusion and Recommendation, This chapter summarized the research findings, and recommendations are made accordingly

## **CHAPTER 2: Literature Review**

### **2.1 Introduction**

The literature review consists of five sub-sections and the main research is partly based on the findings of the literature review. Under the first sub-section existing fund allocation method is reviewed and the second section review available publications related to the common subject results based monitoring and evaluation system. This step is very important in the formulation of Evidence based funds allocation criteria. Defining the key performance indicators and other relevant parameters are identified at this stage. Third section deals with the PFC publications. Fourth section deals with the pavement management theory related to the provincial roads. The final sections of this chapter describe the importance of routine maintenance and practical methods available for evaluation of pavements condition particularly IRI value measurement in the provincial roads.

### **2.2 Present funds allocation system in Sri Lankan Provincial Roads**

Fund allocation for Provincial road maintenance and improvement works is carried out in two stages namely, working out the total fund requirement and distribution of funds among the different roads. As far as general fund allocation methods are concerned there are pre-defined guidelines. PFC recommendation report analyzes most of the non-technical parameters and conclusions are made accordingly (PFC–Recommendations to the H.E president (2016-2021) .

There were no comprehensive technical based studies carried out related to the provincial roads subject. As a result of the non-availability of a scientific method, for the distribution of the funds among the different roads, very few demonstrable results were obtained. Although the results presented in this research and other research are case specific, the approach documented in all papers may be used to prioritize similar roads in other regions. (Pal,Maitra,Sarkar,2016)

Due to the shortage of money, parts of the roads were selected for maintenance work. As far as Sabaragamuwa province is concerned more than eighty percent of the roads were not included in the annual maintenance program (Provincial road ministry annual program,2021). It can be shown that the negligence of routing maintenance has severe adverse effects on the system by increasing the next year maintenance cost drastically. The other crucial factor is the total fund allocation is determined by considering the availability of funds.

### **2.2.1 Present fund allocation system practiced in Sabaragamuwa Province.**

This paragraph analysis the present fund allocation system used in Sabaragamuwa Province. It can be shown that no scientific criteria is involved in this process. Funds allocation for Sabaragamuwa Provincial Ministry of Roads[SPMR] 2010-2022 are given in table 2.1

**Table 2. 1: Funds allocation for Sabaragamuwa provincial Roads**

Year	Recurrent Budget LKR		Capital Budget		Foreign Funded Projects Equivalent LKR Millions			Other Sources LKR Millions		
	1	2	1	2	Source	1	2	Source	1	2
2010	210	200	250	241	JICA	4,150	1,950	MED	4,000	550
2011	220	223	260	242	JICA	4,000	4,750	MED	5,000	2,750
2012	303	244	275	275	JICA	2,000	3,750	MED	4,000	6,750
2013	303	282	275	283		-	-		2,000	4,550
2014	389	364	383	383		-	-		2,000	1,550
2015	424	375	334	551		-	-		1,000	450
2016	433	582	540	658		-	-	I Roads	1,000	350
2017	275	259	240	609	Flood D	250	250	I Roads	1,000	550
2018	572	532	540	408	TCAMP	100		I Roads	-	450
2019	657	507	573	309		1,000			-	-
2020	610	604	304	296		600			-	-
2021	706	455	713	350		-	200		-	-

Year	Recurrent Budget LKR		Capital Budget		Foreign Funded Projects Equivalent LKR Millions			Other Sources LKR Millions		
	1	2	1	2	Source	1	2	Source	1	2
	2022	613		370			-	600		-
Total	5,715	4,627	5,057	4,605		12,100	11,500	-	20,000	17,950
1. Budget					2. Actual Expenditure					

Source : Annual Budget of Sabaragamuwa Province 2010-2022

### 2.2.1.1 Reviewing Negative impacts of the present system

Based on the above information, it is very clear that fund allocation for maintenance works is not sufficient. The other important factor is that there is no rational selection criterion for the capital investment program. Initial Environmental investigations and feasibility studies were carried out for foreign-funded projects under the guidelines given by the respective donor agencies. Initial Environmental investigations are essential for medium scale improvement projects. In addition to this Environmental Impact Assessment [EIA] was carried out for large-scale new projects.

During the last twelve years, 9,232 million LKR were spent for road maintenance and improvement works by the SPMR and nearly 14,000 million LKR were spent by the Ministry of Economic Development. Another 11,500 million LKR approximately equal to 90 million US\$ were spent as Foreign funds. It can be shown that more benefits could be derived if proper funds allocation system was adopted. However, nearly 200 km length of roads out of 2625 km total length, has been in very poor condition.

This gives a clear indication that present funds allocation criteria have to be revised in order to face real economic challenges under the most unfavorable circumstances.

### 2.2.1.2 Reviewing the positive impacts of the present system

General keeping up works of provincial roads, were initially carried out by using the direct labour method. However, it was found that the direct labour method is not cost effective in most of the construction and maintenance works, mainly due to the weakness in labour management. Provincial roads are scattered over a large area and transport of labours and supervisors to the respective workplaces incurred very high overhead costs.

In order to overcome this situation, Sabaragamuwa Provincial Engineering services department launched a pilot project for implementing the section labour contract method for general keep up works. One kilometer-long road segments were identified as measurable units. Weed control, cleaning culverts, reducing high sides and routine observations and reporting works, were handed over to the interested individuals living in the same area by means of a six month contract agreements. Details are given in table 2.2

Table 2. 2: Detail of Section labor expenditure statement 2017-2022

Year	Annual Rate per km segment LKR	Number of km Selected	Actual Cost LKR
2017	60,000	200	12,000,000
2018	65,6000	400	26,000,000
2019	72,000	400	28,800,000
2020	75,000	300	22,500,000
2021	78,000	300	23,500,000
2022	90,000	300	27,000,000

Source : Provincial Engineering services Department approved rates

It can be shown that the entire road network can be maintained at a cost of 250 million LKR per year and this will provide employment opportunities for nearly 500 people and no foreign funds are required for this purpose. People living in the surrounding areas shall be awarded the section labour contracts thus minimizing the transport cost. Due to the prevailing economic crisis in the Sri Lanka, there is an acute shortage of foreign currency. Therefore labour intensive methods for road maintenance works should be encouraged and there is a very high potential to develop this method.

### **2.3 Evidence Based Monitoring and Evaluation system**

Evidence based project planning implementation and evaluation method is commonly used in infrastructure development projects. Fund allocation is the most important step in the case of project planning. As far as road infrastructure development projects are concerned, people living in the command area act as the main stakeholders. The main responsibility of the implementing authorities is to provide a satisfactory service to the

beneficiaries. As such evidence-based fund allocation system has to be formulated for all government organizations (PFC Annual report,2020).

Results based monitoring and evaluation system shall be effectively used in Engineering, Agriculture, Health, and various other sectors. Public Finance Commission [PFC] generally use the Results Based Evaluation system for all sectors. As far as the Provincial Councils are concerned, the annual budget is prepared based on the recommendations given by the PFC.

### **2.3.1 Role of PFC in fund allocation process**

PFC is a government organization responsible for allocating the government funds for infrastructure development projects and monitoring both capital & recurrent programs in Sri Lanka.

PFC grant is meant for financing capital nature development projects paying special attention to infrastructure development under different devolved subjects. Upon the receipt of provincial development plans, prepared by provincial planning divisions. Fund allocation programs are reviewed, and the consensus is reached with some revisions based on the discussions with provincial authorities. The provincial development plans should be aligned with the national policy framework while addressing provincial needs. For each investment, measurable results (output, outcome) need to be identified in the form of pre-defined indicators to facilitate periodical monitoring and evaluation of achievements, adopting a Results Based Monitoring and Evaluation System. (PFC recommendation report,2019) Even though the aforesaid clauses describe fundamental theory related to funding allocation, the existing fund allocation method has to review based on the learning lessons as described in paragraph 2.3.2. This is a cyclic process and this research finding may be useful in formulating a more efficient fund allocation system for the provincial roads sector. In other words, it is necessary to bridge the gap between technical aspects and the present fund allocation system.

### **2.3.2 Evidence Based Monitoring and Evaluation**

Many books describe fundamental theory related to the main research area. The following line process is called results chain and results which consists of five links as

shown below. This is initially applicable to the case study and finally results may be extended to the entire provincial road network. (Spreckly ,2009)

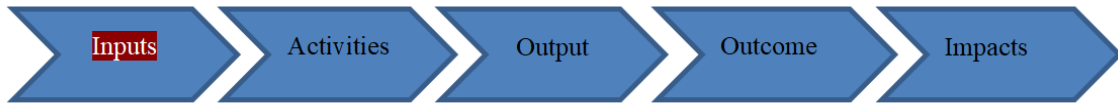


Figure 2. 1: Results Chain

Adopted from Results Based Monitoring and Evaluation toolkit-2009

Most of the researches make use of the previous research finding and there is a continuous technological advancement taking place. Cost effectiveness of infrastructural development projects may be directly attributed to technological advancement taking place. In other words, both ends of the results chain have to be connected to form M&E cycle. Therefore results based monitoring and evaluation system shall be considered as the walkway to successful endless journey (Spreckly, 2009). After completion of first few activities there may be desired outputs and outcomes. However, during the each cycle inputs and activities has to be reviewed in order to achieve better results as described in Figure 2.2

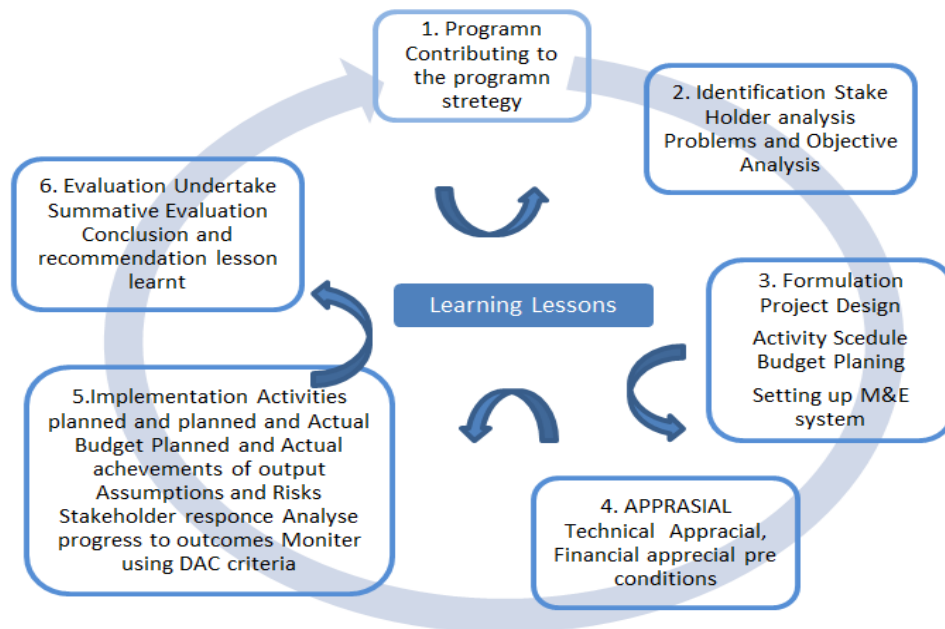


Figure 2. 2: Results Based Monitoring and Evaluation Cycle

Adapted from Results Based Monitoring and Evaluation toolkit (2009)

Provincial councils were established under the 13<sup>th</sup> amendment to the constitution in 1987. Provincial Roads was identified as a devolved subject and during the last 34 years' time periods, there were so many programs and learned lessons. However, very few attempts have been made to incorporate the past experience as described in the monitoring cycle. Technical advancement in the provincial road sector is very small compared to the RDA which was established in the same decade.

World Bank guidelines and recommendations are mainly intent for the borrowers. As such World Bank publications provide comprehensive guidelines which may be used for both local & foreign funded projects.

Ten steps have to be followed in the results based monitoring and evaluation system in accordance with World Bank guidelines (Kusek & Crist, 2005). Those steps are given in the figure 2.3 and it is further described in table 2.3.

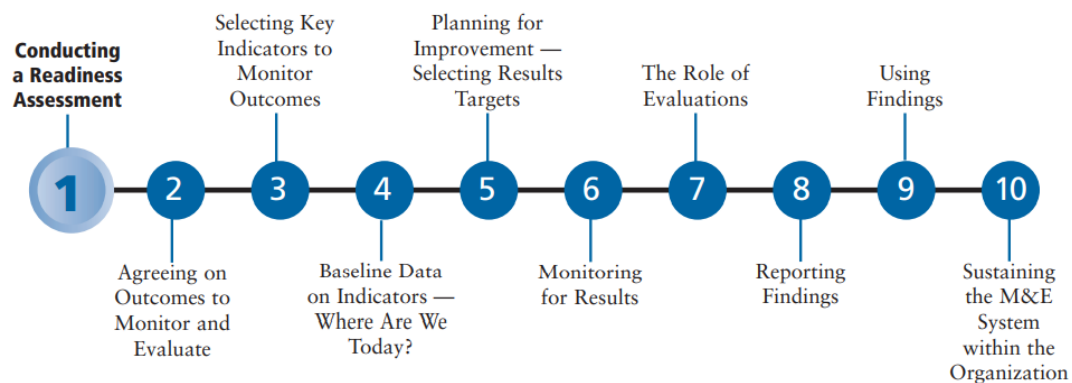


Figure 2. 3 Ten Steps in the results based M&E system

Adopted from Result-Based Monitoring and Evaluation system (2009)

New public management tool, the Results Based monitoring and Evaluation system was introduced by the WB via the above publication. This guideline gives necessary instructions to all government institutions so that all developing nations shall be able to plan their activities with increased public accountability, better governance and demonstrable results (Kusek & Crist, 2005).

This research “Evidence Based fund allocation system for Provincial Road network system shall be considered as a part of the Results Based M&E system. In fact, this research covers the technical aspects which shall be used for the national level planning.

### 2.3.3 Practical application of World Bank guidelines

This research is structured as per the World Bank guidelines. Relevant chapters and applications are given in the table number 2.3

Table 2. 3 Structure of the research paper in accordance with World Bank guidelines.

No	Step definition as described in the World Bank Guidelines	Relevant Chapters	Relevant application in this research paper
1.	Conducting a Readiness Assessment	1,2,3	Formulation of the research topic and problem outline the case study
2.	Agreeing on outcomes to monitor and evaluate	3,4,5	Overall performance of the Provincial Road network system in Sri Lanka Economic benefits to the country
3.	Selecting Key Performance Indicators [KPI]	2,3	Economic benefits due to cost saving Socio economic benefits to roads users Value of time saving & Level of service
4.	Selecting Baselines and gathering Data on indicators	3,4	Population served by each road segment Land Prices ,Carriageway width and present worth of following items Cost of Earthworks, pavements system Drainage system & Bridges Observed and predicted IRI values Level of service present value
5.	Planning for improvements- Selecting Results targets	3,4,5	Routing maintenance program Capital investment program for the next two decades Planning the activities in collaboration with Finance commission.

No	Step definition as described in the World Bank Guidelines	Relevant Chapters	Relevant application in this research paper
6.	Monitoring for Results	2,4,5,	Monitoring long term outcomes Learned lessons will be very important in this trial and error process. Monitoring the output of the optimization equation.
7.	The E in M&E – Using Evaluation information’s to support a Results based management system	4,5,6	Effects of heavily loaded trucks on Provincial roads. Non availability of ROW in the roads Land acquisition plans
8.	Reporting the findings	4,5	Population and area percentage served by the provincial roads Other parameters like ROW, Land acquisition cost and cost effectiveness of pavements. Introduce the proposed provincial roads management system.
9	Using the findings	5,6	Design suitable cross Sections for the roads Design the alternative structure to suit the actual conditions.Design the pavements to suit the subgrade soil properties and traffic loads Determine the land acquisition plan Introduce the other utilities incorporating system
10.	Sustaining the M&E system within the Organization	2,6	Learned lesson and amendment to fund allocation system Introduce cost effective pavement management system

It is necessary to make reasonable assumptions in the formulation of the funds allocation criteria. Even though funds allocation is described under the stage three of the main cycle, the entire cycle is governed by the fund allocation component (Kusek & Rist,2005).

Integrated rural & urban development project planning and implementation is now very popular in the developing nations. Provincial roads, national roads, water supply system, power distribution system and part of the irrigation canal system and irrigation reservoirs are in network systems which share the available space in the road network system. Initially the road network system had to be finalized making provisions for other public utilities (Integrated rural development project [IRDP] project report for Sabaragamuwa Province,1992).

New Road construction and improvement works normally implemented on project basis. World Bank[WB], Asian Development Bank[ADB], Japan International Corporation Agency[JICA] other foreign sources funds those projects. Most of the donor agencies release the funds under soft loans and certain projects are pure grants. (World Bank Guidelines-2020)

Project management theory shall be used in the capital investment projects. However, road maintenance is equally important, and all maintenance works carried out by utilizing the local funds. Proper maintenance works shall be able to minimize the rehabilitation cost.

Despite the UN and donor agencies guidelines, Sri Lanka has to develop our own blueprints and strategic plans to achieve the desired goals.

#### **2.3.4 Key Performance indicators of the research project**

According to the general definition key performance indicators are specific and measurable. After the completion of the research project there should be a positive change in most of the indicators. As far as this research project is concerned, there are two types of indicators presence namely socio-economic indicators and technical based indicators. Economic indicators are specific and measurable. However, most of the social and environmental indicators are not measurable. Therefore indirect indicators are used to

evaluate social impact. Number of complaints received by the implementing agency may be treated as an indirect performance indicator.

Key performance indicators (Economic based)

1. Increase in per capita household income before and after implementation of the project
2. Reduction in Maintenance cost per 1 km road segment
3. Value of time saving in each road segment per year
4. Reduction in migration to the city centers persons per year

Key performance indicators (Technical based)

1. Reduction in maintenance unattended road segment as a percentage of total length
2. Increase in vehicle moving speed per each road segment
3. Increase/decrease in fatal and minor accidents (accident per km segment per year)
4. Increase in IRI score (Reduction in IRI values) as described in the

Performance indicators (Indirect)

1. Reduction in complains received by the implementing agency (complains per year per road/road segment)
2. Increase in land prices
3. Increases in tourist trips by using the provincial roads
4. Reduction in traffic congestion in the main roads

## **2.4 Reviving the general funds allocation criteria proposed the PFC and Central Bank**

### **2.4.1 Present Economic Status of the Country**

Sri Lanka was among the countries with the fastest economic growth rate until 2017. GDP was reaching the limit of 4000 US\$ per person with government revenue over 1800 Billion LKR. (Central bank- Annual report, 2016) There is a well-known fact that passing the GDP margin of US\$ 4000 per person, shall be considered as an economic barrier for any developing country, even under the most favorable circumstance. Under the prevailing condition, Sri Lankan government is facing a real challenge of allocating the limited funds for different developments projects

As a result of aforesaid developments, gross official reserves increased up to US dollars 7.6 billion by end September 2019 from US dollars 6.9 billion at end of 2018(Central Bank Annual Report 2017-2020). Lankan Rupee was quite stable against the other foreign currencies until March 2020 (Central bank- annual report, 2019).

COVID 19 pandemic had severe adverse effects on the economy by reducing the gross official reserves up to 4.5 billion US\$ at the end of September 2021. Health sector expenditure increased dramatically while there was a drastic decrease in GDP. At the end of year 2021 gross official reserves drop up to 1.5 billion US\$ and depreciation of LKR continues (Central bank- Annual report, 2021).

The Government's plans to reduce the budget deficit over the medium term remain critical in ensuring macroeconomic stability and the sustainability of public debt in the period ahead (Central bank- annual report, 2020).

After successful control of COVID -19 Pandemic, foreign currency reserves depleted rapidly and at the end of March 2022 liquidated foreign currency reserves became zero resulting in very high inflation rates.

This will have significant adverse effects on the entire construction industry. Most of the capital investment projects had already been temporarily suspended.

#### **2.4.2 Contribution to the Social welfare by means of infrastructure development**

Living standard of the provincial community substantially depends on the infrastructural facilities available to them. United Nations SDG also deals with the social welfare of the low-income bearers. However, the average annual household income of a person is around 800 US\$. As far as Sabaragamuwa Province is concerned, per capita household income is slightly lower than national average (PFC annual report,2018).

#### **2.4.3 PFC data analysis and Recommendation for year 2021**

The PFC recommends the financial grants for all provincial councils for the devolved subjects under the amendment to the constitution in 1987. Government grants consist of the following components.

1. Block Grant for recurrent expenditure
2. Provincial Specific Development Grant [PSDG]

3. Criteria Based Grant [CBG]
4. Revenue based Provincial grant [RPG]

The PFC report clearly stated the relevant economic indicators.

Funds allocation criteria for different provinces are basically governed by the defined performance indicators

The total fund allocation for each province is determined by considering the population, land extent and other relevant parameters like average income of people etc.

Recurrent block grant (340 billion LKR) amounts to 81% of the total funds allocated for provincial councils (421 billion LKR). Total recurrent and capital fund allocation for the Sabaragamuwa provincial roads improvements works amounts to 1200 million LKR and this is only 2.7% of the provincial budget. Japan International Cooperation Agency[JICA] suggested that at least 5% of the provincial grant shall be allocated for road maintenance and mid-term improvement works in order to achieve desired benefits in the next two decades (JICA project report for Sabaragamuwa Province, 1999). These recommendations are valid for the entire country and before 2020, fund allocation for provincial roads improvement works was less than 2.0%. of the provincial budget.

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#### **2.4.5 Mass flow direction in provincial roads( Direction of freight movement)**

Sri Lanka has an agriculturally based economy. Most of the food items and the export crops are produced in the rural areas and mass flow direction is towards the city centers from the remote areas. On the other hand, heavy raw materials, construction materials are also extracted from the rural areas.

According to the PFC annual reports agriculture production in North Central, North Western, Uva and Sabaragamuwa Provinces. Western Provinces, especially Colombo District mainly depend on the foods produced in other provinces or the imported items. Even in the other provinces food items are normally produced in the remote areas. Therefore, Provincial roads play a vital role in the freight transportation sector.

#### **2.4.6 Trip generation by the provincial roads users**

Most of the developed countries have large housing schemes and the rural population is less than twenty percent (Urbanization by country-Wikipedia,2022). In Sri Lanka the rural and suburban population is as high as 80% and part of the rural population normally travel from their households to their respective workplaces in the urban and suburban areas. Based on this analysis, it can be shown that at least 10-15% of the rural population living in the command area of the provincial roads, make return trips up to the sub urban destinations. This simplified assumption can be used instead of a complicated origin destination matrix.

#### **2.4.7 Land use plan and road improvements**

Forests covered in the world are about 31 percent of global land area but are not equally distributed among the countries.(FAO,2020) . As far as Sri Lanka is concerned forest

cover is 21130 km<sup>2</sup> and it is almost equal to the Global average.(FAO,2020) Remaining 64% of the land is used by the population living in the country. Mountains are progressively being invaded by highways for development and defense purposes (Banerjee and Ghose,2016). As far as Sri Lanka is concerned this statement is partly applicable for the hilly area of the country. People living in the hilly area need more infrastructure facilities to improve their quality of life. The second option is resettlement of the people in the hilly areas which is not a practical solution for an agricultural country.

Land use plan has a very complex relationship with the road network planning. As a result of the growing need for conservation of existing forests and reforestation, the most eco-sensitive land use plans have to be used. Human settlement, agricultural, industrial zones and commercial centers should be carefully planned with a properly designed road network.

Developed countries like Japan, South Korea are maintaining a forest covering 60% of the total land extent (FAO, 2020). Road tunnels are used in South Korea in order to minimize environmental degradation caused by road constructions. Environmental damage mitigation cost is comparatively high in developed countries. However, in Sri Lanka most of the road embankments are unprotected. Due to the landslides created by unprotected road embankment, considerable environmental degradation was caused during the period 2000-2018 (NBRO disaster mitigation plan for Sabaragamuwa Province-2020).

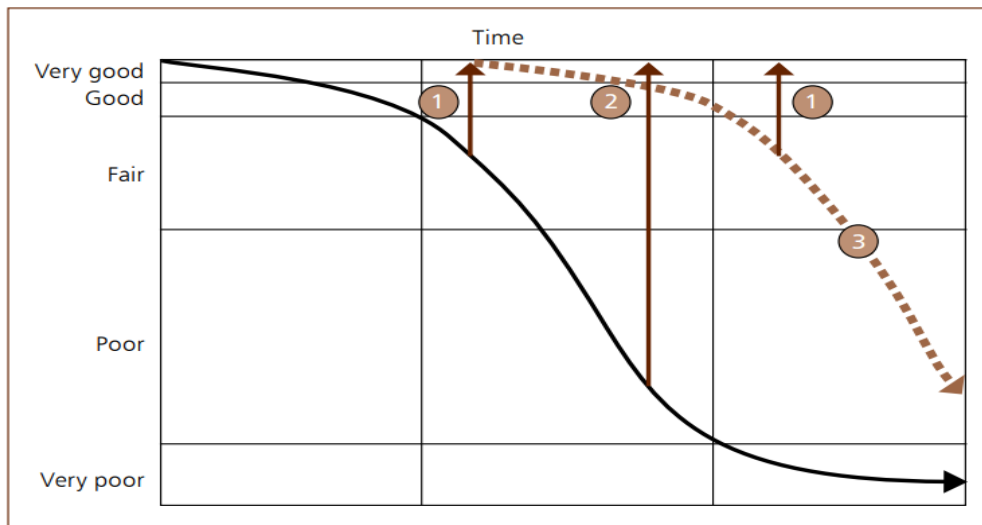
Therefore road widening has to be carefully planned by paying due attention to the socio environmental problems.

## **2.5 Pavement management theory applicable to provincial roads**

Road management originates from the premise that the road network is an asset which needs to be maintained and improved so as to secure best performance and value for money and the maximum service life. (Overseas Road Note 15, 1998) This statement highlights the importance of road pavement management.

### 2.5.1 Relationship between maintenance cost and assets value

Routine road maintenance is essential to minimize the life cycle cost. Lifetime of a provincial road shall be increased from 10 years to 20 years with routing, preventive and mid-term maintenance as described in the figure 2.4. Roads pavements are highly vulnerable for deterioration and as a result of aforesaid deterioration road assets values drastically reduced. (ADB publication,2020) Due to the excessive deterioration of road pavement there will be an increase in the IRI value resulting in a poor level of service. Poor level of service ultimately results in less benefits to the road users (Performance Based maintenance of Rural roads ,2012).



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Figure 2. 4 Increase in life cycle cost due to non-attendance of routing maintenance  
Adopted from performance based maintenance of rural roads

Figure 2.4 clearly explains the importance of pavement management. Lifetime of any pavement is depend on the pavement type, axle loads and maintenance program. Following example further illustrate the importance of pavement management

Assume initial construction cost of pavement is 20 million LKR per km

Original lifetime is 10 years and extended life time is 20 years.

Routing maintenance cost is 200,000 LKR per km and midterm improvement cost is 5 million LKR.

It can be shown that the life cycle cost saving per km length is 6 million LKR if a proper pavement management system is used.

Table 2. 4 Life cycle Benefits with different maintenance strategies

Year	No Maintenance		Strategy 1			Strategy 1		
	IRI Score	Benefits fraction	1,4 Investment -2,5 pavement value -3,6 Benefits					
			1	2	3	4	5	6
1	95	0.95	0.2	19	0.71	0.1	19	0.71
2	94	0.95	0.2	18.8	0.71	0.1	18.8	0.71
3	93	0.94	0.2	18.6	0.70	0.1	18.6	0.70
4	91	0.93	0.2	18.2	0.69	0.1	18.2	0.69
5	89	0.92	0.2	17.8	0.69	0.1	17.8	0.69
6	86	0.90	5	21.5	0.75	0.1	17.2	0.67
7	82	0.88	0.2	21.3	0.74	0.1	16.4	0.66
8	78	0.85	0.2	21.1	0.74	0.1	15.6	0.64
9	75	0.83	0.2	20.7	0.73	0.1	15	0.62
10	72	0.82	0.2	20.3	0.72	0.1	14.4	0.61
11	70	0.81	0.2	19.7	0.71	0.1	14	0.61
12	68	0.80	5	24	0.78	15	24.8	0.75
13	66	0.79	0.2	23.8	0.78	0.1	24.4	0.74
14	64	0.78	0.2	23.6	0.77	0.1	24	0.74
15	62	0.77	0.2	23.2	0.76	0.1	23.4	0.73
16	60	0.76	0.2	22.8	0.76	0.1	22.8	0.72
17	59	0.76	0.2	22.2	0.74	0.1	22	0.71
18	58	0.75	5	26.5	0.82	0.1	21	0.69
19	57	0.74	0.2	26.3	0.82	0.1	20.2	0.67
20	56	0.73	0.2	25.9	0.81	0.1	19.6	0.66
Total / Final value			18.4	25.9	14.93	16.90	19.6	13.72
Life Cycle Benefit			22.43			16.42		
1-6 All monetary values in LKR Millions - 3,6 Benefits derived								

## 2.6 International Roughness index (IRI) measurement in provincial roads.

### 2.6.1 General Definition of IRI

The International Roughness Index [IRI] measures the pavement surface condition in terms of vertical acceleration, amplitude of the vibration wave and frequency of the wave. Finally the IRR index measures the roughness in terms of m per km or inches per mile. IRR value less than 1.5 m per km is identified as the best condition for highway pavement (Sayers and Karamihas-,1998).

If vehicle moving speed is more than 20 km per hour IRR value is purely governed by the surface condition.

Following chart described the relationship among IRI values, type and age of the pavement and speed of normal use. As far as provincial roads are concerned this chart is valid except the speed of normal use (Sayers and Karamihas-,1998).

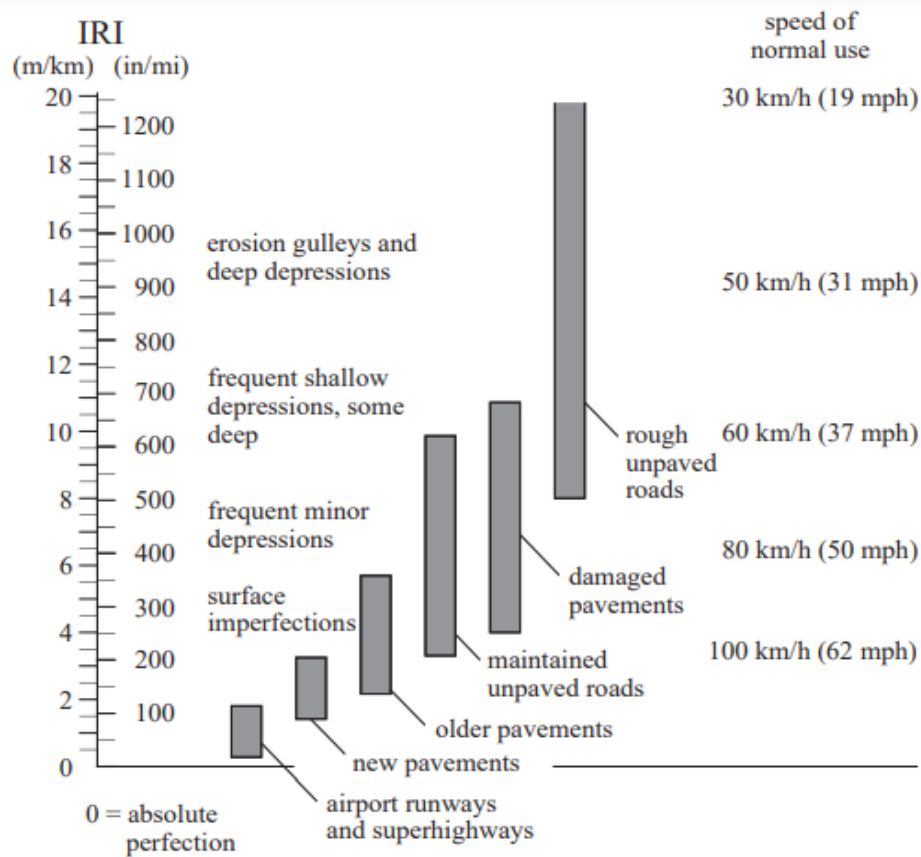


Figure 2. 5 IRI value variation with type of pavements and speed limits- Original source Little Book of profiling (1998)

## 2.6.2 Available research findings related to IRI Values of provincial roads

Sirisumana, & Pasindu (2016) deals with Development of a Geometric Design Index for upgrading and decision making-case study for a provincial road network in a developing country, reveals that safe design speed for provincial roads is in the range of 40-50 km per hour. Speed limits given in Figure 2.5 are applicable for properly designed highways with curve radius more than 30 m. However, in the provincial roads the curve radius is as small as 5 m. Therefore allowable speed limits given in the chart are limited to 50% of the given values.

.Table 2. 5 :Appropriate speed ranges with different IRI values

	Type of Pavements	IRI value m per km	Speed Range Highways km/hr	Speed Range Provincial Roads km/hr
1	Airport Runway Pavements	1-1.5	100-250	-
2	New Asphalt Pavements	1.2-2.0	80-100	40-60
3	Well Maintained Pavements	2.0-4.0	60-100	30-50
4	Older Pavements	3.0-5.0	50-60	25-30
5	Damaged pavements	5.0-16.0	10-50	15-25
6	Rough Unpaved Sections	8.0-20.0	10-20	5-10

Bump integrator IRI test is very expensive and involves certain control parameters such as speed of measuring vehicle and traffic condition etc. As a result of those restrictions, the standard method is not a practical solution for Provincial roads.

(Sandamal and. Pasindu, 2021) carried out important research related to IRI measurement in provincial roads by using mobile apps. IRI value ranking by experience of a qualified person may also be used for this purpose. It was found that mobile apps are capable of measuring the IRI value with reasonable accuracy. However, mobile app application is always not possible due to the speed variation and loss of GPS signals.

It was found that the correlation of the Road-roid mobile application and the standard test relationship is given by following equation

$$IRI_{BI}=1.0958 IRI_{Roadroid}+.3266 \text{ with a } R^2 \text{ value of } 0.78\text{-----}2(2)$$

(Sandamal and. Pasindu, 2021)

The same research paper, IRI value is related to the IRI ranking by the experienced engineer.

The correlation is given by  $IRI[Y]=10.98/[1+(X/65.79)^{4.27}]$ -----2(3)

Number of X values is the predicted IRI ranking. (Sandamal and. Pasindu, 2021)

Pernia and Gunaratna (2015) describes the ability of determining the certain test parameters by guessing a by an experienced person and those results are complying with the actual test with reasonable accuracy.

Experienced engineers can determine an approximate value for IRI with reasonable accuracy. Neural network in the human brain is a very powerful tool for predicting certain test parameters by experience.(Pernia and Gunaratna, 2015) During the field visits three experienced persons guessed almost the same value of IRI and all results were verified by the mobile app test. IRI value is sensed by the visual observation, vibration of the vehicle, noise and the other parameters like speed reduction etc.

Further simplified method is suggested to determine the IRI value of provincial road segments by the IRI score method.

IRI Value of a road Segment=  $1.2+[100-IRI\ Score]*16/100$  -----2(4)

where IRI score varies in between 5-98

This equation results in 15.6, 4.4, 2.0 & 1.52 m/km IRI values when IRI scores are 10,80, 95 and 98 respectively.

## **CHAPTER 3 : Methodology and outline of the case Study**

### **3.1 Introduction**

It is essential to determine the basis of fund allocations among the provincial roads. Provincial road name and class is used to identify the respective roads as per general convention. However, it was found that there is a drastic variation of parameters within the same road. Therefore one kilometer long road segments are identified as the primary measurable units. Provincial roads are in a massive network. Therefore under the first section network behavior is analyzed. Relevant economic theories are revived to formulate the objective function. Third subsection deals with valuation of road assets within the segment. Finally benefits derived from the respective road segment are considered and initial fund allocation criteria is formulated.

### **3.2 Road Network system in Sri Lanka**

#### **3.2.1 Schematic diagram of road network system**

Road network system comprised of seven types of roads with different characteristic which provides with vehicle moving paths in between the any two points within the network. This system comprised Expressways(E), Major highway(A), Highway (B), Provincial Roads (Class C &D) other roads managed by the various authorities.. Trunk roads, Major Highways, the part of the provincial and local roads, are in the network. However, of provincial and minor roads end with dead ends. Typical schematic diagram is given in the Figure 3.1

#### **General Background**

According to the definition, all highways have at least one lane for each direction to accommodate the traffic flow in both directions. This is an essential requirement for highway design (National Thoroughfare Act, 2008).

As far as provincial roads are concerned more than 99% of the provincial roads are single lane roads with a lane width ranging from 2.7 m to 5.4 m. (Provincial road data base-2015)

Provincial roads in a large network serve as shortcut roads by reducing the traffic congestion in the main arterial roads.

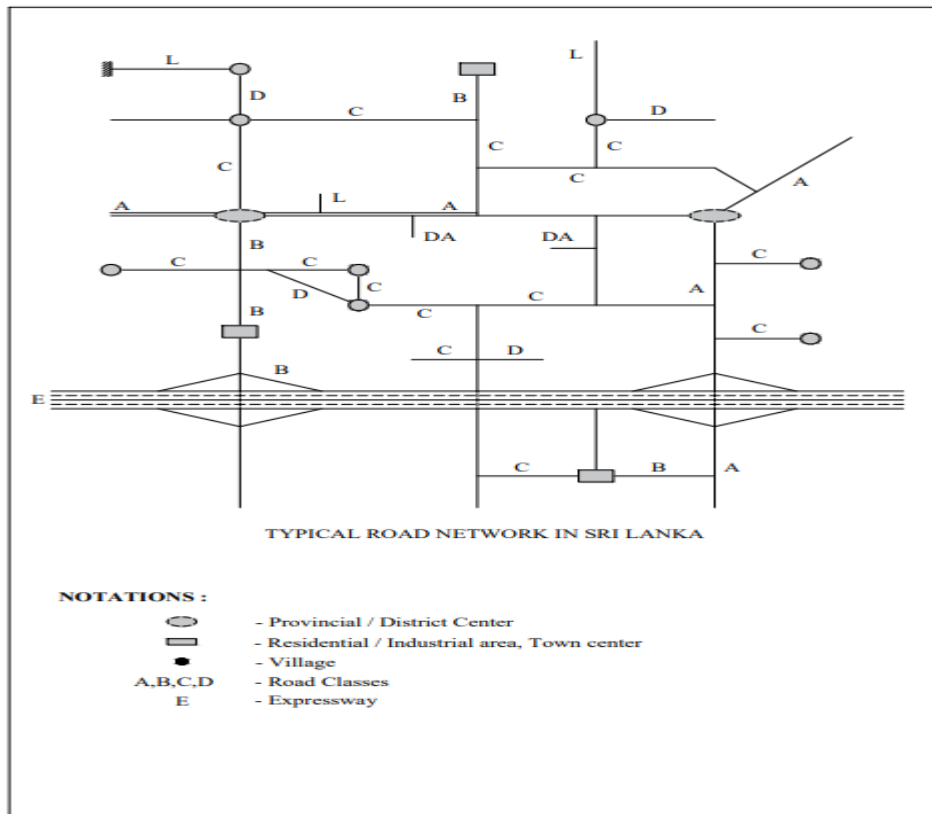


Figure 3. 1 Schematic diagram of roads network in Sri Lanka RDA roads network

Original Source: RDA Geometric Design Standard (2005)

Sri Lanka has 116,000 km length roads connected in a massive network. Trunk roads (Class A), Highways (Class B) roads and Expressways are managed by RDA and total length of the roads managed by RDA is 12500 km while other 18500 km lengths of roads are managed by nine Provincial councils. In addition to the class A, B, C, D and Expressways there are about 85,000 km length of Local roads as far as Sri Lanka is concerned average road density is 2.23 km per square km. Let us assume that the average ROW is 8.0m. This means nearly 1.23 % of the ground surface is used for roads. In the case of urban areas area covered by road network is as high as high as 10% and in the rural areas this percentage is as low as 0.1-2% percent.(Google Maps,2021)

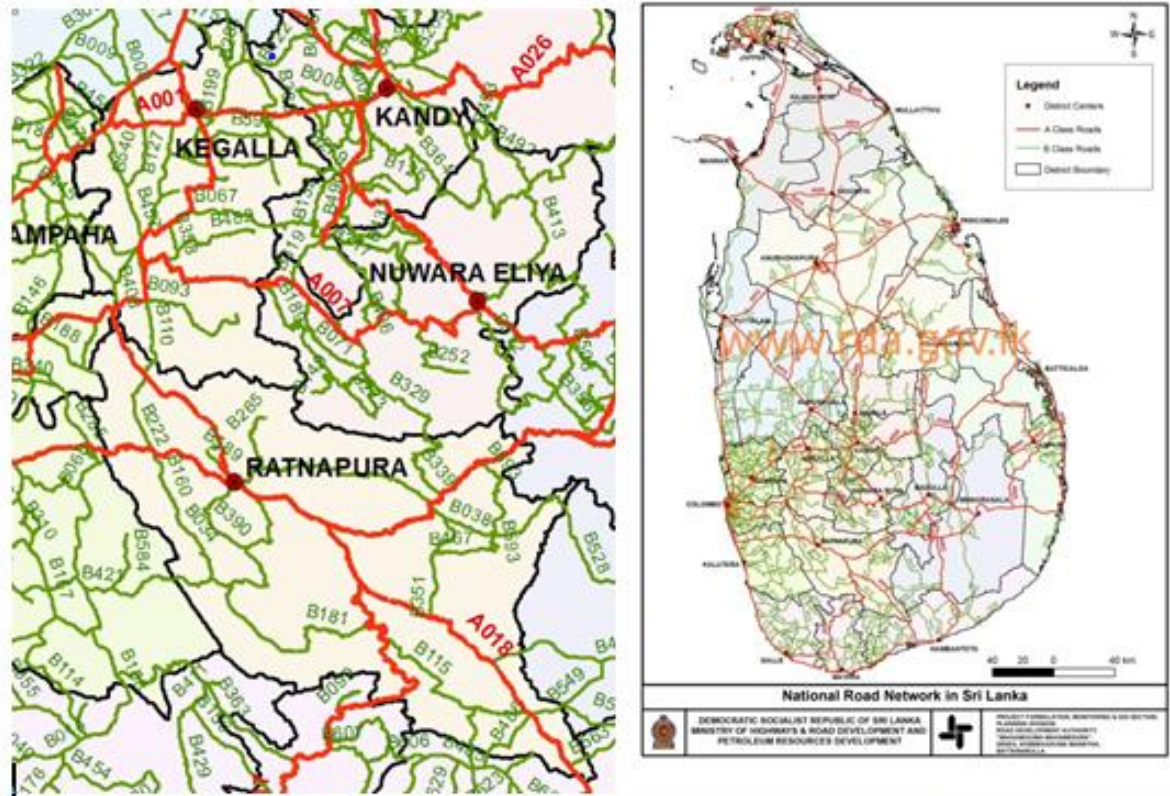


Figure 3. 2 : National Roads [RDA roads] Network in Sri Lanka

Original Source: [www.rda.lk](http://www.rda.lk) (Official website of RDA)

On other hand there are trip attractors served by the provincial roads. As far as rural community is concerned, they are enjoying less benefit compared to the urban community where they have a comparatively good road network.

In the case of provincial roads there is a balance between mobility and accessibility.

The other classification is Arterial, Collector and distributor roads. Provincial roads have two classes' namely C class and D class roads. C class roads may be considered as minor collector roads and main distributor roads. There are large numbers of accesses for households even from major arterial roads and in Sri Lanka. However there are 5% of provincial and local roads that function as shortcuts with comparatively high traffic flow..

Position of the provincial roads are shown in the figure 3.3

### 3.2.2 Accessibility- mobility level comparison of provincial roads.

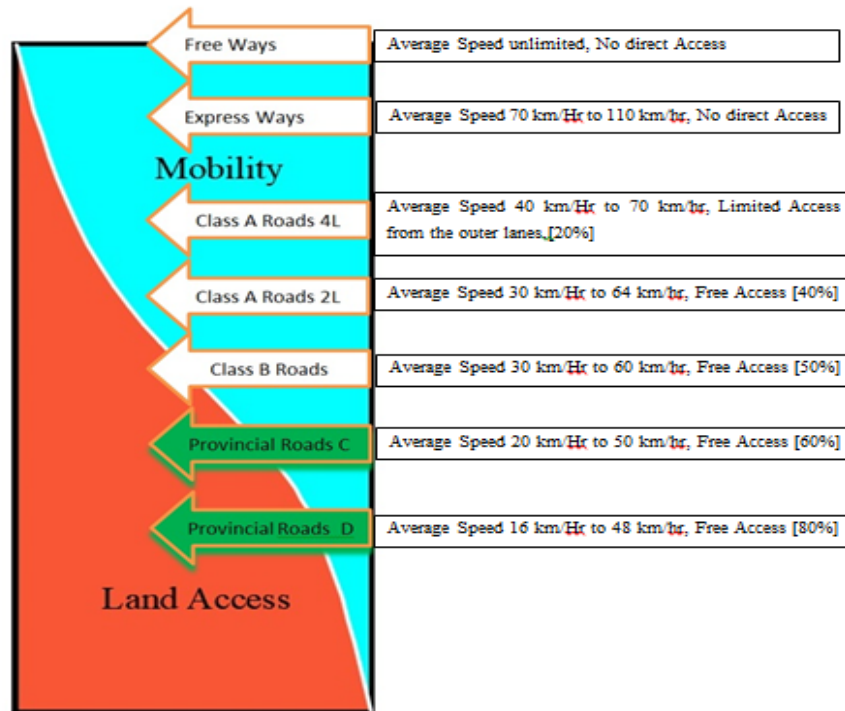


Figure 3. 3 Accessibility mobility function of different roads

### 3.2.3 Comparison of benefits derived from different roads in the road Network

Table 3. 1 Comparison of benefits derived from different roads

Maximum hourly Traffic	Average speed kmph	WB <sub>1</sub>	WB <sub>2</sub>	WB <sub>3</sub>	WB <sub>4</sub>	WB <sub>5</sub>	Total Benefits
		30	25	25	10	10	100
Express Ways							
1000	100	30	25	25	5	10	95
1000	90	27	25	25	5	10	92
Polonnaruwa-Baticolo Road							
600	75	22.5	15	12	10	8	67.5
Pamankada Pokunuwita Road							
800	50	15	20	16	10	8	69

Maximum hourly Traffic	Average speed kmph	WB <sub>1</sub> 30	WB <sub>2</sub> 25	WB <sub>3</sub> 25	WB <sub>4</sub> 10	WB <sub>5</sub> 10	Total Benefits 100
A4 Road Colombo –Ratnapura Road							
800	50	24	20	10	10	8	55.5
400	40	12	10	8	10	8	48
Class B RDA road							
300	40	12	7.5	6	8	6	39.5
Kuruwita-Erathna Provincial road							
300	36	10.8	7.5	4.5	8	5	35.8
Other low traffic roads							
200	30	9	5	3	8	4	29
100	24	7.2	2.5	1.5	8	4	23.2
75	20	6	1.875	1.125	6	4	19
50	20	6	1.25	0.75	6	4	18
25	16	4.8	0.625	0.375	6	3	14.8
20	16	4.8	0.5	0.3	6	3	14.6
WB <sub>1</sub> –Benefits due to average speed- 30 marks for average speed 100 kmph							
WB <sub>2</sub> –Benefits due to maximum hourly traffic- 25 marks for 1000 PCU per hour							
WB <sub>3</sub> –Benefits due to Daily Traffic 25 marks for 10,000 Vehicles per Day							
WB <sub>4</sub> -Benefits due to accessibility -10 marks							
WB <sub>5</sub> -Socio-Environmental benefits-10 marks							

### 3.2.4 Comparison of the funds allocated for major and minor roads

It is obvious that assets values of major roads cannot be compared with the low traffic volume roads. However, construction cost of 1 km long road lane shall be compared with each other. This comparison reveals that fund allocation for provincial roads are not sufficient.

Table 3. 2: Comparison of the asset value of different road segments

	Name of the Road Segment	Number of Lanes	Land Price Per km Segment	Construction Cost LKR per km Millions	Total Cost per lane per km LKR Millions	Price Ratio
1.	Rajagiriya Fly Over	4	8000	8000	4000	1:80
2.	Southern Expressway	4	600	1800	600	1:12
3.	Kandy Expressway	4	400	3600	1000	1:20
4.	Pamankada Pokunuwita	4	1000	1000	500	1:10
5.	Thiriwanaketiya- Agalawatta	2	100	200	300	1:6
6.	C005- First 500 m	2	50	70	60	1:1.2
7.	Lelopitiya Hettikanda	1	20	40	60	1:1.2
8.	Godakawela Bibilagama	1	20	30	50	1:1
9	Local Road	1	10	10	20	1:0.4

Original source [www.rda.gov.lk](http://www.rda.gov.lk), [www](http://www), Wikipedia

### 3.3 Economic Analysis

#### 3.2.1 Formulation of Economic theories related to the research

Financial analysis is carried out by defining the following parameters, in order to facilitate statistical analysis. As described in the previous chapters one km road segments were considered for the analysis.

Fund requirement for a particular road segment =  $FR(i,j,k) = C(i,j,k)$

$FR(i,j,k)$  =  $i^{\text{th}}$  road,  $j^{\text{th}}$  km Road Segment,  $k^{\text{th}}$  Year

$A(i,j,k)$  = Assets value of road, km Road Segment during the Year

$B(I,J,k)$  = Benefits derived from the  $i^{\text{th}}$  road,  $J^{\text{th}}$  km Road Segment during the  $k^{\text{th}}$  Year

$C((i,j,k)$  = Cost incurred for the  $i^{\text{th}}$  road,  $j^{\text{th}}$  km road segment during the  $k^{\text{th}}$  Year

Mathematical optimization equation

Recurrent expenditure is normally utilized to maintained the road segment under the prevailing condition throughout a specified time period

Maximization of the objective function,

For current year  $k=1, k=20$  for long term project planning

$N=(1,2,\dots,235)$   $X=0-23$  km Where  $N=235$  for Sabaragamuwa Province,  $X=$  length of the longest provincial road in Sabaragamuwa Province. For other roads  $N$  and  $X$  may be different from the given values.

Note In the case study Total number of roads =  $N = 235$  and

Maximum length of provincial road =  $X = 23$  km

*Maximize Monetary and service value Function*

$$\sum_{i=1}^n \sum_{j=1}^X A(i, j, k) + \sum_{k=1}^{20} [\sum_{i=1}^n \sum_{j=1}^X B(i, j, k) - \sum_{i=1}^n \sum_{j=1}^X C(i, j, k)] \text{-----} 3(1)$$

subjected to the constraint

$$F(k) > \sum_{i=1}^n \sum_{j=1}^X C(i, j, k) \text{-----} 3(2)$$

- $F(k)$  = Available recurrent fund allocation for  $k$  year
- $F(k)$  LKR = Recurrent Expenditure LKR + Emergency repair cost LKR
- Normally  $A(i, j, k) < A(i, j, k+1)$  due to the interest rate and inflation
- under the severe deterioration of pavements (Depreciation)
- $A(i, j, k-1) > A(i, j, k) \text{-----} 3(3)$
- Due to the flood damages and earth slips  $A(i, j, k-1) > A(i, j, k)$
- $C(i, j, k) = f(B(i, j, k), A(i, j, k), \text{Other non-technical parameters})$
- In the case of recurrent expenditure normally  $C(i, j, k) < B(i, j, k)$
- Capital investment Program  $C(i, j, k) > B(i, j, k)$  and  $\sum_{k=1}^n (B(i, j, k)) > \sum_{k=1}^n (C(i, j, k))$
- $[\sum_{k=1}^n (B(i, j, k))] / [\sum_{k=1}^n (C(i, j, k))] =$  Long term benefits cost ratio—3(4)
- In the case of highway improvements projects project life time  $n$  shall be taken as 10-20 years In the chapter 5 & 6 validity of the formula is verified by using the case study data

### 3.2.2 Capital Investment Program

According to the government policy 85% of the economic benefits are counted as direct financial benefit to the road users and balance 15% accounts to the government financial benefits. In the case of toll highways, financial benefits to the government are much higher than normal highways.

Even under the restricted conditions, investing money on provincial roads is financially viable. This is one of the reasons for granting soft loans on provincial road improvement

projects (JICA Project feasibility report for Central and Sabaragamuwa Provinces Roads Improvement Project,2000).

CI=Total Capital Investment

AIB=Average Incremental Benefit

n= Project Return Period

r= Internal Rate of return

$$CI = \left[ \frac{AIB}{1+r} \right] + \left[ \frac{AIB}{(1+r)^2} \right] + \left[ \frac{AIB}{(1+r)^3} \right] + \dots + \left[ \frac{AIB}{(1+r)^n} - 1 \right] + \left[ \frac{AIB}{(1+r)^n} \right]$$

--2(3)

$$CI = AIB[1 - [1/(r + 1)n + 1]]/[1 - [1 - 1/r + 1]]-----3(5)$$

$$CI = AIB/r * [1 - \alpha(n + 1) ] -----3(6)$$

If CI, AAB and n is known IRR value can be calculated.

If IRR ≥ Lending Rate

Project is financially viable. If there are many economically viable projects, most economically viable projects are selected for implementation in the descending order of the viability.

### 3.2.3 Foreign funded projects

There are three main donor agencies that provide soft loans with an interest rate of around 1% for road infrastructure development projects. However, there are no provisions for land acquisition under the foreign fund components. The Sri Lankan government has to spend money on land acquisition. Therefore land acquisition is not commonly used in provincial road projects unless there is an essential need.

The selection of the roads for the foreign-funded projects will be further discussed under Chapter 6.

### 3.4 Valuation of road assets

Road infrastructure value consists of the price of lands, the cost of earthworks, the cost of pavements, drainage systems and structures, and the value of bridges. The valuation process is discussed in detail under Chapter 4.

Let  $A(i,j) = \text{Land value} + \text{Earthworks value} + \text{Pavement cost} + \text{Drainage and Structures cost} + \text{Bridge}$ .-----3(7)

It is observed that the value of a 1 km long road segment varies between 2-300 million LKR.

In urban areas, high road asset values are recorded mainly due to high land prices. Due to the very high land prices required ROW is not maintained in most places. Similarly in the rural and hilly areas, land prices are comparatively low land prices, but restricted carriageway width and poor pavement condition, improper drainage, protection systems, and certain other factors.

Note: Tentative estimates are prepared based on the HSR Rates 2021 and other market values. Initial mathematical and financial values are subjected to a price increase.

$$A(i,j) = A_{\alpha} \quad \alpha = (1,2,3,4,5,6)$$

Note this estimate is based on the 2021 rates.

Classification of road segments according to the road asset value is given in Table 3.3

Table 3. 3 : Classification of Road Segments According to Total Assets Values

Asset value class [ $A_{\alpha}$ ]	Value Range of 1 km road segment [LKR]	Average value of 1 km Road Segment [LKR& US\$ ]
$A_1$	90,000,000-150,000,000	120,000,000 [60,000 US\$]
$A_2$	70,000,000-90,000,000	80,000,000 [40,000 US\$]
$A_3$	50,000,000-70,000,000	60,000,000 [30,000 US\$]
$A_4$	30,000,000-50,000,000	40,000,000[20,000 US\$]
$A_5$ –Marginally Developed	10,000,000-30,000,000	20,000,000[10,000 US\$]
$A_6$ –Underdeveloped	2,000,000-10,000,000	6,000,000[3,000 US\$]

### 3.4.1 Deviation from normal road assets value criteria.

Land prices are very high, closer to town centers and main roads and part of provincial roads start from such places. This will normally result in very high land values even though the required ROW is not maintained. The other reason for high road segment

asset value is a presence of a road bridge in the particular segment. In order to analyze this situation, it is necessary to evaluate road assets without land and bridge values. This value is defined as  $A^*(i,j)$  and  $A^*(i,j)=\text{Earthwork cost} + \text{Pavement construction cost} + \text{Drainage and protective system cost}$ -----3(8)

For recurrent expenditure, allocation ignores the effect of  $A(i,j)$ . In the case of capital fund allocation consider the parameter  $X = A(i,j) / A^*(i,j)$  -----3(9)

Table 3. 4  $A^*(i,j)$  value deviation with land prices.

B(i,j) million	LKR	A(i,j) million	LKR	A(i,j)/ A*(i,j)=X	Old $\alpha$ Value	New $\alpha$
B(i,j)>9		A(i,j) >90		1.2<X<1.5	1	2
				1.5<X	1	3
6<B(i,j)<9		70< A(i,j)<90		X<1.5	2	3
For other $B_\beta$ values ignore the effects of $A^*(i,j)$ is not counted						

Land prices vary between 20,000 LKR to 500,000 per purchase depending on the location. In most of the places required ROW is not maintained and it was found that 6.0 ROW on either side of the road is sufficient for class C roads and 4.8 m ROW is sufficient for class D roads. Land acquisition decisions may be taken with the help of the information given in Table 3.5

Table 3. 5 : Variation of land assest value with ROW

Land Price LKR per Purchase	ROW in (m)/Land Assent Value In LKR Million						
	8	9	10	11	12	13	14
100,000	32	36	40	44	48	52	56
125,000	40	45	50	55	60	65	70
150,000	48	54	60	66	72	78	84
175,000	56	63	70	77	84	91	98
200,000	64	72	80	88	96	104	112
225,000	72	81	90	99	108	117	126
250,000	80	90	100	110	120	130	140

Land Price LKR per Purchase	ROW in (m)/Land Assent Value In LKR Million						
	8	9	10	11	12	13	14
275,000	88	99	110	121	132	143	154
300,000	96	108	120	132	144	156	168
325,000	104	117	130	143	156	169	182
350,000	112	126	140	154	168	182	196
375,000	120	135	150	165	180	195	210
400,000	128	144	160	176	192	208	224
425,000	136	153	170	187	204	221	238
450,000	144	162	180	198	216	234	252
475,000	152	171	190	209	228	247	266
500,000	160	180	200	220	240	260	280

### 3.5 Calculation of benefits derived from a provincial road segment.

The first two chapters mainly describe the role of provincial roads in the sustainable development process. As mentioned in chapter 2, the number of people served by a road segment is the most important factor. Provincial and local roads basically serve the residents in the command area. Therefore it is necessary to calculate the number of people served by each road segment.

#### 3.5.1 Calculation of the number of people served by a provincial road segment

There are two types of provincial roads namely provincial roads in a network and provincial roads serving an isolated area. The following integral function can be used to calculate the number of residents served at any distance irrespective of the type.

$$\text{Population served at distance } x = \int_x^L k(x) * N1(x) dx + \int_0^x k(x) * N2(x) dx \text{-----3(10)}$$

Where k(x) is a population distribution per unit length at distance x from the main node

L=Total length of the road

N1(x)=fraction of people moving towards main node

N2(x)= fraction of people moving towards minor node

$$\int_0^L \frac{k(x)dx}{L} = k_{\text{average}} \quad \text{where } k_{\text{average}} = (k_1 + k_2)/2 \text{-----3(11)}$$

$$\int_x^L (k_1 - (k_1 - k_2) * \frac{x}{L}) * N1(x)dx + \int_0^x (k_1 - (k_1 - k_2) * \frac{x}{L}) * N2(x)dx \text{-----3(12)}$$

N1(x)+N2(x)=1 and for a given road N1(x)=N1 and N2(x)=N2

$$= [k_1(L-x) - (k_1 - k_2)[L/2 - x^2/2L]]N1 + N2[(k_1Lx - (k_1 - k_2)x^2/2)] \text{-----3(13)}$$

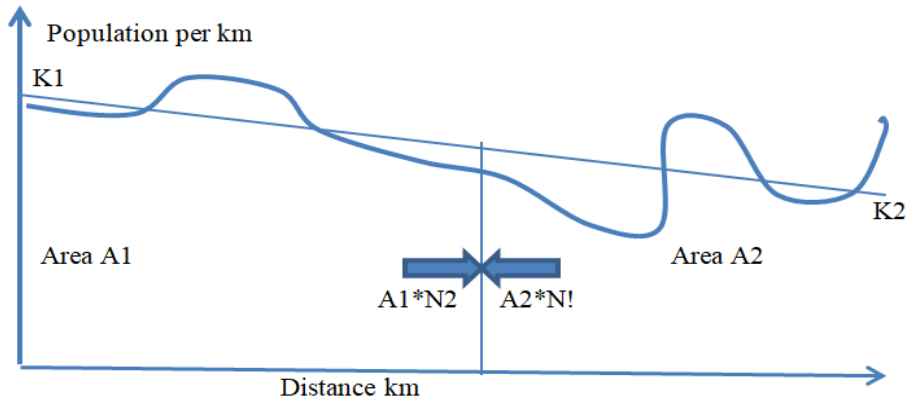


Figure 3. 4 Graph showing population density along the road

For a discrete function

$$\text{Population served at distance } x = \sum_{i=x}^n n1i * ki + \sum_{i=1}^x n2i * ki \text{-----3(14)}$$

Where X is measured in 1 km segments.

In both cases, formula is very complicated therefore it is not possible to have pure theoretical formula. There are three possible of cases of roads.

1. Roads connecting two national roads.-

N1&N2 approximately equal to 0.5 and N1>N2 and K1 approximately equal to k2

2.Roads starting from a national road and continuing after the second location.

0.9 >N1>0.8 <0.1,N2<0.2 and K2<K1/2

3. Roads starting from main road and connecting dead 0.95>N1>0.9. 0.05<N2<0.1 and K2<K1/3

### 3.5.1.1 Derivation of empirical formula for Kuruwita- Erathna road by Regression analysis

Kuruwita-Erathna road is a very much familiar road and the researcher has forty-year experience living in the command area. Therefore N1,N2, K1, and K2 parameters pertaining to different segments are known. Results are tabulated in table 3.6.

Table 3. 6 Actual and Calculated number of people served.

Distance (m)	Population this segment	No of people served U/S	No of people served D/S	Actual Value of people served	Theoretical Number of people served
0	1450	21720	73	22,882	23,529
500	1000	20270	123	21,412	22,941
1000	1600	19270	219	20,463	22,353
1500	800	17670	275	18,842	21,765
2000	600	16870	323	18,052	21,176
2500	350	16270	354	17,455	20,588
3000	450	15920	399	17,135	20,000
3500	200	15470	421	16,686	19,412
4000	200	15270	445	16,501	18,823
4500	280	15070	481	16,329	18,235
5000	400	14790	537	16,094	17,647
5500	550	14390	620	15,760	17,059
6000	500	13840	700	15,267	16,470
6500	500	13340	785	14,831	15,882
7000	550	12840	884	14,410	15,294
7500	600	12290	998	13,952	14,706
8000	1650	11690	1,410	13,755	14,117
8500	850	10040	1,623	12,246	13,529
9000	400	9190	1,723	11,459	12,941
9500	440	8790	1,833	11,154	12,353

Distance (m)	Population this segment	No of people served U/S	No of people served D/S	Actual Value of people served	Theoretical Number of people served
10000	550	8350	1,998	10,865	11,764
10500	1225	7800	2,365	10,674	11,176
11000	1325	6575	2,829	9,874	10,588
11500	1750	5250	3,704	9,402	10,000
12000	3500	3500	5,454	9,402	9,411

Following equation is used to calculate the population served at distance X from the Kuruwita town

$$P_x = P_0 [1.1 - 0.65 * X / 12] \text{-----} 3(115)$$

Regression analysis shows that above equation results fairly accurate results with R<sup>2</sup> value of 0.969 and trend line equation of  $P_{\text{Predicted}} = 1.0978 * P_{\text{Actual}} - 508.7 \text{-----} 3(16)$

$$P_{\text{Actual}} = (P_{\text{Predicted}} + 508.7) / 1.0978 \text{-----} 3(17)$$

Polynomial trend line results R<sup>2</sup> value of 0.97 with trend line equation  $P_{\text{Predicted}} = 2.0e-05 * (P_{\text{Actual}})^2 - P_{\text{Actual}} * 1.8525 - 6158 \text{-----} 3(18)$

It can be shown that equation 3(12) can be used to calculate number of peoples served with reasonable accuracy.

Similarly, regression analysis was carried out for different road configurations and the R<sup>2</sup> value for the given formulas is less than 0.9. Derived equations are given in Tables 4.10 and 4.11 under chapter 4.

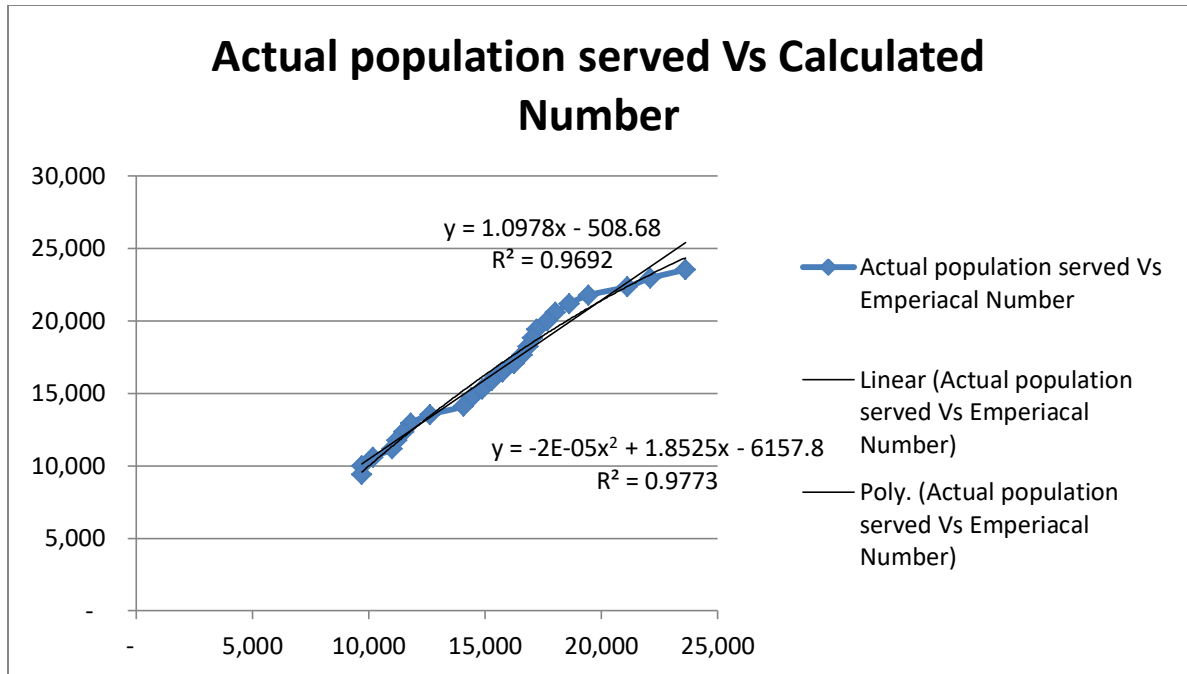


Figure 3. 5 Regression analysis results for number of persons served

1. Semi empirical formulas are used to determine the area served and population served
  2. Base year for rates is December 2020
- . As described in the introduction, benefits derived from a provincial road segment or a particular road depends on a number of factors such as the number of peoples served by the road, trips generated by the residents, agriculture and plantation area served by the road segment, industries served by the road segment and the tourist attraction locations served.
- Sri Lanka is named an agricultural country and the rural community makes a significant contribution to the process of sustainable development. The value of time saved is considered the highest benefit, derived from road infrastructure development.
- In addition to the main beneficiaries agricultural, plantations, and manufacturing industries and tourists are benefitted. Those benefits can be incorporated by forming benefits classes by means of daily traffic as described in the last few paragraphs of section 3.4.

The average speed of a provincial road is mainly governed by the road geometry and the IRI value of the road pavement and marginally on traffic conditions. In the analysis average vehicle moving speed of 9-54 km per hour is considered. The level of service of a provincial road has a correlation with the average vehicle moving speed.

The following assumptions are made in the analysis.

1. Average value of time of the people served is 200 LKR per hour.
2. Only 10% -15% of the rural population makes return trips up to the main road or the city of origin. This percentage is as high as 20%-25% closer to trunk roads.
3. Head carrying cost of goods rate is 2.5 LKR per km.kg (BSR Rate 2021)
4. Lorry and Truck transport costs varying in between 2-20 cents per kg per km depending on the average speed and distance traveled.(District buying committee Rates,2021)
5. Agricultural and plantation production is around 4000 kg per year per Ha (Provincial Agriculture Department Data Analysis,2019)
6. Fuel efficiency is proportional to the average speed
7. Population served by each road segment is calculated by using catchment data analysis.

### **3.5.2 Worst case scenario analysis - provincial roads.**

In most of the city areas, vehicle moving speed is mainly governed by traffic density. However, in the case of provincial and local roads, vehicle moving speed is restricted due to substandard design and construction. Nonpareils road(D120) is a classic example of a substandard road and due to the non-attendance of improvements and the presence of very steep slopes and sharp curves, the average vehicle moving speed is in the range of 6-10 km per hour. [This road is considered under the case study and the relevant photograph is in annexure C. ] Vehicle movements are restricted on this road beyond 11+500 km and this road segment can be considered the worst-case scenario in the provincial roads. The average vehicle moving speed of 6.0 km per hour, is assumed as a datum line with negligible benefits.

Table 3. 7: Net financial benefits to government based on the average vehicle moving speed

Average Speed kmph	VOT Saving in LKR per person	Good Transport cost Saving LKR year person	Fuel Saving Benefits LKR/year	Total Benefits LKR per year per person	weighted Benefits LKR
6	-	-	0	-	0
8	137	233	-20	349	7
16	342	234	-10	566	142
24	411	235	0	645	232
32	445	236	5	685	164
40	465	236	20	722	90
48	479	237	30	746	7
56	489	238	40	767	38
Average Benefits in LKR					681
Standard Deviation LKR					87
Allow 181 LKR for maintenance Works					181
Remaining Net Benefits in LKR per person per year					500

Average net financial benefits derived from a road segment after deducting recurrent, Mid-term, routing, and emergency repair costs of 143 LKR per person per km, Net financial benefits shall be taken as 500 LKR per person per km.

Economic benefits comprised of financial benefits and socio-economic benefits like the number of people served by the road segment, trips generated by the residences and trip attractors, and trips generated by the agriculture-based industries.

There are some provincial roads serving industrial and agricultural areas, places with tourist attractions. Example Kuruwita- Erathna road serving the tourist visiting Adams peak, Divaguhawa, and Batadomba Lena caves, tea factories, and agricultural areas.

Therefore either number of people served or the designed daily traffic flow is used to determine the benefit class.

Initial investigations show that the number of people served by a provincial road segment varies between 200-25000. Design traffic flow varies between 100-2500 PCU per day. Based on this information following benefits classes were formed. In this classification, it is necessary to satisfy either number of people served or design traffic flow conditions.

Number of people served by a road segment shall be calculated by using the equation given in table No 4.10

Table 3. 8: Classification According to the Benefits Derived

Benefit Class [B <sub>β</sub> ]	It is necessary to satisfy criteria 1 or 2			
	(1) Number of Peoples Served		(2) Design Traffic Flow(PCU) per Day	
	Range	Average	Range	Average
B <sub>1</sub>	18000 an above	20,000	1800 and above	2,000
B <sub>2</sub>	12000-18000	15,000	1200-1800	1,500
B <sub>3</sub>	8000-12000	10,000	800-1200	1,000
B <sub>4</sub>	5000-8000	6,500	500-800	650
B <sub>5</sub>	2000-5000	3,500	200-500	300
B <sub>6</sub>	Below 2000	1,000	Below 200	150

This result can be converted to monetary values multiplied by 500 LKR. LKR prices shall be converted to US\$ by using the exchange rate of 200 LKR=1 US\$ in the year 2021.

Table 3. 9: Monetary benefits for different classes

Benefit Class [ $B_{\beta}$ ]	Annual Monetary Benefit in LKR per year per 1 km segment	
	Range	Average in LKR and US\$
B <sub>1</sub>	9,000,000 above	10,000,000 [50,000]
B <sub>2</sub>	6,000,000-9,000,000	7,500,000 [37,500]
B <sub>3</sub>	4,000,000-6,000,000	5,000,000 [25,000]
B <sub>4</sub>	2,500,000-4,000,000	3,750,000[18,750]
B <sub>5</sub>	1,000,000-2,500,000	1,750,000[9,375]
B <sub>6</sub>	Below 1,000,000	500,000[2,500]

### 3.6 Grouping road segment according to combined Assets and Benefits criteria

It can be shown that all provincial road segments belong to one of the following benefits class. (B<sub>1</sub>, B<sub>2</sub>, B<sub>3</sub>, B<sub>4</sub>, B<sub>5</sub>, B<sub>6</sub>)

Similarly all road segments one of the total assets value class (A<sub>1</sub>, A<sub>2</sub>, A<sub>3</sub>, A<sub>4</sub>, A<sub>5</sub>, A<sub>6</sub>)

For any road segment R(I,J) belongs to ( $B_{\beta}, A_{\alpha}$ ) following table shows the possible classes.

Table 3. 10: Road Segment Classified Under Combined Benefit Assets classes ( $B_{\beta}, A_{\alpha}$ )

Category	A1	A2	A3	A4	A5	A6
B1	(B1,A1)	(B1,A2)	(B1,A3)	(B1,A4)	-	-
B2	(B2,A1)	(B2,A2)	(B2,A3)	(B4,A4)	(B2,A5)	-
B3	(B3,A1)	(B3,A2)	(B3,A3)	(B3,A4)	(B3,A5)	-
B4	-	(B4,A2)	(B4,A3)	(B4,A4)	(B4,A5)	-
B5	-	-	(B5,A3)	(B5,A4)	(B5,A5)	(B5,A6)
B6	-	-	-	(B6,A4)	(B6,A5)	(B6,A6)

### 3.7 Primary fund allocation criteria

The fundamental fund allocation formula can be formulated as described in the flow chart given in figure 3.1. This criterion shall be revised after the completion of each cycle.

Road segments to be included for capital investment program

$((B_1, A_4), (B_1, A_3), (B_1, A_2), (B_2, A_5), (B_2, A_4), (B_2, A_3))$

Second Priority for capital projects  $= ((B_3, A_5), (B_3, A_4))$

If there is a specific need, following categories shall be considered  $= ((B_1, A_1), (B_2, A_2), (B_3, A_3))$  If there is a plan to develop as a connecting road  $= (B_4, A_4), (B_5, A_5), (B_6, A_6)$

All other road segments have to be maintained by using recurrent budget.

From recurrent expenditure  $CR(i,j) = \text{Average of } [ B(i,j)*5\% + A(i,j)*1\% + 50,000 ]$

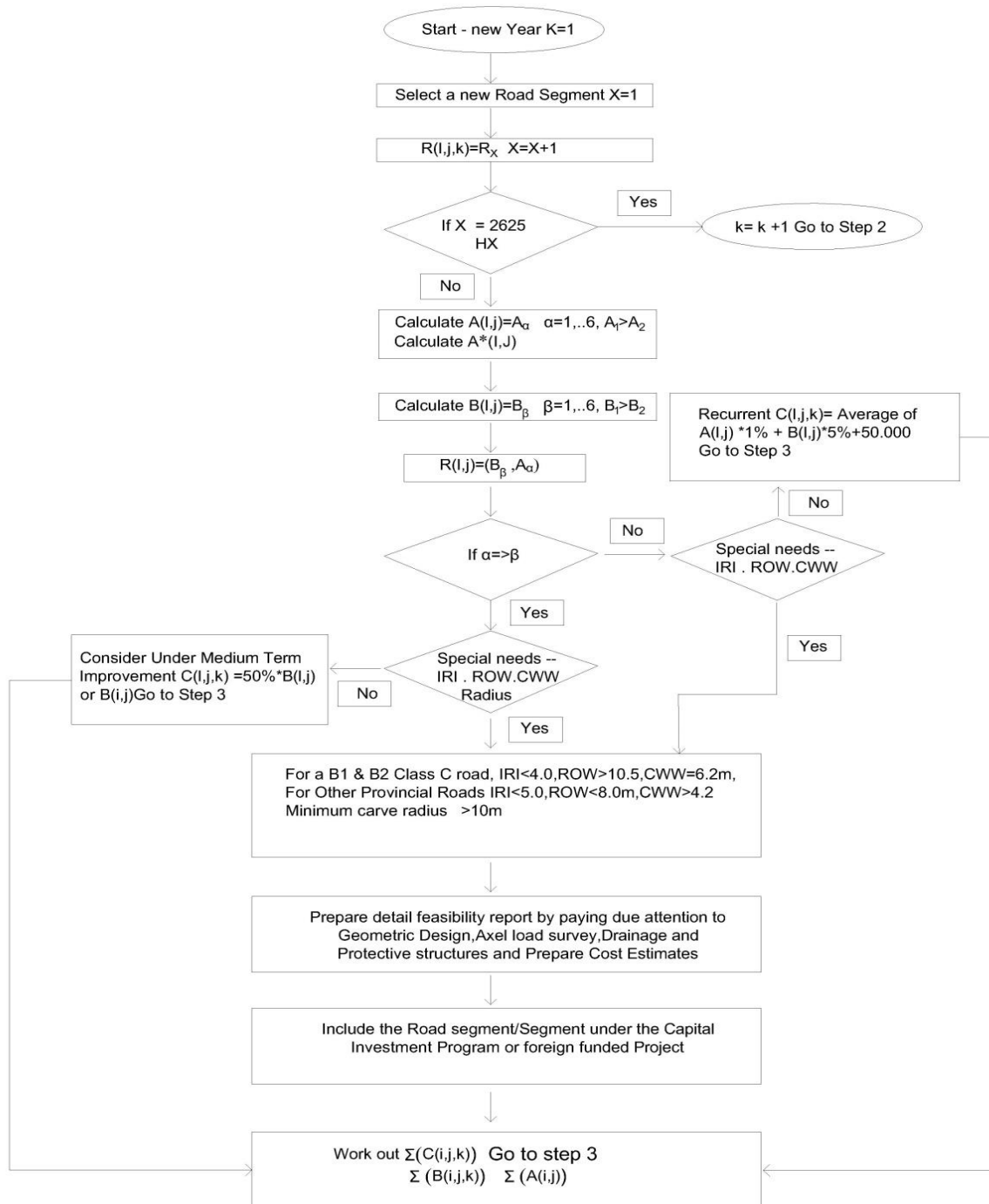
From the mid-term investment program  $CM(i,j) = 50\% * B(i,j)$

For capital investment Program  $5 * B(i,j) < CC(i,j) < 10 * B(i,j)$

Those results are verified under Chapters 4 & 5. The relevant flow chart is given in figure 3.6. It is possible to write a computer algorithm and finally, the software may be developed for the fund allocation process. As described in chapter 2, the best fund allocation program shall be developed after 3-5 cycles.

Tentative fund allocation plan will be verified under the chapter 4 & 5 case study.

EVIDENCE BASED FUND ALLOCATION SYSTEM FOR PROVINCIAL ROAD NETWORK



Note:- This flow chart is subjected to the modification as described on the chapter

Figure 3. 6 Flow Chart showing the methodology

## CHAPTER 4 :Case Study- Formulation of funds allocation criteria for Sabaragamuwa Provincial road network

### 4.1 Introduction

#### 4.1.1 Sabaragamuwa Provincial Road Network

Sabaragamuwa Province has a plantation and agriculture-based economy with a small number of industries scattered throughout the province. Most of the agriculture and plantation areas are served by provincial roads. Sabaragamuwa province which is surrounded by five other provinces with different characteristics represents all geographical regions in Sri Lanka except the coastal belt. Most of the parameters of the socio-economic and geographical features, pertaining to Sabaragamuwa, are very close to the national average. Therefore, the fund allocation method prepared for Sabaragamuwa provincial network can be easily modified to suit the other provinces.

A summary of the Sabaragamuwa provincial road system is compared with the national-level road system and details are given in Table 4.1

Table 4. 1 Comparison of road network details in different regions

Region	Area Sq km	RDA road km	PR km	Local Rural road km	RDA Density km/sqkm /Area %	Provincial R Density km/sqkm /Area %	Local roads Density km/sqkm /Area %	Total Road Density km/sqkm /Area %
Ratnapura	3275	721.7	1500	4850	0.22 0.24%	0.571 0.428%	1.481 0.665%	2.272 1.33%
Kegalle	1693	502.9	1125	3025	0.297 0.327%	0.664 0.498%	1.787 0.804%	2.748 1.63%
Sabaragamuwa Province	4968	1225	225	7871	0.246 0.295%	0.528 0.396 %	1.589 0.72%	2.36 1.41%
Western Province	3593	1800	1952	11180	0.501 0.751%	0.54 0.407%	3.112 1.400%	4.15 2.56 %

Region	Area Sq km	RDA road km	PR km	Local Rural road km	RDA Density km/sqkm /Area %	Provincial R Density km/sqkm /Area %	Local roads Density km/sqkm /Area %	Total Road Density km/sqkm /Area %
Sri Lanka	62705	12500	18754	110800	0.1993 0.299 %	0.299 0.15%	1.767 0.795%	2.265 1.244%

#### 4.1.2 Main Objectives of the case study

- (a) It is very important to find out how each and every household is connected to the national road network. In this exercise population percentage connected to the RDA network through provincial roads can be determined.
- (b) Formulation of an results based fund allocation system for Sabaragamuwa Province

### 4.2 Data Collection

Data collection is performed in two stages.

1. Collection of household connectivity data-How each house is connected to the National road network(A class road is identified as the starting point for provincial road users)
2. Selecting the sample of roads and collection of technical data pertaining to all segments in order to verify the formulated fund allocation criteria

#### 4.2.1 Household connectivity to highway systems- Data analysis

It is very important to find out how each and every trip generating location (Houses)are connected to the national highways. There are 35 ways of reaching the National highways or the main cities. Under normal circumstances, people make use of shortcuts by using the provincial and local roads. Following shortcuts are commonly used by road users especially to bypass the main city centers.

RDA roads > Provincial road>RDA road

RDA roads > Local road > RDA road

RDA Road>Provincial road> Local road> RDA road

This information is very useful in the provincial road planning, management, and fund allocation process.

DVA-Direct Vehicle access –This means those households are directly connected to the road network. Walking along the roads and head carrying is not required. They can easily use their private vehicles.

FPA-Foot Path access-People has to walk some distance to reach a service road. Walking distance is limited to 2 km. (SDG Goal Number 9,2012)

Table 4. 2: Different way approaching Households from National Network

No	Road sequence category	Road Sequence						Percentage	
1	A only	A>	DVA					38%	5.3%
2		A>	FPA						0.8%
3	A and Local road only	A>	LR>	DVA				29%	15.9%
4		A>	LR>	FPA					1.0%
5	A&B only	A>	B>	DVA				29%	5.5%
6		A>	B>	FPA					0.8%
7	A,B and LR only	A>	B>	LR>	DVA			29%	7.0%
8		A>	B>	LR>	FPA				1.8%
9	A,B and C only	A>	B>	C>	DVA			29%	3.0%
10		A>	B>	C>	FPA				1.3%
11	A,B ,Cand D only	A>	B>	C>	D>	DVA		29%	1.3%
12		A>	B>	C>	D>	FPA			1.0%
13	A,B,C & LR only	A>	B>	C>	LR>	DVA		29%	0.5%
14		A>	B>	C>	LR>	FPA			0.5%
15	A,B,C,D & LR	A>	B>	C>	D>	LG>	DVA	29%	1.0%
16		A>	B>	C>	D>	L>	FPA		0.3%
17	A&C only	A>	C>	DVA				29%	7.6%
18		A>	C>	FPA					2.5%

No	Road sequence category	Road Sequence						Percentage	
19	A,C & LR only	A>	C>	LR>	DVA				8.3%
20		A>	C>	LR>	FPA				1.5%
21	A,C, D only	A>	C>	D>	DVA			6%	0.8%
22		A>	C>	D>	FPA				1.0%
23	A,C,D & LR only	A>	C>	D>	LR>	DVA			3.0%
24		A>	C>	D>	LR>	FPA			1.0%
25	A & D only	A>	D>	DVA				31%	9.3%
26		A>	D>	FPA					0.3%
27	A,D & LG only	A>	D>	LR>	DVA				11.1%
28		A>	D>	LR>	FPA				2.0%
29	A,B&D Only	A>	B>	D>	DVA				1.8%
30		A>	B>	D>	FPA				0.5%
31	A,B,D & LR Only	A>	B>	D>	LR>	DVA			0.8%
32		A>	B>	D>	LR>	FPA			0.5%
33	Shortcut 1 RDA and PR	NR>	PR>	NR>				4%	1.3%
34	Shortcut 2 RDA PR&LR	NR>	PR & LR>	NR>					2.2%
35	Shortcut 3 RDA&LR	NR>	LR>	NR>					1.0%

#### 4.2.2 Collection of Road segment data

Following sample was selected from both districts and both categories of roads. This sample comprised of 352 number of 1 km road segments .

Sample consists of four groups of roads.

Group 1- Class C roads in Ratnapura district

Group 2- Class C roads in Kegalle district

Group 3- Class D roads in Ratnapura District

Group 4- Class D roads in Kegalle district

Table 4. 3:Detail of Selected Sample of Roads

No	Total Population(2675)				Sample(352)	
	Name of the Division	Number of Roads	Grade	Length km	Number of roads	Length in km
01	Ratnapura	30	C	215	5	43
		40	D	143	4	16
02	Pelmadulla	17	C	123	1	14
		30	D	147	3	18
03	Kalawana	19	C	119	1	4
		33	D	163	3	29
04	Balangoda	12	C	129	2	11
		39	D	180	2	28
05	Embilipitiya	16	C	107	3	36
		39	D	134	3	13
06	Kegalle	42	C	191	3	28
		77	D	248	3	14
07	Rambukkana	34	C	134	2	16
		62	D	166	3	18
08	Dehiowita	48	C	250	4	44
		45	D	173	3	21

Table 4. 4: Summary of the provincial roads in Sabaragamuwa

No	Population				Sample	
	Name of Division	Number of Roads	Grade	Length Kms	Number of Roads	Length in Kms
S1	Ratnapura District	94	C	693	12	108
		181	D	768	15	104
S2	Kegalle District	124	C	575	9	88
		184	D	587	9	53
S3	Ratnapura District	275	C&D	1511	27	212

	total					
S4	Kegalle District total	308	C&D	1114	18	141
S5	Grand Total	583	C&D	2625	45	353

There are directly measured parameters and calculated parameters pertaining to a particular road segment as described in Table 4.5

Table 4. 5 : Road data /and calculated parameters

No	Description of Data	Purpose of Data/Parameters
1	People served at head end	Calculate peoples served by road segments
2	End Connectivity	Calculate peoples served by road segments
3	Industrial/ Agricultural Trips	To calculate daily Traffic
4	Minimum Curve radius	To make a conclusion
5	Trip Generated by tourist	Calculate daily Traffic
Calculated Parameters		
1.	Total Asset value of the segment A(I,J)	To determine the fund allocation plan
2.	Number of people served	-do
3.	Total trip Generated	-do
4.	Legal land acquisition cost	-do
5.	Minimum Land acquisition cost	-do
6.	VOT saving due to road improvement	-do
7.	VOT cost when road is blocked	-do

### 4.3 Calculation of value of Road asset in a given segment

Provincial Roads System is subdivided into one km road segments. There may be a fraction of one km segments when a road is divided into full 1 km segments. In order to facilitate the statistical analysis fractions are curtailed or extended to form an integer number of segments.

### 4.3.1 Right of way [ROW] values defined by RDA

The estimated value of a road segment depends on ROW and carriageway width. Nearly thirty percent of the provincial roads are on rolling and hilly terrains and additional width is required to maintain side slopes. Typical road cross sections are shown in figure 4.1 and dimensions are given in Table 4.6

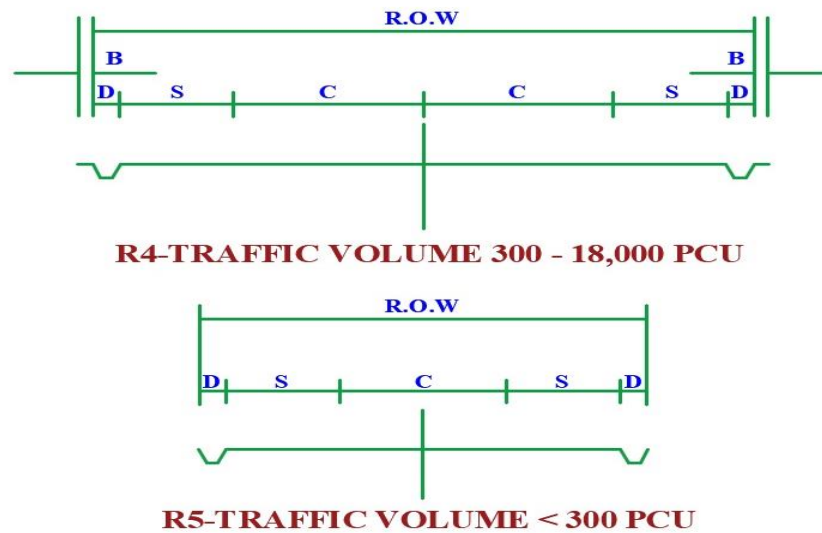


Figure 4. 1 Typical Road cross Sections original source RDA geometric design standard  
Original Source: Geometric Design Standard of RDA 2008

Table 4. 6 : Cross sectional detail of conventional road

Type of cross Section	Berm (m)	Drain (D) (m)	Shoulder (S) (m)	Carriage Way (C) (m)	Median (M) (m)	Right of Way (R.O.W) (m)
R4	1.2x2	0.9x2	2.1x2 1.5 min	3.3x2	-	15
R5	-	0.9x2	2.1x2 1.5 min	4.0	-	10

### 4.3.2 Calculation of A(i,j) for a road segment

Road asset value calculation is a compulsory requirement in government and semi-government organizations (National Audit Act, 2017). It is necessary to maintain the required ROW on all highways. (National Thoroughfare Act, 2008) As described in chapter 3, the asset value of a road segment can be calculated by using the following equation.

$$A(i,j) = \text{Land value} + \text{Earth works value} + \text{Pavement cost} + \text{Drainage and Structures cost} + \text{Bridge Value}$$

#### 4.3.2.1 Land value calculation

Land prices basically depend on the infrastructural facilities available for the area concerned. During the road widening process land acquisition is required and as a result of road improvements prices of the remaining lands increase drastically. Finally, lands used for road construction is counted as road asset.

Let us assume that land price is X million LKR per Purchase

Actual Right of Way [ROW] = W in meters

Area of 1 km segment =  $160 * 2.5 * (W * 1000 / 10000)$  Purchase

Area of 1 km segment =  $16 * 2.5 * W$  -----4(1)

Value of the land per 1 km road segment =  $40 * X * ROW$  -----4(2)

Example: X = 0.1 million LKR per Purchase W = 15 m

Value of 1 km road segment =  $0.1 * 40 * 15 = 60$  million LKR

#### 4.3.2.2 Approximate valuation of earthworks

Provincial roads initially originated as footpaths or cart roads with marginal width. Earthworks involved considerable cost, especially in hilly and rolling terrains. Value addition due to the earthworks and protective structures has to be maintained throughout the lifetime of the road. Earthworks costs consist of five major components namely cutting cost, filling volume, displaced volume, burrowed volume, and hauling distance. Based on the above parameters, earthworks cost can be calculated. This is a function of terrain type and width of the road following tentative values may be used for the analysis.

Table 4. 7 : Estimated Values of Earth Works

Estimated Values of Earthworks (LKR millions) Tentative Estimate Base Year 2021										
Type of Terrain	ROW in Meters/Carriageway width in meters									
	6/3.6	7/3.9	8/4.5	9/4.5	10/4.5	11/4.8	12/6.0	13/6.0	14/6.3	15/6.3
Flat	7	8	9	10	11	12	13	14	15	16
Rolling	8	10	12	14	15	18	20	22	24	26
Hilly	10	12	15	18	20	24	28	32	35	40

#### 4.3.2.3 Cost of Pavements

This is the most important parameter which determines the quality and level of service. International Roughness Index [IRI] is the most commonly used parameter to measure the quality of the road surface. As far as provincial roads are concerned Traffic classes shall be taken as T2 or T3(Overseas road Note 31, 1993), and as a result of this low traffic loads lifetime of the roads are also very high provided that correct pavement design is used. IRI value of ordinary provincial roads varies from 1.25-4.00 m/km depending on the pavement type and maintenance plan. There are seven main pavement types used in provincial road networks.

##### 4.3.2.3.1 Traditional dry bound macadam pavements

Traditional dry-bound macadam pavements are the cheapest type. The cost of construction of ordinary 3.6 m wide macadam paved road segment will be 5-6 million LKR per km. This type of road needs sand sealing at least once a year. Annual maintenance cost will be around 600,000 LKR per km and due to the high maintenance cost after a ten-year time period, life cycle cost may be in the range of 10 million LKR per km with comparatively poor performance.

##### 4.3.2.3.2 Concrete pavements without dowel bars (Traditional concrete Pavements)

Most of the provincial and local road authorities use 150 mm thick Grade 20-25 concrete irrespective of subgrade strength and traffic loads. However, pavement thickness has to be determined depending on the subgrade type and the traffic loads. The

approximate cost for 3.6 m wide provincial road with necessary ground improvements will be 15 million LKR.

#### **4.3.2.3.3 Concrete pavements with dowel bars (properly designed concrete pavements).**

RDA and most of the designers used grade 30 concrete for the construction of road pavements. This type of concrete road is ideal for heavy traffic loads. As far as provincial roads are concerned even though the total accumulated axel loads are low there is a chance of having very few heavy axel roads during the lifetime of the roads. If the subgrade strengths are very poor there is a chance of shear and bending failure of pavements. The approximate construction cost for a 4.5 m wide 1 km long concrete road will be 25 million LKR.

#### **4.3.2.3.4 .Pavement constructed by using interlocking blocks**

These types of pavements are suitable for low-traffic roads. The main advantage of this type of pavement is that repair work cost is comparatively less and surface undulations can be corrected at a minimum cost. The construction cost of a one km road segment is in the range of 12-24 million LKR depending on the width of the road and subgrade strength and width of the road.

#### **4.3.2.3.5 Cold mix laid asphalt pavements**

Twenty years ago, most of the provincial roads were macadam roads. Cold mix layers are used for pothole patching or as a correction layers on the top of the existing macadam surface. However, this method is very good for the places with high subgrade strength and low traffic. Cost of construction will be in the range of 8-10 million LKR per km depend on the width of the road. and the patching area.

#### **4.3.2.3.6 Hot Mix laid asphalt pavements.**

This is the most commonly used improving method in the world. Existing surface condition is very poor scarifying the damaged surface and laying a ABC base with a compacted thickness of 150mm -200mm is recommended. Existing surface is fairly good, 50 mm correction layer and 40 –to 50 mm wearing course is used. Approximate asphalt pavement construction cost 15-25 million LKR per km depend on the width of road, subgrade condition and traffic load. (Tentative Estimates prepared for 100,000 km progrmn-2021 )

#### 4.3.2.3.7 DBST Roads

DBST roads were introduced in late 1990 and these types of pavements are very good for dry zones. DBST roads can be converted to hot asphalt roads at a minimum cost provided that the road base is in fairly good condition. The approximate cost per 1 km road segment is about 8-15 million LKR depending on the width of the road. (Estimates prepared for JBIC funded project in the year 2000)

#### 4.3.2.4 Drainage system and protective structures cost

A considerable cost has to be incurred for the construction of drainage systems and structures. This involves the construction of culverts, side drains, lined canals, retaining structures, and other structures.

The proper drainage system is essential for any road construction. Natural waterways should not be blocked during road construction. Depending on the topography of the area side drains have to be provided on one side or both sides. The cost of structures and drainage systems varies between 5-25 million LKR per km (Tentative Estimate prepared for JICA-funded projects 2002-2012)

#### 4.3.2.5 Valuation of Bridges

Construction costs of highway bridges are comparatively high and depend on various parameters. Provincial roads networks consist of bridges with an estimated value ranging from 8-50 million. There are large number of composite steel bridges and those bridges needs routing maintenance. Even concrete bridges need some repairs like painting and replacement of hand rails and uprights.

Estimation of the total assets value of the road segment

Based on the above analysis average value of a road segment can be found.

$$A(i,j,k)=LV(i,j,k)+EWV(i,j,k)+PV(i,j,k)+DRSTV(i,j,k)+BV(i,j,k)-----4(2a)$$

Where

$A(i,j,k)$ = Total estimated value of assets in road <sup>th</sup> segment.

Table 4. 8 : Valuation of Road assets in Kuruwita- Erathna Road.

Km Number	Price of Lands in LKR	Value of Earthworks ( In LKR	Cost of Pavements in LKR millions	Drainage System value in LKR millions	Bridges Value in LKR millions	Value of Road Segment in LKR millions
1	50	10	24	12	0	96
2	39	15	18	8	12	92
3	26	15	18	8	0	67
4	19	20	18	8	12	77
5	19	15	18	8	0	60
6	19	25	18	8	0	70
7	19	15	18	8	12	72
8	19	20	18	8	0	65
9	22	12	18	8	0	60
10	25	10	18	8	20	81
11	31	10	18	8	0	67
12	25	12	18	8	0	63
Total	314	179	222	100	56	870

Note : Tentative values are used for the cost estimates Base year 2021 1 US\$=200 LKR

#### **4.4 Calculation of B(i,j) for Sample Provincial Road Segments in Sabaragamuwa Province**

The following method is used to determine the population percentage served by provincial roads. At the end of the research, it can be shown that the number of people served by the road segment and the design PCU determines the B(i,j)

##### **Assumptions**

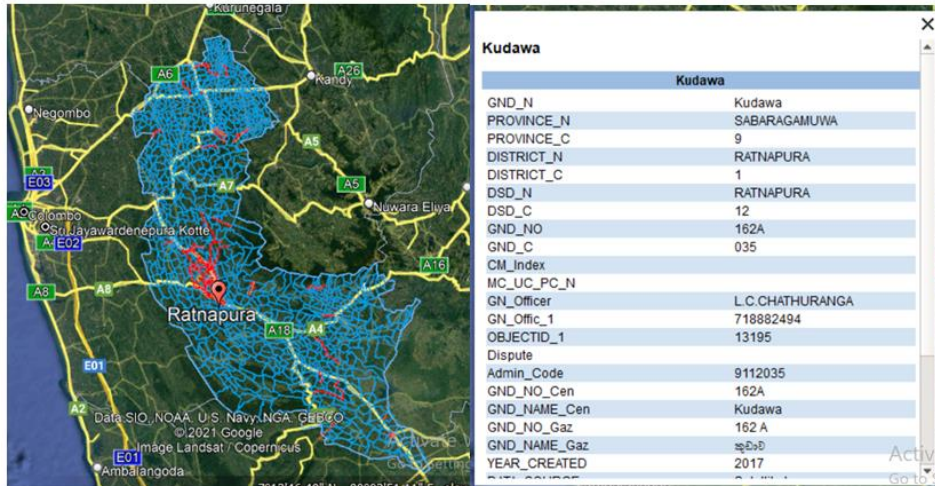
The rural population remains unchanged during the last nine years time period.

Trip generation by the rural population is very small compared to the urban community.

Five passenger trips make one PCU

Most of the provincial roads are single-lane roads.





**Figure 4. 3** Google Map with GN division overlaying showing Ratnapura and Kegalle districts and selected roads segments

Original Source: Google Map and Surveying Department web site

Step 3-There are four main types of Provincial roads available in the network

1. Provincial roads continue from the final destination to join another sub urban city. e.g.Kuruwita- Erathna Road (C005)
2. Provincial roads connect almost dead end. Godakawela Bibilegama road.
3. Provincial road connect major trunk road. Kuruwita Gorakaela road C002 which join A04 and A08 road
4. Provincial roads in a small mesh of other small or medium road.

#### Sample Calculation for Kuruwita- Erathna C005 Road

Kuruwita Erathna road is one of the provincial road with high traffic flow. Average annual daily traffic is was estimated in 2011 and it was found that AADT is in the range of 2400-3000 PCU per day with an average of 2625 PCU per day. Night traffic in between 9.00 p.m. to 5.00 is about 100 PCU. This means maximum hourly rate is about 200 PCU per one direction and about 100 PCU for minor direction. This result was obtained after the traffic survey conducted in year 2011 and verified by the following analysis. [There may be a reduction of traffic level due to the unprecedented increase in fuel prices during the last few months]

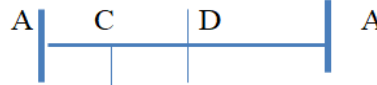
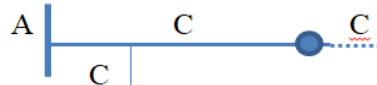
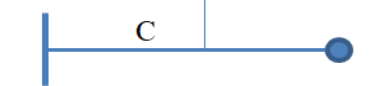
Table 4. 9 : Sample data collected from Google maps , Censes and statistic department publications Kuruwita -Erathna Road

Relevant GN division	GN No	Total area of GN divisions (hectares )	Area served by the road (Ha)	Population ( Census of Dept - 2012 )	Population percentage served by the road	People served by the road
Kuruwita	155	440	44	4385	20%	877
Ekneligoda	159C	110	99	1722	100%	1,722
Ekneligoda- N	159B	325	195	1495	100%	1,495
Sudagala	161A	1,237	619	2137	100%	2,137
Lassakanda	161C	683	478	1800	100%	1,800
Erathna	161	692	450	1533	100%	1,533
Walandura	154	775	116	2762	30%	829
Udakada	159A	39	2	777	10%	78
Devipahala	160A	961	48	2850	10%	285
Endiriyawala	160	942	188	1820	100%	1,820
Adawikanda	161B	1,191	357	937	100%	937
Guruluwana	162G	1,055	105	1439	35%	504
Gileemale	162	700	70	1656	50%	828
Ketawala	162E	686	69	1309	50%	655
Yatiwala	113B	728	36	1882	80%	1,506
Kosgahakanda	113A	955	96	2336	40%	934
Magala	113	2,192	658	1076	80%	861
Miyanawita	114G	541	27	2216	40%	886
Nakkavita	112A	494	25	1273	30%	382
Poddenikanda	112C	899	45	2323	30%	697
Maliboda	112	2,132	320	1942	30%	583
Total		17,776	4,046	39670		21,347

From this table number of persons served at the head end.P<sub>0</sub>=21350

Numbers of people served by the remaining segments are calculated by following semi empirical formulas. Following table shows formulas used in the analysis

Table 4. 10 Semi Empirical equation for calculation of number of peoples served and design Traffic flow

Type/ Start and End Junction	Configuration	Number of Peoples served/ Design Traffic Flow at X <sup>th</sup> km IT= Industrial Trips VT=Tourist trips
Type 1		$P_X = P_o * [0.7 + 1.2 * (0.5 - 0.8 * X/N)^2]$ —4(3)
ACA		$DTF = P_N * 0.6/5 + IT + VT$ -----4(4)
AAC		$P_o =$ People served at main end
Type 2		$P_X = P_o * [[1 + 1/N] - 0.65 * X/N]$ -----4(5)
ACA		$DTF = P_N * 0.3(1 - .3X/N)/5 + IT + VT$ -----4(6)
C Continuing		$P_o =$ People served at head end
Type 3		$P_X = P_o * [[1 + 1/N] - 0.8 * X/N]$ -----4(7)
ACA		$DTF = P_N * 0.3(1 - .3X/N)/5 + IT + VT$ -----4(8)
Dead End		$P_o =$ People served at head end
<u>Note</u> : Local roads and other access roads are not shown for clarity.		

Simplified traffic generation model type 2 is used to determine the population served and the design PCU for Kuruwita- Erathna road

Population served at the main head end=21500 persons( Rounds up to nearest 500 persons)

Population served by the N<sup>th</sup> km segment  $P_N = P_o * [1.1 - 0.65 * N/12]$ ----4(10)

Design PCU at N<sup>th</sup> km segment =  $P_N * 0.3(1 - .3N/12)/5 + IT + TT$ -----4(11)

Where IT- Industrial trips, TT-Tourist Trips

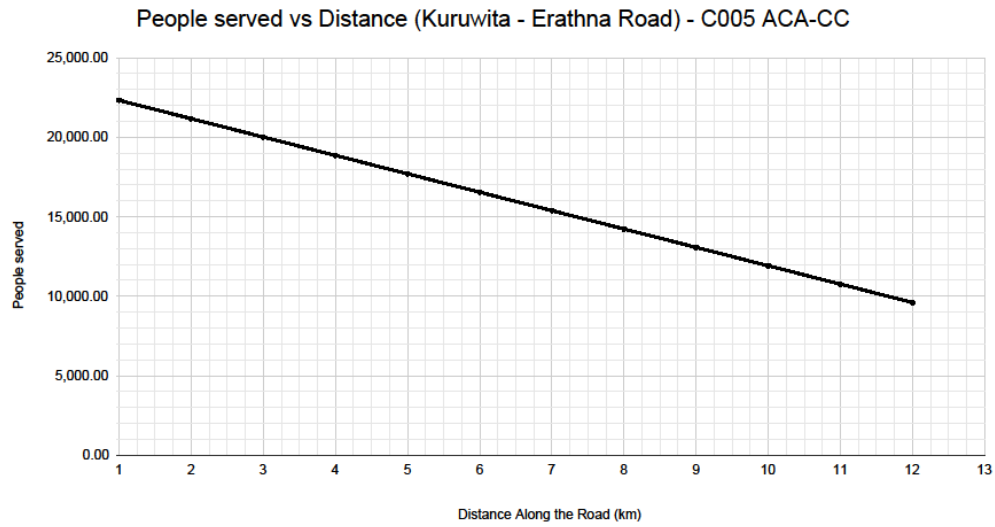


Figure 4. 4 People served vs Distance (Kuruwita – Erathna Road)

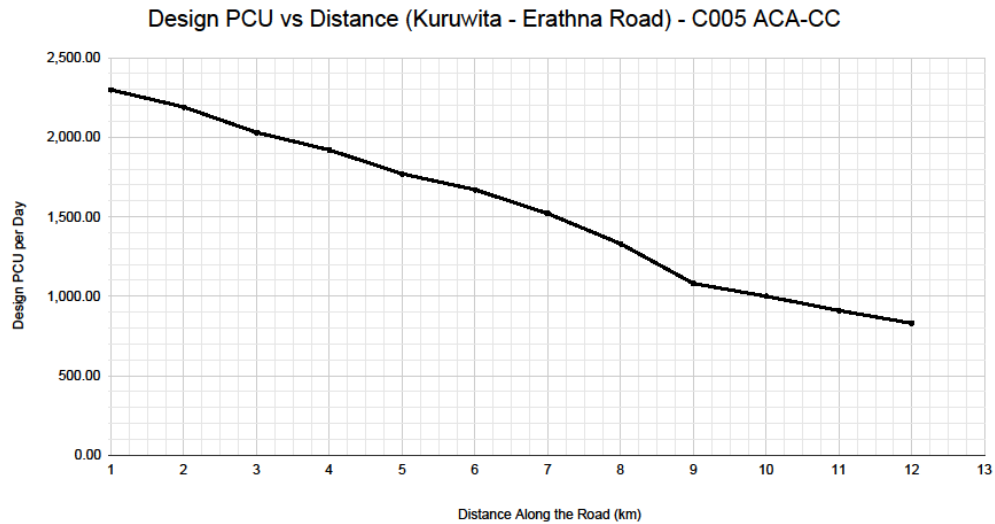


Figure 4. 5 Design PCU vs Distance (Kuruwita – Erathna Road)

Type 111 Model Godakawela- Bibilegama D076 road Starting from AAC junction going towards dead end  $P_o=5325$

Population served by the  $N^{th}$  km segment  $P_N= P_o*[1.2-N/5]$ -----4(12)

Design PCU at  $N^{th}$  km segment  $= P_N*0.3(1-.3N/5)/5+IT+TT$ -----4(13)

Type 11 Kuruwita \_Pathagama via Gorakaela C002 Starting from AAC junction end at ACA junction.

Population served by the  $N^{\text{th}}$  km segment  $P_N = P_o * [0.7 + 1.2 * (0.5 - 0.8 * N/9)^2]$ -----4(14)

Design PCU value of the segment no N=

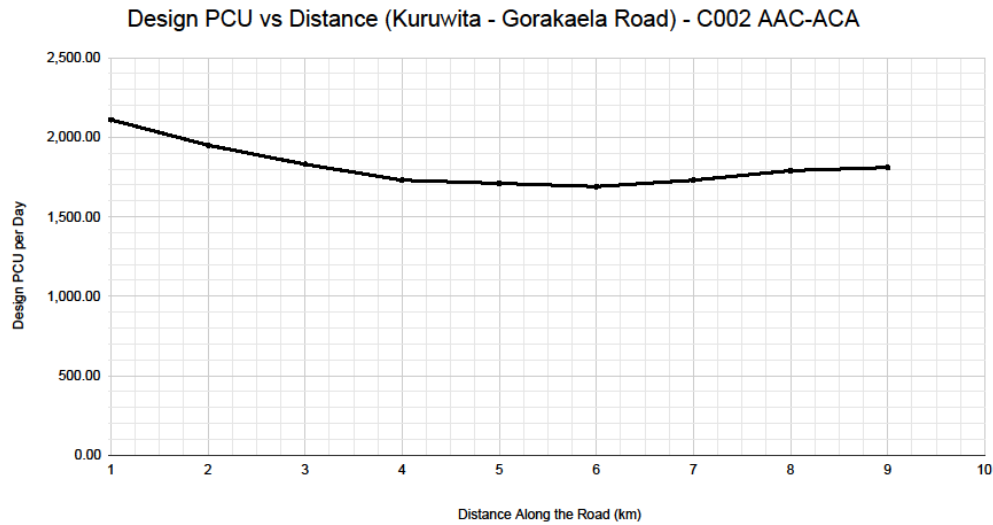


Figure 4. 6 Design PCU vs Distance (Kuruwita – Gorakaela Road): People served Vs Distance km

Table 4. 11 : Population served and design PCU for different road segments- Class C Roads

Index number of the Road	Length Considered	Population Served at Head End $[P_o]$	Population Served at $N^{\text{th}}$ km $P_N$	Design PCU at $N^{\text{th}}$ km AADT
C 001	3 km	5012	$P_o = P_N$ Through out	$(P_o * 0.3/5) + IT + VT$
C002	9 km	17150	$P_o * [0.7 + 1.2 * (0.5 - 0.8 * N/9)^2]$	$P_N * 0.6/5 + IT + VT$
C004	9 km	14600	$P_o * [0.7 + 1.2 * (0.5 - 0.8 * N/9)^2]$	$P_N * 0.6/5 + IT + VT$
C005	12 km	21347	$P_o * [1.1 - 0.65 * N/12]$	$P_N * 0.3(1 - .3N/12)/5 + IT + VT$
C017	10 km	4911	$P_o * [1.1 - 0.3 * N/10]$	$P_N * 0.3(1 - .3 * N/10)/5$
C036	14 km	8909	$P_o * [1.1 - 0.9 * N/14]$	$P_N * 0.3(1 - .3N/14)/5 + IT + VT$
C049	5 km	3475	$P_o * [0.7 + 1.2 * (0.5 - 0.8 * N/5)^2]$	$P_N * 0.3(1 - .2 * N/7)/5 + IT + VT$
C055	5 km	3738	$P_o * [0.7 + 1.2 * (0.5 - 0.8 * N/5)^2]$	$P_N * 0.3(1 - .3 * N/6)/5$
C069	4 km	3112	$P_o * [1.2 - 0.9 * N/4]$	$P_N * 0.3(1 - .3 * N/4)/5$
C079	23 km	13243	$P_o * [0.7 + 1.2 * (0.5 - 0.8 * N/23)^2]$	$P_N * 0.33/5 + IT + VT$

Index number of the Road	Length Considered	Population Served at Head End [P <sub>0</sub> ]	Population Served at N <sup>th</sup> km P <sub>N</sub>	Design PCU at N <sup>th</sup> km AADT
C083	4 km	8622	$P_0 * [0.7 + 1.2 * (0.5 - 0.8 * N / 4)^2]$	$P_N * 1.5 / 5 + IT + VT$
C093	9 km	8314	$P_0 * [0.7 + 1.2 * (0.5 - 0.8 * N / 15)^2]$	$P_N * .575 / 5 + IT + VT$
C097	12km	18526	$P_0 * [0.9 + 1.5 * (0.5 - 0.8 * N / 12)^2]$	$P_N * .6 / 5 + IT + VT$
C101	5 km	4678	$P_0 * [1.2 - 0.9 * N / 5]$	$P_N * 0.3(1 - .3 * N / 5) / 5$
C133	11 km	8746	$P_0 * [0.7 + 1.2 * (0.5 - 0.8 * N / 11)^2]$	$P_N * 0.3 / 5 + IT + VT$
C 154	10 km	10685	$P_0 * [0.7 + 1.2 * (0.5 - 0.8 * N / 10)^2]$	$P_N * 0.75 * .3 / 5 + IT + VT$
C176	6 km	5500	$P_0 * [0.7 + 1.2 * (0.5 - 0.8 * N / 12)^2]$	$P_N * 0.6 * .3 / 5 + IT + VT$
C179	13 km	7190	$P_0 * [1.077 - 0.9077 * N / 13]$	$P_N * 0.3(1 - .3 * N / 13) / 5$
C182	15 km	18540	$P_0 * [1.067 - 0.9067 * N / 15]$	$P_N * 0.3(1 - .3 * N / 15) / 5$
C189	11 km	7994	$P_0 * [1.1 - 0.7 * N / 11]$	$P_N * 0.3(1 - .3 * N / 11) / 5$
C198	5 km	5027	$P_o = P_0 * [1.2 - 0.9 * N / 5]$	$P_N * 0.3(1 - .3 * N / 5) / 5$

Table 4. 12 : Population served and design PCU for different road segments- Class D Roads

Index number of the Road	Length	Population Served at Head End [P <sub>0</sub> ]	Population Served at N <sup>th</sup> km P <sub>N</sub>	Design PCU at N <sup>th</sup> km AADT
D005	3 km	4190	$P_0 * [1.33 - *N / 3] * 1.25$	$P_N * 0.75 * .3 / 5 + IT + VT$
D009	3 km	4396	$P_0 * [1.33 - 0.7 * N / 3]$	$P_N * 0.3(1 - .2 * N / 3) / 5 + IT + VT$
D012	3 km	5709	$P_0 * [1.33 - 0.7 * N / 3]$	$P_N * 0.3(1 - .2 * N / 3) / 5 + IT + VT$
D018	7 km	4075	$P_0 * [1.14 - 0.7 * N / 7]$	$P_N * 0.3(1 - .2 * N / 7) / 5 + IT + VT$
D049	5 km	3131	$P_0 * [1.2 - 0.7 * N / 5]$	$P_N * 0.3(1 - .2 * N / 5) / 5 + IT + VT$
D068	12km	2414	$P_0 * [0.5 + 0.6 * (0.5 - 8 * N / 12)^2]$	$P_N * 0.3 / 5 + IT + VT$
D068R	12km	2414	$P_0 * [0.7 + 1.2 * (0.5 - 8 * N / 12)^2]$	$P_N * 0.3 / 5 + IT + VT$
D076	5 km	5325	$P_0 * [1.2 - N / 5]$	$P_N * 0.3(1 - .3 * N / 5) / 5 + IT + VT$
D 107	12 km	4760	$P_0 * [1.083 - 0.7 * N / 12]$	$P_N * 0.3(1 - .3 * N / 11) / 5 + IT + VT$
D120	16 km	2088	$P_0 * [1.066 - 0.7 * N / 16]$	$P_N * 0.3(1 - .2 * N / 16) / 5 + IT + VT$
D147	2 km	3178	$P_0 * [1.5 - N / 2]$	$P_N * 0.3(1 - .2 * N / 16) / 5 + IT + VT$

Index number of the Road	Length	Population Served at Head End [P <sub>0</sub> ]	Population Served at N <sup>th</sup> km P <sub>N</sub>	Design PCU at N <sup>th</sup> km AADT
D151	8 km	4491	$P_o*[1.125-0.8*N/8]$	$P_N*0.3(1-.2*N/8)/5+IT+VT$
D158	3 km	5973	$P_o*[1.125-0.8*N/8]$	$P_N*0.3(1-.4*N/8)/5+IT+VT$
D Class Roads Kegalle				
D194	6 km	2309	$P_o*[1.116-0.7*N/6]$	$P_N*0.3(1-.2*N/6)/5+IT+VT$
D204	1 km	2278	P <sub>o</sub> Throughout	$(P_o*0.3/5)+IT+VT$
D 237	8 km	1999	$P_o*[1.125-0.8*N/8]$	$P_N*0.3(1-.2*N/8)/5+IT+VT$
D275	9 km	7773	$P_o*[1.11-0.6*N/9]$	$P_N*0.3(1-.2*N/9)/5+IT+VT$
D276	7 km	2662	$P_o*[1.14-0.7*N/7]$	$P_N*0.3(1-.2*N/7)/5+IT+VT$
D297	5 km	2480	$P_o*[1.2-0.8*N/5]$	$P_N*0.3(1-.2*N/5)/5+IT+VT$
D312	3 km	962	P <sub>o</sub> = P <sub>N</sub> Through out	$(P_o*0.3/5)+IT+VT$
D349	11 kmy	6330	$P_o*[0.7+1.2*(0.5-.8*N/11)^2]$	$P_N*0.75*.3/5+IT+VT$

#### 4.5 IRI value prediction for different types of Provincial Roads

IRI value of 1.5-4.0 m/km is an ideal value range for provincial roads and it can be shown that the best results of travel time reduction and fuel saving could be obtained under these conditions.

Different type of road pavements shows different IRI values with the time. Table No 4.8 is prepared by using the experience gathered during the last 15 years. IRI value score method is used to estimate the IRI values of different type of pavements after construction, one year and ten years' time period. Values given in the table may be used to determine the appropriate pavement type. Further analysis is given in the chapter 5.

Table 4. 13: IRI Values for different types of pavements

Type of Provincial Road pavement	Predicted IRI values and Impaired tolerance					
	After Construction		After 1 year		After 10 years	
	IRI	Tolerance	IRI	Tolerance	IRI	Tolerance
Hot Asphalt pavement	1.5	-5%+20%	1.8	-10%+25%	2.4	±15%
DBST Pavements	1.8	-5%+25%	2.0	-5%+30%	2.5	-10%+50%

Type of Provincial Road pavement	Predicted IRI values and Impaired tolerance					
	After Construction		After 1 year		After 10 years	
	IRI	Tolerance	IRI	Tolerance	IRI	Tolerance
Concrete Pavements	2.2	±20%	2.2	-10%+10%	2.5	-10%+30%
Interlock block pavements	2.2	±20%	2.5	±20%	3.0	±30%
Macadam pavements	2.4	±25%	3.0	±25%	4.0	-5%+200%

#### 4.6 Average speed of a road segment.

Most of the provincial roads are single-lane roads with a carriageway width ranging from 3.1 m to 4.8 m. Therefore, overtaking operation is not permitted on most of the roads. Two small vehicles cross each other with a lesser speed and there if there is a large vehicle in one direction crossing speed is further reduced in the case of two large vehicles overcrossing both vehicles come to a standstill position and then passing operation begins. Sometimes reversing one vehicle is required to cross each other.

This is the main reason for low average speeds on provincial roads. However, daily traffic is comparatively small compared to the main arterial roads. A recent traffic survey carried out reveals that the maximum hourly traffic rate is in the range of 25-400 PCU for class C roads 5-100 PCU for class D roads.

The average speed maintained in the main arterial roads is in the range of 9-64 km per hour and in most of the provincial roads 12-42 speed range is maintained.

#### 4.7 Driving Cycle for provincial roads

Driving Cycle may be used to calculate the VOT saving and fuel saving. Typical driving cycle for Kuruwita- Erathna Road is given in the appendix C. It is possible to take following decisions with help of driving cycle.

1. Keep the roads cross section without widening.
2. Add another lane roads to accommodate the vehicle travelling in two opposite directions
3. Construction of passing bays at the regular intervals

#### **4.8 Fuel saving benefits**

Fuel consumption is a very much complex function which depends on various parameters. However, fuel efficiency can be increased by converting the medium traffic single lane provincial roads in to two lane roads or by constructing passing bays at regular intervals of 100-200 m. It is also possible to increase fuel efficiency by maintaining IRI value less than 4. Horizontal and vertical alignment also has significant effects on fuel efficiency. Part of these parameters are incorporated in the initial benefits calculation under the section 3.5.2

#### **4.9 Value of time saving**

Value of time[VOT] saving is the most significant factor in the case of provincial roads. Value of time, saving is a complex function and it had been already incorporated in the benefits calculations under section 3.5.2

#### **4.10 Effects of heavily loaded trucks**

Provincial roads are marginally designed for heavy axle loads. In most places, lateral support given by the shoulders is inadequate. Deterioration of a road pavement system can be attributed to the heavy traffic load class, pavement condition, subgrade strength, and lack of ROW in the flat terrains and the construction difficulties in the hilly terrains. Governing Equation for the equivalent axel loads are given by the following equation (Road Note 31)

$$\text{Equivalent Axle Load} = \left[ \frac{\text{Axle load (kg)}}{8160} \right]^{4.5} \text{-----4(15)}$$

Table 4. 14 : Effects of Heavy Axel Loads on Road Pavement

Type of Vehicle	Front Axel load kg	Real axel load kg	Equivalent front load standard axel	Equivalent rear load standard axel	Total Equivalent load standard axel	Effects of the Vehicle
Three Wheelers	250	300	0	0	0	Negligible
Motor Car	800	800	0	0	0	Negligible
Dual purpose Vehicle/ Jeep	1200	1200	0.0005	0.0005	0.001	Negligible
Van 12 passenger	1500	2000	0.0005	0.0025	0.003	Marginal
Mini Bus	2000	2500	0.002	0.005	0.007	Marginal
Medium Bus	3200	4800	0.02	0.1	0.12	Medium
Large Bus	3500	6500	0.04	0.10	0.14	Upper medium
5 tones tipper	3000	4800	0.06	0.10	0.16	Medium
10 tones Tipper Lorry	5000	9000	0.1	1.5	1.6	High
15 tones tipper/lorry	6000	14000	0.25	11.33	11.5	Critical/Instantaneous failure
20 tones tipper /lorry tandem axel	6000	2*9000	0.25	5	5.25	Heavy
Heavily loaded truck	5000	18000	0.1	35.2	35.3	Instantaneous Failure /critical

It can be shown that there are two types of pavement failures may occur in the provincial road pavements due to the excessive loads.

Instantaneous failure might occur due to the very heavy axel loads especially in the concrete pavements.

Rutting and crocodile crack formation in the pavement.

The easiest way of preventing the excessive damage is restricting the heavily loaded trucks on provincial roads.

#### **4.11 Other reasons for pavement deterioration**

Side erosion is the other reason for the instantaneous failure during the wet season.

Present provincial road pavement failures may be attributed to four reasons.

Poor CBR values are present in subgrade which is less than 4

Insufficient structural number of the pavement (Under the design of the pavement) Damage caused by natural disaster.

## CHAPTER 5: Presentation of Results (Output of the case study)

### 5.1 Introduction

Under the data collection, provincial road data pertaining to 352 provincial road segments were manipulated. However, it is necessary to carry out statistical analysis in order to arrive at a decision. The output of the case study has to be transferred into the outcome of the research by means of statistical analysis so that general recommendations can be made more accurately.

### 5.2 Population Served by the Provincial Roads

According to the results of the survey, nearly 65% of the population is served by the Provincial roads. Nearly 50% of the population makes use of local roads to access their houses. Finally, it can be shown that people are served by the different road combinations and Provincial and local roads serve nearly 75% of the population. This gives a clear indication of the necessity of the well-managed provincial and local road Network.

Figures 5.1 Shows the results and survey details are given in the appendix. A

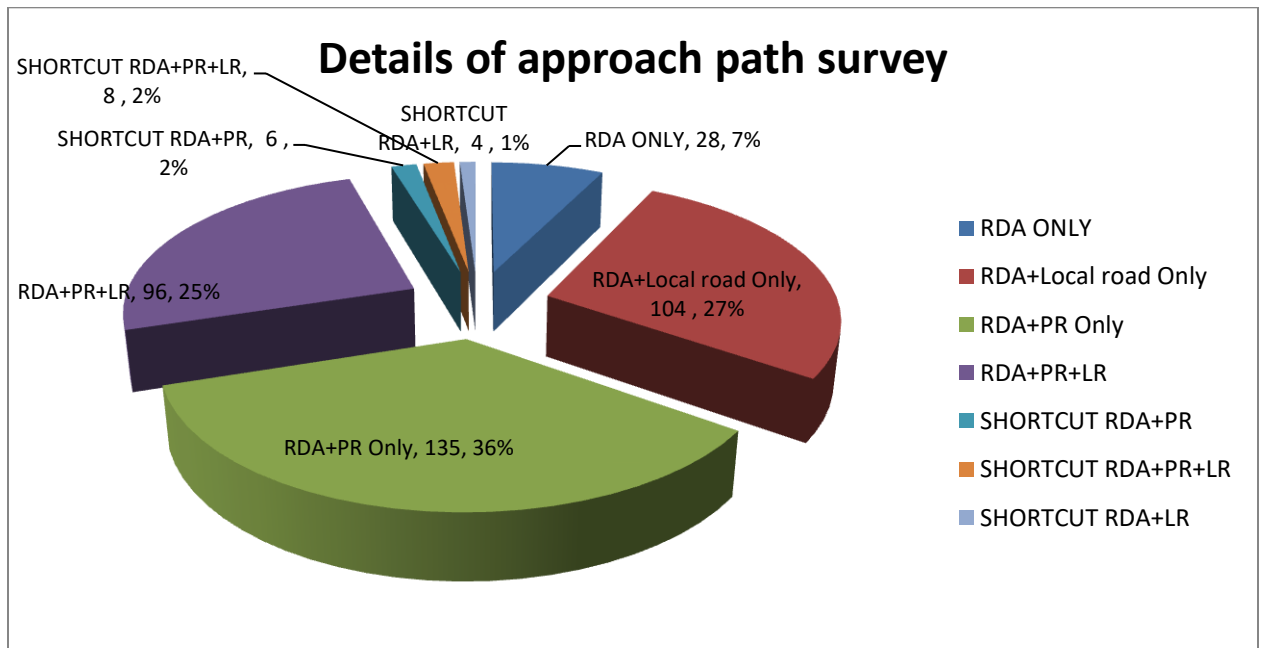


Figure 5. 1 Showing the people served by different road combinations

As far as Sabaragamuwa province is concerned 65% of the population is served by the provincial roads. In the case of the Western province, there may be a small reduction in the percentages of the population served by the provincial roads. Four percent of the population use provincial roads to serve as shortcuts roads. This analysis shows that 93% of the households are connected to the main roads either through local roads or provincial roads Fifteen percent of the population does not enjoy the benefits of direct vehicle access and 93.4% of the aforesaid group is served by the provincial roads. All those figures are summarized in the Venn diagram

Where

E= Entire population in the road network system All classes of roads-100%-Blue colour

PR=Population served by provincial roads=65%

LR= Population percentage served by local roads=55%

FPA= Population does not have vehicle access=15%-Red

SC= Population percentage use either provincial, Local, or both roads as shortcuts=5%

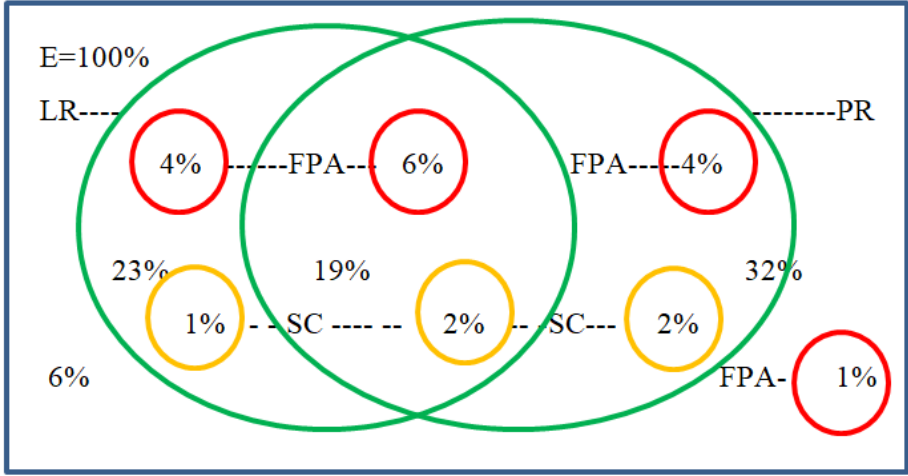


Figure 5. 2 Peoples served by different road combinations

### 5.3 Road Asset values A(i,j) –Final result for the sample roads segments

An average roads assets value is about 50 million SLR and class C roads have an average value of 60 million SLR per km. The other important parameter is the legal land acquisition cost and essential land acquisition cost. Most of the provincial roads were initially cart roads or foot paths. The other important factor is part of the lands were

donated by the land owners. Therefore it is necessary to acquire minimum lands for road improvement. Therefore essential land acquisition cost was calculated for each road segment. Average essential land acquisition cost is in the region of 3.0-3.5 million per km.

Results of the statistical analysis are given in the table No 5.1

Table 5. 1: Roads Assets Values and Essential land acquisition cost.

Group	Parameters	Mean	Stranded Deviation	Median	Maximum	Minimum
1. Ratnapura C Class (108) LKR millions	Road Assets Value	58.99	21.11	57.00	145.00	27.00
	Legal LA Cost	17.92	7.91	16.00	54.00	10.00
	Essential LA Cost	4.75	4.39	3.30	31.50	-
2. Kegalle C Class(88) LKR millions	Road Assest Value	57.32	17.02	55.00	107.00	28.00
	Legal LA Cost	19.84	8.00	19.00	56.00	11.00
	Essential LA Cost	4.77	2.86	4.05	15.70	0.30
3. Ratnapura D Class(107) LKR millions	Road Assest Value	38.70	13.18	34.00	72.00	8.00
	Legal LA Cost	5.71	4.16	5.00	24.00	-
	Essential LA Cost	1.79	2.14	0.80	11.30	-
4. Kegalle D Class(49) LKR million	Road Assest Value	42.94	7.77	44.00	74.00	28.00
	Legal LA Cost	4.41	1.82	4.00	10.00	-
	Essential LA Cost	1.66	1.97	1.20	10.10	-
5. Total C&D Roads 352 LKR Million	Road Assest Value	50.17	18.78	48.00	145.00	8.00
	Legal LA Cost	12.81	9.29	11.00	56.00	-
	Essential LA Cost	3.42	3.47	2.50	31.50	-

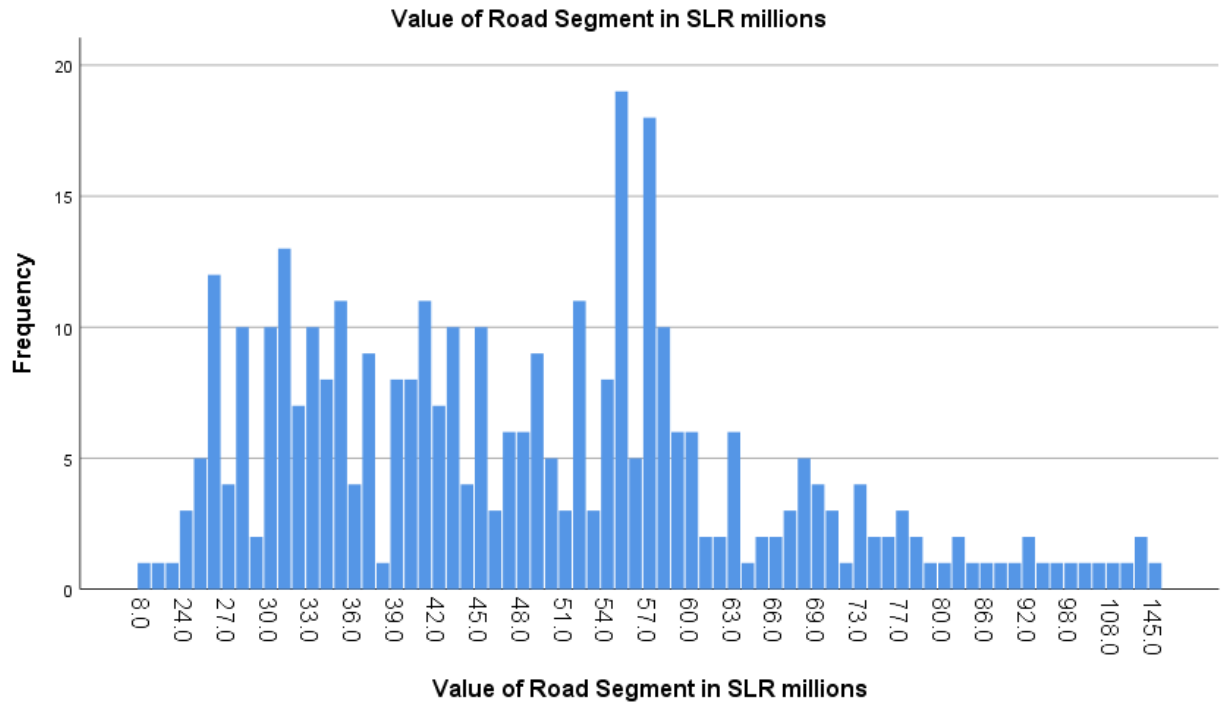


Figure 5. 3 Value of Road Segment in LKR millions

Average estimated value of a road segment is 48 million LKR per km.

Maximum  $A(i,j)=A_1=145$  Million LKR per km.

Minimum  $A(i,j)=A_6=8$  million LKR per km

Total Estimated value of the Provincial Road Assets= $48 \times 2625 = 127.2$  Billion LKR

Asset value class formulated under the Chapter number 3 is justified by this result.

Land acquisition will be discussed under the recommendations.

## 5.4 Benefits Derived –Final Result for the selected sample

### 5.4.1 Population served by road segments

This information is very useful in fund allocation purpose. This is the most socially sensitive benefit component associated with the provincial road system. Population served at the head end and each road segments were calculated and daily traffic flow is estimated by using the population served, industrial trips and (IT) and tourist trips. Those details are given in the sample calculations.

Table 5. 2: Statistical analysis of population served and designs PCU

Group	Population Served and Trip Generation PCU per Day	Number	Mean	Median	St Deviation	Skewness	Maximum	Minimum
1	Population Directly Served	108	8540	8950	4624	0.574	22300	1100
	Trip Generation PCU per day		1055	900	576	0.368	2300	200
2	Population Directly Served	88	8684	7050	5434	0.881	21700	900
	Trip Generation PCU per day		856	700	538	0.492	2000	100
3	Population Directly Served	107	2616	2000	1274	0.802	5700	700
	Trip Generation PCU per day		298	200	244	1.484	1300	50
4	Population Directly Served	49	3122	2200	2357	1.335	10000	1000
	Trip Generation PCU per day		322	200	220	1.658	400	100
Total	Population Directly Served	352	6021	4550	4850	1.272	22300	700
	Trip Generation PCU per day		673	500	557	1.00	2300	50

The mean Population served by a Provincial Road is 6550 persons per 1 km road segment.

Number of people served by is mainly depending on the total length of a road. Normally class C roads serve more people due its long length. Average length of the class C, Class D and Provincial road in both districts are summarized in the following table

#### 5.4.2 Trip Generation (design PCU value for a road segment)

There is a correlation between the trip generation and number of people served by the roads. In addition to this there may be trip attractors, and Industrial and Tourist trips Generated

Therefore, benefit class  $B_1$ =People Served more than 18,000 or AADT more than 18000 PCU per day. Relevant Graphs are given below

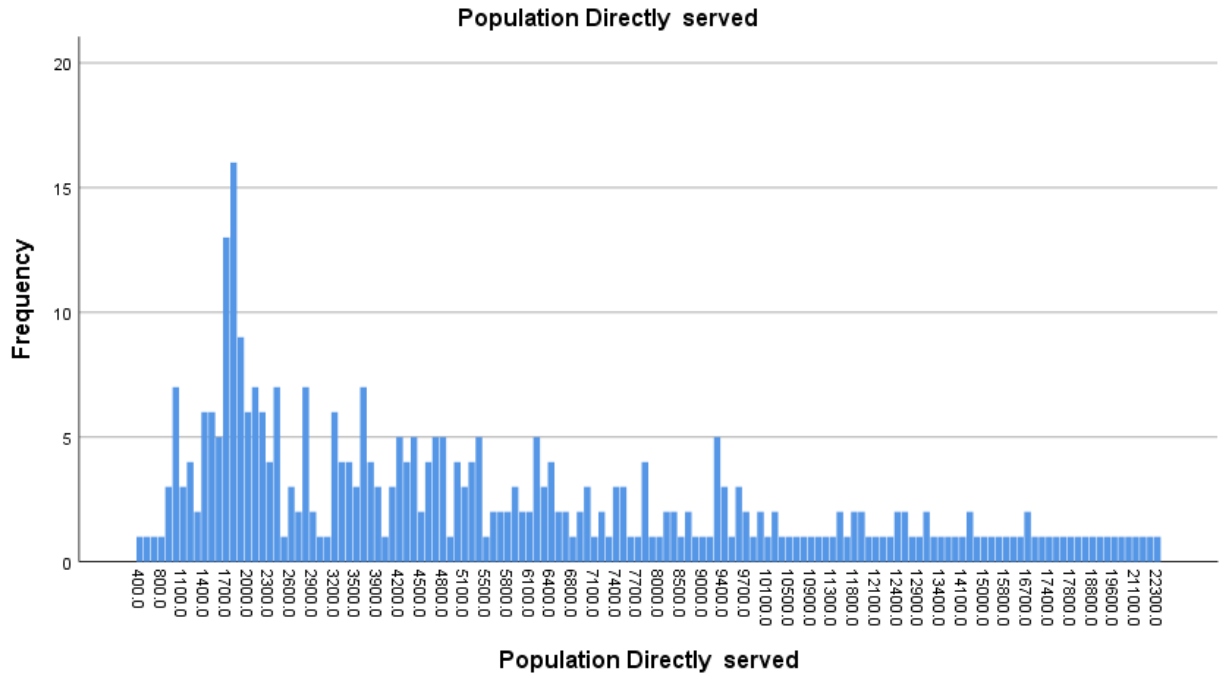


Figure 5. 4: Population directly served by the Provincial Roads segments. (Frequency chart)

Total Estimated Economic Benefit per year=6000\*500\*2625= 6 billion LKR.

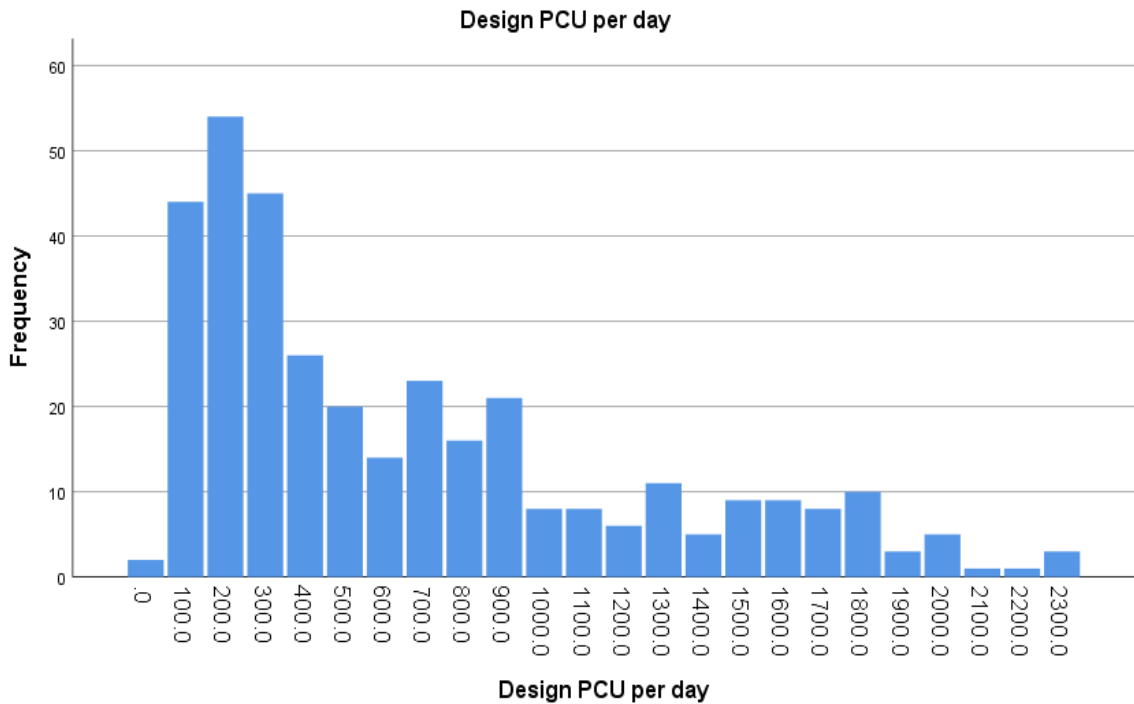


Figure 5. 5: Design PCU value of Road segments.

### 5.4.3 Grouping roads segments according to combined benefit-assets

#### 5.4.4 (B,A) Groups

Each road segment belongs to one of the combined benefits assets class. This sample represent all provincial roads in both districts. Fund allocation is basically governed by the combined (B,A) group. Figure 5.16 describes about the fund allocation based on this criteria.

Table 5. 3 Roads Segments with combined (B,A)

Category	A1 (5.1%)	A2 (5.1%)	A3 (36.8%)	A4 (43.0%)	A5 (9.7%)	A6 (0.3%)
B1 (6.5%)	(B1,A1) (4.3%)	(B1,A2) (1.4%)	(B1,A3) (0.9%)	(B1,A4) (0.0%)	-	-
B2 (12.2%)	(B2,A1) (0.9%)	(B2,A2) (2.6%)	(B2,A3) (6.3%)	(B4,A4) (2.6%)	(B2,A5) (0.0%)	-
B3 (17.5%)	(B3,A1) (0.0%)	(B3,A2) (1.1%)	(B3,A3) (15.4%)	(B3,A4) (1.0%)	(B3,A5) (0.0%)	-
B4 (19.9%)	-	(B4,A2) (0.0%)	(B4,A3) (10.5%)	(B4,A4) (9.1%)	(B4,A5) (0.3%)	-
B5 (31.2%)	-	-	(B5,A3) (3.8%)	(B5,A4) (22.8%)	(B5,A5) (5.0%)	(B5,A6) (0.0%)
B6 (12.8%)	-	-	-	(B6,A4) (7.7%)	(B6,A5) (4.8%)	(B6,A6) (0.3%)

## 5.5 Right of Way [ROW], Carriageway width , Revised ROW,

### 5.5.1 Right of Way

Required ROW is not provided in more than 99% of the cases and this has resulted in insufficient shoulder width and carriageway widths. In addition to this, it is necessary to

maintain another 2-3 m distance in the hilly terrains to accommodate side slopes. Under the prevailing conditions, road widening has become a serious problem. The remaining width is required to construct shoulders and to accommodate other utilities.

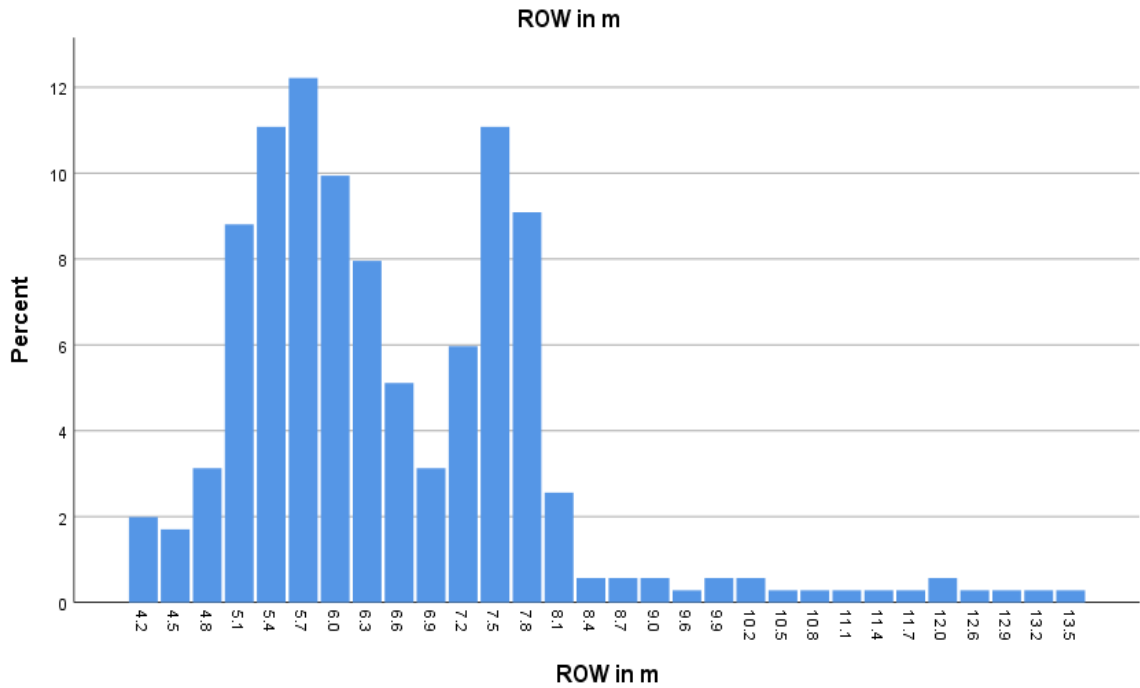


Figure 5. 6: Showing the ROW values.

The required ROW width is 15 m for class C roads and 10 m for class D roads. This analysis reveals that the available average ROW is 7.1 m for class C roads and around 6.0 m in class D roads. It can be shown that it is very difficult to obtain the required ROW, especially in populated areas. Picture number B.6 in appendix B shows that in certain places ROW is as low as 4.5 m

Benefit class B<sub>1</sub> and B<sub>2</sub> class roads has be upgrade by providing two lanes. Other roads shall be widened to have a better LOS with passing bays at regular intervals. Alternative cross sections were designed by the Highway Department of the Kingdom of Thailand. Typical alternative cross sections are in Figures 5.8 and 5.9. Alternative cross sections designed by the PESD are given in figure 5.10

### 5.5.2 Carriageway width

Carriageway width is a very important parameter. It is necessary to have at least 6.2 widths in order to have two lanes. However, more than 95% of the provincial roads do not have the required carriageway width. Even for a single lane, it is recommended to have a carriageway width of 5.1 m in order to have 1m wide bicycle lanes on either side of the road as shown in figure 5.7

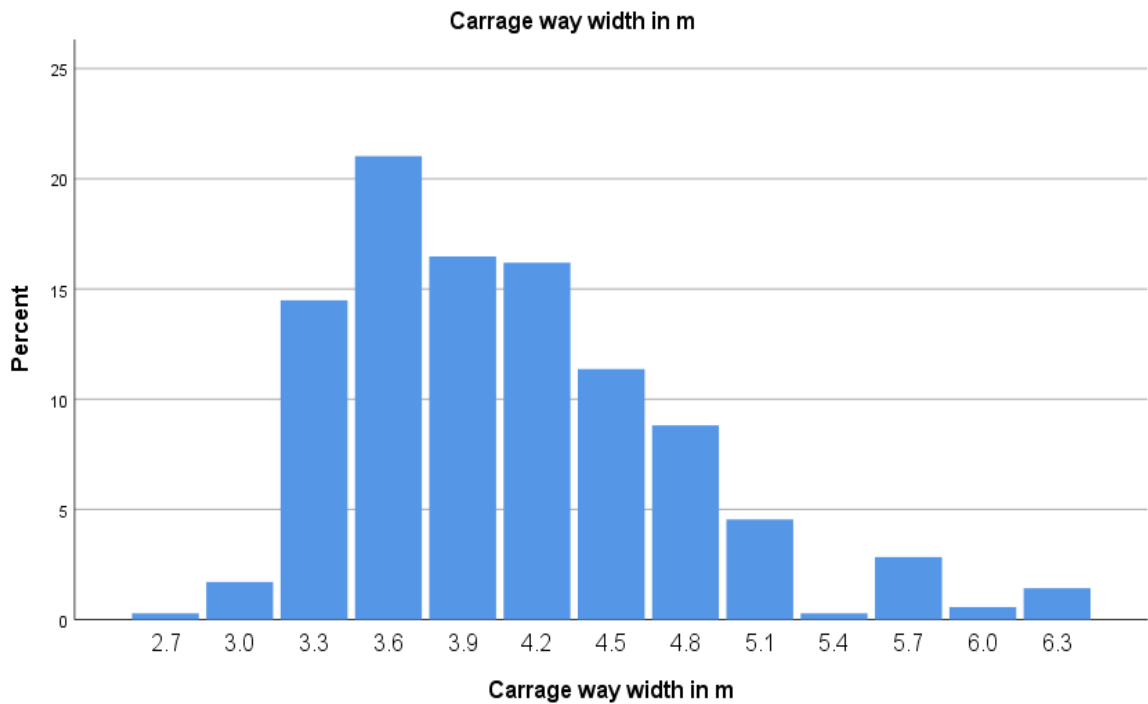


Figure 5. 7: Showing the Carriageway width. (Frequency Diagram)

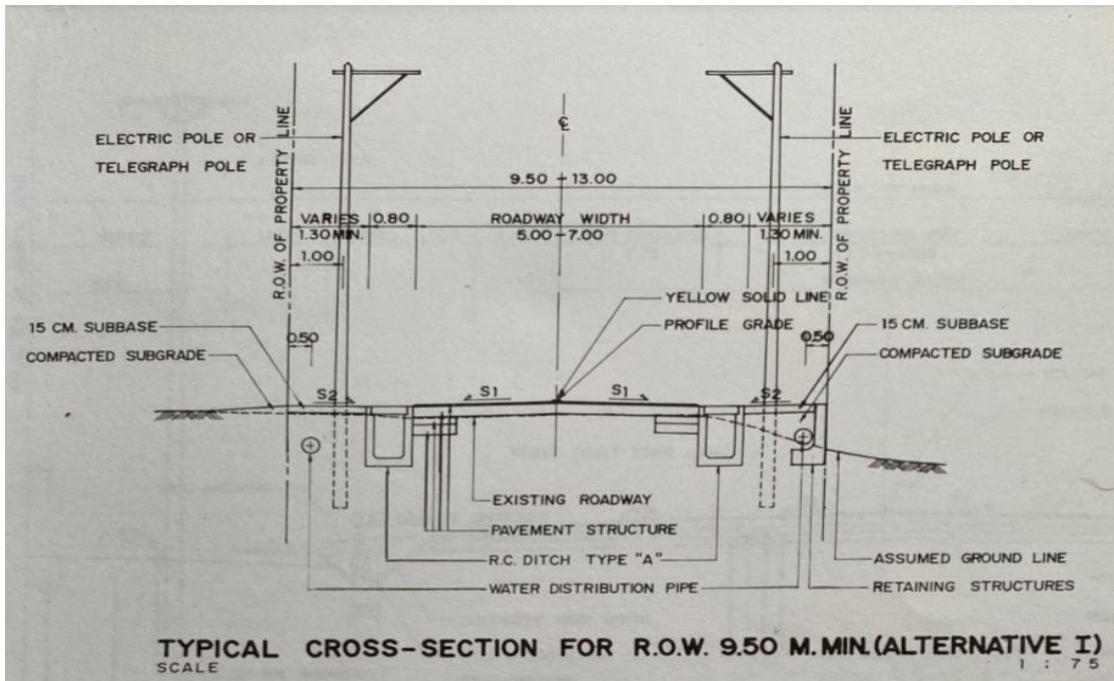


Figure 5. 8: Alternative cross section Type 1-(Original source-Standard Drawings Ministry of highways Thailand

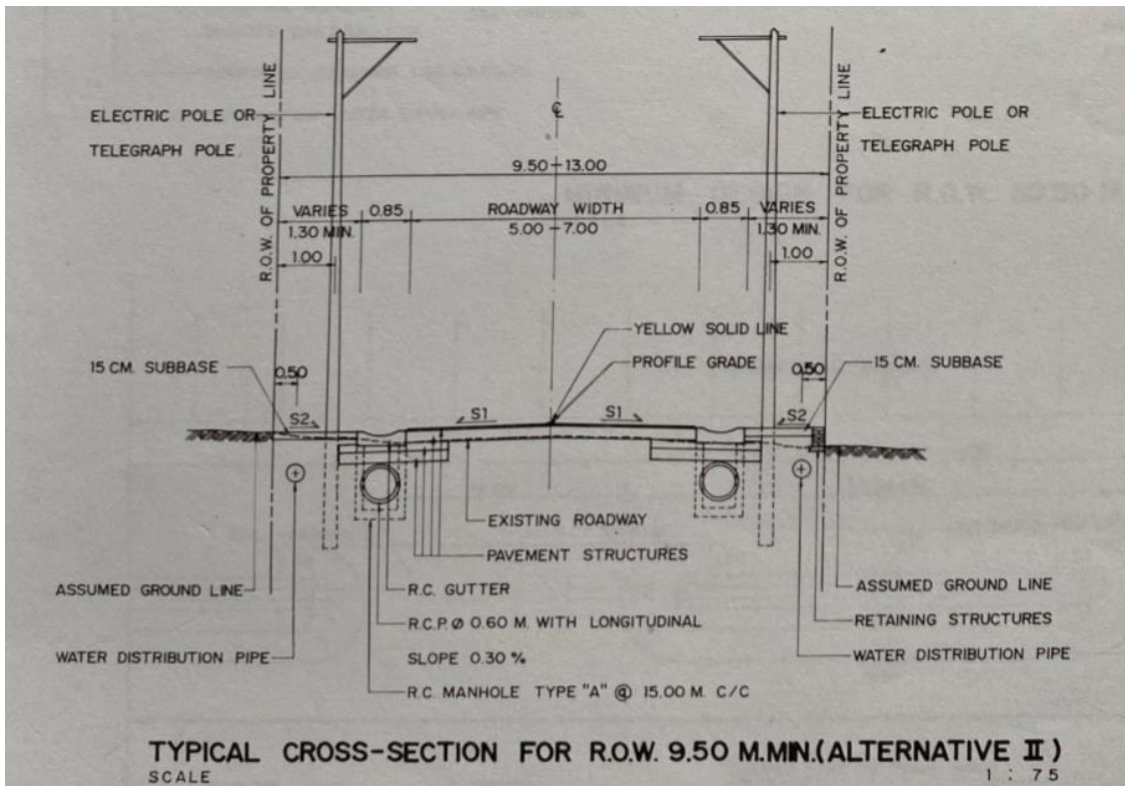


Figure 5. 9: Alternative Cross Section Type 11-(Original source-Standard Drawings Ministry of highways Thailand

**ALTERNATIVE CROSS SECTIONS FOR PROVINCIAL ROADS**

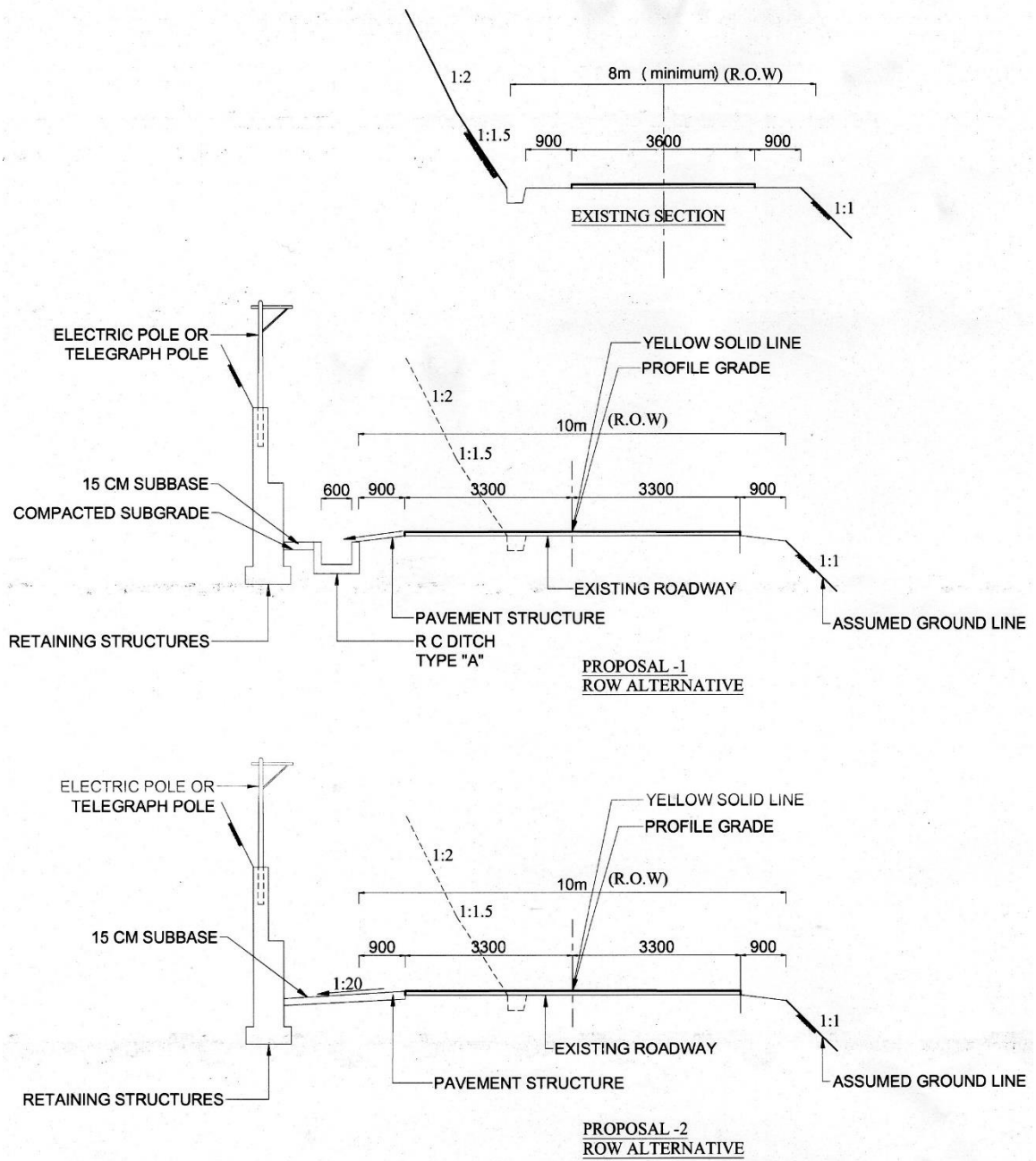


Figure 5. 10 Alternative cross Sections designed by PESD(Sabaragamuwa)

### 5.5.3 Revised ROW values for Provincial Roads

RDA guidelines proposed 15m ROW for class C roads and 10 m ROW for class D roads. However, it was found that required ROW is not maintained in most of the places. Therefore it is possible to have slightly small sections as given in the table 5.4

Table 5. 4 Dimensions of the alternative cross sections

Type of cross Section	Berm (m)	Drain and Shoulder (D) and (S) in m	Carriage Way (C) (m)	Median (M) (m)	Right of Way (R.O.W) M
R4 (ALT1)	1.2x2	1.5x2	3.1x2+1.2x2	-	13.9
R4 (ALT2)	1.0x2	1.0 x2	3.1x2	-	10.2
R4 (ALT3)	0.75x2	1.0 x2	3.1x2	-	9.7
R5(ALT1)	0.8x2	1.2x2	3.6+1.2*2	-	10.0
R5(ALT)	0.8x2	1.0x2	4.5	-	8.1

### 5.6 IRI values measurement in provincial road segments

Mobile phones app measure instantaneous IRI values at one-second intervals and there are large numbers of data available. Mobile app IRI values Kuruwita- Gorakaela (C002) road were measured and part of the results are given in Appendix C. At the same time, IRI score guesses by the two engineers were recorded. In addition to the Kuruwita – Gorakaela road, IRI values of certain road segments were measured. It was found that GPS coordinates given by the mobile apps exactly coincide with Google Maps. Details are given in Appendix C.

Estimated IRI values give a clear indication of the pavement condition. If the IRI value is less than 3.5 no improvements are required for the pavements

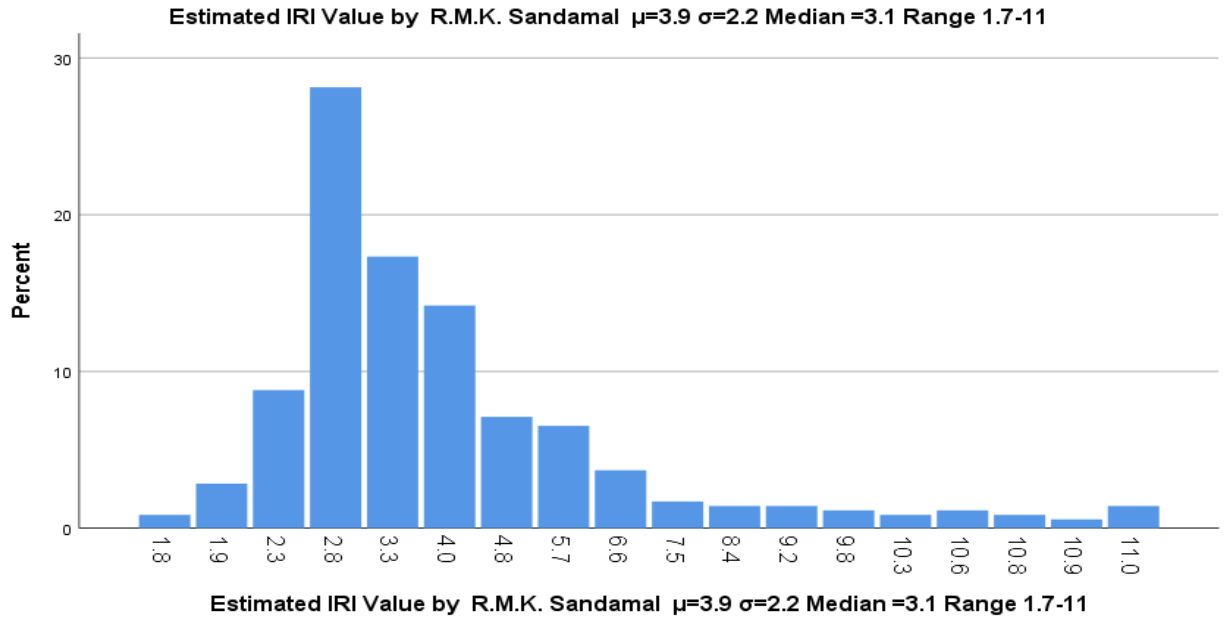


Figure 5. 11 Predicted IRI values by R.M.K. Sandamal and Pasindu method

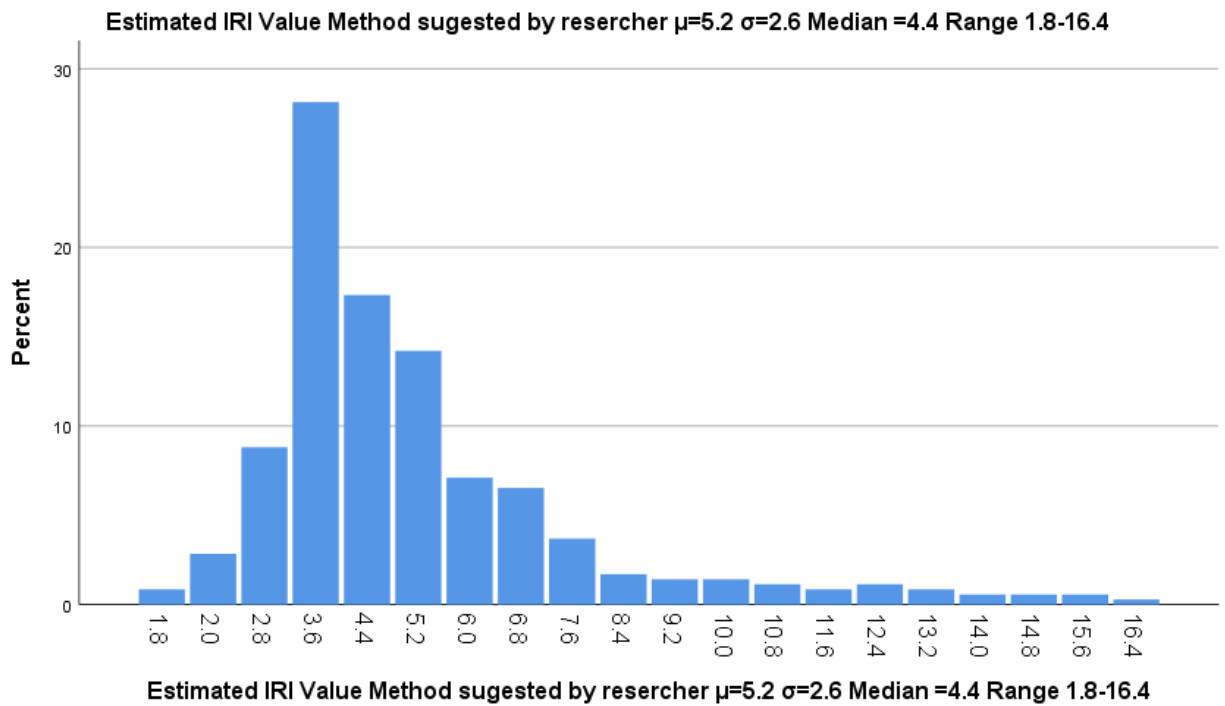


Figure 5. 12 : Estimated IRI Value frequency distribution chart

It can be shown that IRI score system proposed by this research paper is more applicable for provincial roads. All pavement management decisions can be based on this method. An experienced technical officer or Engineer will be able to estimate IRI score and finally approximate IRI values can be determined with time and money saving

### **5.7 Land acquisition for road improvement works**

As such it is necessary to acquire the lands, either free of charge or by making compensation payments. Part of class C roads will be improved as two lane roads during the next couple of years. Case Study shows that for this purpose it is required to pay compensation for such road segments and compensation per km length is around 4-5 million LKR per km. This is an issue that needs serious consideration by the Provincial roads authorities.

### **5.8 Repairs under the natural disasters**

If one road segment is blocked or unusable due to natural disasters, economic losses to the country are as high as some 100,000 LKR to 1,000,000 LKR per day per one km road segment. Therefore under the natural disaster mitigation program, immediate action should be taken to mitigate the damages. As far as Sabaragamuwa province is concerned, the natural disaster mitigation cost is in the range of 10-500 million LKR per year. In the year 2017, natural disaster mitigation cost was as high as 450 million LKR. It is advisable to allocate 200 million LKR for the emergency repair works.

### **5.9 Annual recurrent and mid-term fund allocation plan for Sabaragamuwa Province**

Based on the results of the case study annual fund allocation plan is given in Table 5.5. This table is generated by using the flow chart given in the chapter 3.6. It is possible to generate this chart by using the computer algorithms.

:

Table 5. 5 Tentative Fund allocation chart for SPMR year 2021

Class of B&A	Percentage	A(I,J) LKR Millions	B(I,J) LKR Millions	Recurrent cost LKR Millions	Mid term cost LKR Millions	Annual Allocation LKR
(B1,A1)	4.2%	13,482	1123.5	60.64	-	60.64
(B1,A2)	1.4%	2,996	374.5	20.21	93.63	113.84
(B1,A3)	0.9%	1,445	240.8	12.99	60.19	73.18
(B2,A1)	0.9%	2,889	180.6	10.04	-	10.04
(B2,A2)	2.6%	5,564	521.6	29.01	-	29.01
(B2,A3)	6.3%	10,112	1263.9	70.28	315.98	386.27
(B2,A4)	2.6%	2,782	521.6	27.30	130.41	157.71
(B3,A2)	1.1%	2,354	147.1	8.66	-	8.66
(B3,A3)	15.4%	24,717	2059.8	121.28	-	121.28
(B3,A4)	1.0%	1,070	133.8	7.88	66.88	74.75
(B4,A3)	10.5%	16,853	1053.3	65.46	-	65.46
(B4,A4)	9.1%	9,737	912.8	56.73	-	56.73+
(B4,A5)	0.3%	161	30.1	1.58	22.57	24.15
(B5,A3)	3.8%	6,099	177.9	13.72	-	13.72
(B5,A4)	22.8%	24,396	1067.3	82.29	-	82.29
(B5,A5)	5.0%	2,675	234.1	18.05	-	18.05
(B6,A4)	7.7%	8,239	103.0	15.16	-	15.16
(B6,A5)	4.8%	2,568	64.2	9.45	-	9.45
(B6,A6)	0.3%	48	4.0	0.47	-	0.47
Total Fund allocation		138,185	10,214	631	690	1,321

Calculation of the incremental value of the monetary value function from 2021-2022  
Sabaragamuwa Provincial roads network system

$$MVF = \sum_{i=1}^n \sum_{j=1}^X A(i, j, k) + \sum_{i=1}^n \sum_{j=1}^X B(i, j, k) - \sum_{i=1}^n \sum_{j=1}^X C(i, j, k) \text{---}5(1)$$

By analyzing statistical table data

$$\sum_{i=1}^n \sum_{j=1}^X A(i, j, k) = 138,185 \text{ million LKR} \text{-----} 5(2)$$

$$\sum_{i=1}^n \sum_{j=1}^X B(i, j, k) = 10,214 \text{ million LKR} \text{-----} 5(3)$$

$$\sum_{i=1}^n \sum_{j=1}^X C(i, j, k) = 1,321 \text{ million LKR} \text{-----} 5(4)$$

Let us assume that under the prevailing economic conditions benefits derived has fallen to the 100 LKR per km per one year time period.

Under the most unfavourable conditions benefits derived

$$\sum_{i=1}^n \sum_{j=1}^X B(i, j, k) = 2021 = 2043 \text{ million LKR} \text{-----} 5(5)$$

Following assumptions are made during the economic analysis. Those assumptions are made by the author based on experience gained during the last fifteen years

1. Two percent of the recurrent expenditure make value addition to total asset value of the roads,  $\sum_{i=1}^n \sum_{j=1}^X A(i, j, k)$ , is a function of roads  $\sum_{i=1}^n \sum_{j=1}^X C(i, j, k)$
2. Ninety percent of the mid term investment make value addition to asset total asset value of the roads
3. Foreign funded and other capital investment projects make 70% value addition to the total road assets
4. Road pavement value is approximately one third of the total asset value
5. Complete negligence of routine maintenance make 10% value deduction to the total road assets.
6. Partial negligence of routine maintenance makes 5% value deduction to the total road assets
7. Land acquisition price increase the total roads assets value by the same amount.
8. Pavement damage due to the heavy truck loads, land slides and flood damages has to be considered separately
9. Design life time of a provincial road pavement is 20 years

It can be shown that due to the inflation and other economic factors roads assets value continue to increase. Proper pavement management system road asset value increased atleast by 2% annually.

Benefits were calculated by assuming a value of 500 LKR per person served per year.

During the year 2021 only seventy percent of the roads were maintained in good condition. Another 20 percent of the roads were marginally maintained.

### **5.10 Hard shoulder construction in provincial roads**

Based on the unique experience of the researcher and group of engineers, it was decided to construct concrete hard shoulders for critical places. This program was launched in 2018 and now there is about 200 km length of provincial roads with properly constructed hard shoulders which provide sufficient lateral support to the asphalt pavements. Hard shoulder constructions may derive the following benefits.

- Additional space for pedestrians and vehicle
- Easy weed control/ Increase the durability of the asphalt pavements
- Minimize the side erosion by rainwater

The following photograph shows the advantage of concrete hard shoulders in the provincial road pavements.



Figure 5. 13 Godagama -Handurukanda road Hard shoulder construction

Based on the research finding tentative fund allocation program is given in table 5.8

Table 5. 6: Tentative recurrent fund allocation plan for SPMR year 2022

Recurrent cost plan	Description of the works	Annual Fund allocation per km	Length of Road Segments km	Funds Requirement LKR millions
C1	Weed control & cleaning Drains	100,000	2000	200
C2	Weed Control, cleaning drains and poth hole patching	250,000	400	100
C3	Weed Control pothole patching and sand sealing	800,000	125	100
C4	Metal overlaying and reconstruction	2,500,000	40	100
C5	Cold mix overlaying	8,000,000	40	320
M1	Construction of hard shoulders and passing bays and others	10,000,000	40	400
E1	Emergency Repairs	-	-	80
Total				1300

## 5.11 Selection of roads for roads widening program

This section of the report describes another important outcome of the research. A survey carried out shows that more than 99 % of the provincial roads are single lane roads.

Due to the Socio-Environmental constraints, most of the roads have to be maintained by carrying out routine maintenance and mid-term improvements. However, nearly ten percent of the roads have to be widened in order to accommodate two lanes. Table 5.10 may be used to work out possible investments under different traffic flows and IRR values.

Table 5. 7: Possible investment under the different IRR values

Design PCU per day	VOT saving LKR (000)	Fuel Saving LKR(000)	Total Saving LKR(000)	Possible investment LKR (000) per km		
				IRR= 25%	IRR=20%	IRR=15%
1000	4,562	1,460	6022	23,812	29,327	37,696
1200	5,475	1,752	7,227	28,574	35,192	45,326
1400	6,387	2,044	8,431	33,337	41,057	52,775
1600	7,300	2,336	9,636	38,100	46,923	60,314
1800	8,212	2,628	10,840	42,862	52,788	67,854
2000	9,125	2,920	12,045	47,624	58,654	75,393
2200	10,037	3,212	13,249	52,386	64,519	82,333

## CHAPTER 6 :Recommendations and Conclusion

### 6.1 Recommendations

Some recommendations had already been made under chapter 5 and some specific recommendations are listed below. (Outcomes of the research)

Based on the study following recommendations can be made.

1. As far as Sabaragamuwa Provincial road network is concerned, fund allocation can be planned according to the output of the case study.
2. Regular maintenance of road pavement increases the durability and A(I,J) asset value. Therefore regular maintenance should be carried out according to the pre-planned schedule.
3. Extend the research finding to the other provinces and rural network systems in Sri Lanka
4. Select (B1,A4), (B1,A3), (B1,A2), (B2,A4) and (B2,A3) Class roads segments for foreign-funded capital investment projects. There is a possibility of having a high asset value due to the very high land prices and the presence of a large bridge within the segment. Calculate A\*(i,j) for the segment and include (B1,A1) and (B2,A2) roads for the capital investment program.
5. It was found that the main required ROW is not maintained in most areas. Acquire the necessary lands to maintain the minimum required ROW. It is also required to mark the ROW reservation limits.
6. Integrated road development plans should be prepared by paying due attention to the other utilities like Water, Electricity, and telecommunication. Make provision for other utilities
7. Use alternative cross sections for the restricted areas. Thailand Highway department has designed alternative cross sections for the restricted ROW values and similar cross-sections may be used for Sri Lankan provincial roads . Bicycle lanes may be provided on flat terrains
8. Restrict the heavily loaded truck movement on the Provincial roads by means of damage claims as described in chapters 4 & 5.

9. Recurrent Expenditure of one percent of the value of the total assets shall be allocated for routine maintenance works. This is a general recommendation and it can be shown that minimum fund allocation is essential to control the rate of deterioration.
10. Introduce section labor system for weed control and general keep-up works on all roads as described in Chapter 2
11. Two lanes shall be constructed, if AADT is more than 1500 PCU in accordance with RDA guidelines
12. Widening of the road pavements if AADT is more than 800 PCU and construction of passing bays at regular intervals.
13. Use Dynamic Programming for the Capital and recurrent expenditure planning if there is a shortage of funds / Curtailment of funds.
14. Clause number 16. (1) of the National Audit act says that Every audited entity shall maintain proper books and records of all its income, expenditure, assets, and liabilities, to enable annual and periodic financial statements to be prepared in respect of such entities. The proposed assets valuation system has to be introduced for all provincial road agencies in accordance with the audit act.

## **6.2 Conclusion**

This research project commenced in December 2021 when the LKR exchange rate was 200 LKR per US\$. LKR has depreciated by 90% during the last six months. Therefore all assets and benefits values have to be recalculated taking the LKR depreciation into account. However, it is assumed that LKR will stabilize against US\$ during the next six months.

Highways should essentially consist of at least two lanes to accommodate the vehicle moving in two opposite directions. According to the general classification system, all class C roads belong to the highway category. Part of class D roads also belongs to the highway category and the remaining roads shall be considered as low traffic volume roads with AADT less than 300 PCU as stipulated in the RDA guidelines.

There was a dramatic increase in transport costs mainly due to the increase in fuel prices. Bicycle riding will be a cost-effective solution, especially on flat terrains. It is recommended to construct bicycle lanes if there is a sufficient ROW width.

More than 80% of the class D roads in the Ratnapura district belong to the low traffic volume category. No road widening is required and sometimes it is necessary to construct passing bays at regular intervals in order to have better service.

If annual daily traffic increases by 1500 PCU per day, according to RDA guidelines it is essential to construct roads with two lanes. ( Maximum Hourly traffic will be 200 PCU equivalent in one direction and 100 PCU per hour in the other direction.)

According to the National Thorofare act 2008, it is essential to maintain a ROW of 7.5 m on either side of the roads. However, it was found that available ROW is in the range of 7.5 m to 9.0 m in most cases. Land acquisition is required to improve the provincial roads.

The case study reveals the real situation of the provincial roads network in the Sabaragamuwa Province and these results may be used for other provinces as well. Nearly half of the population uses provincial roads and more than eighty percent of the population uses provincial roads and local government roads. This information will be very much useful in the fund allocation planning process. The finance commission and SPMR shall make use of the research findings.

National roads are designed for comparatively high mobility levels. However, actual mobility levels on most of the national roads and Class C roads are almost equal due to the traffic congestion in the urban areas. This gives clear indications that part of the provincial road segments serves as an alternative road by reducing travel distance and time.

Roads safety levels in the Provincial roads

Most of the provincial roads segments consist of sharp curves with a radius of 6-12m. As far as provincial roads are concerned, the fatal accident rate is comparatively low. Accidents shall be prevented by education, enforcement of the law with police intervention, and finally engineering solutions. The present situation shall be further improved by proper geometric designs and an effective pavement management system.

It can be shown that the required ROW is not maintained at most of the segments. If there is a scarcity of land ROW might reduce up to 10-11 m on class C roads and 7.5-8.0 m in class D roads.

It is necessary to improve the B<sub>1</sub> and B<sub>2</sub> class benefit category roads as two-lane roads. Most of the provincial roads are designed for T<sub>2</sub> accumulated axle load class and there is a possibility of having T<sub>3</sub> axle loads in the provincial roads. This is mainly due to the heavily loaded trucks on the provincial roads. During the case study and field visits, it was observed that most of the road pavements were on the structurally weak subgrade. In certain locations, it was found that the subgrade strength class is S<sub>2</sub>. During the next rehabilitation project, it is necessary to consider the pavement design, and overlaying should be planned accordingly.

Geometric designs in most of the provincial roads do not comply with the AASHTO guidelines. Sometimes the curve radius is as low as 6 or 7.5 m. In the case of improvement project road widening and improvement of both horizontal and vertical alignment has to be considered. More research has to be carried out by paying due attention to the pavement design and continue the Results Based monitoring and evaluation process.

Finally Results based evaluation and monitoring system is a cyclic process and the fund allocation system has to be reviewed every year. This system may be used by the other provincial road management agencies with necessary modifications.

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## APPENDIX: A

### A.1 Details of approach path survey

Table A.1. 1 : Details of approach path survey

No	Name	Method of Survey	NIC Number if available	Access path
1	MRs Kusuma Wilegoda	Visited		A>DVA
2	U. Nikapotha	Visited		A>DVA
3	Sepali Pemachandra	Visited		A>DVA
4	Parakrama Piyasena	Visited		A>DVA
5	Jagath Wijesinghe	Visited		A>DVA
6	Ven Madalagama Wajrabuddi	Visited		A>DVA
7	Jayatissa Ranaweera	Visited		A>DVA
8	D.P. Thilakaratna	Visited		A>DVA
9	A.D.K.A. Anil	Visited		A>DVA
10	Damithra Premathilaka	Visited		A>DVA
11	Nandajeewa Gunasekara	Visited		A>DVA
12	Sumudu Pagoda	Visited		A>DVA
13	P.L.W.Rathnayaka	Visited	716512223V	A>DVA
14	B.K.C.R. Wikramasinghe	Interviewed	820654250V	A>DVA
15	M.H.S. Jayasooriya	Interviewed	861753590V	A>DVA
16	M.M.P.Chandrasena[R]	Interviewed		A>DVA
17	M.M.D.D.Kumari	Visited	897050439V	A>DVA
18	A. P.S. Wimalaweera	Visited	712133015V	A>DVA
19	H.A.M.Yasawardana(Q)	Visited	708171107V	A>DVA
20	E.B.S.Kumara	Interviewed	703291600V	A>DVA
21	W.M.R.C.Marambe	Interviewed	785751364V	A>DVA
22	S. Ranatunaga	Visited		A>FPA
23	L.A.A.S.Jayasekara	Interviewed	901531030V	A>FPA
24	G A I Asoka	Visited	626791379V	A>FPA
25	Ajith Panagoda	Researcher	196215702784	A>LR>DVA
26	Sagarika Panagoda	Visited		A>LR>DVA
27	Y.M.Bisomenike	Visited		A>LR>DVA

28	Sarath Liyanage	Visited		A>LR>DVA
29	W.A.W.L. Hemantha	Visited		A>LR>DVA
30	Aanda Weeraratna	Visited		A>LR>DVA
31	U.D Purasena	Visited		A>LR>DVA
32	Ven Akarelle Ganawasa	Visited		A>LR>DVA
33	G.S Amarasinghe	Visited		A>LR>DVA
34	P.M.De Alwis	Visited		A>LR>DVA
35	S.S. Kumara	Visited		A>LR>DVA
36	Dr Vipula Indrajith	Visited		A>LR>DVA
37	Damith Batawala	Visited		A>LR>DVA
38	Hearath P. Kularatna	Visited		A>LR>DVA
39	Ananda Wjiesekara	Visited		A>LR>DVA
40	Piyaseeli Jayamanna	Visited		A>LR>DVA
41	G.L. Susantha Dharmakeerthi	Visited		A>LR>DVA
42	Millawitiya Sir	Visited		A>LR>DVA
43	K.B Kalyanawathi	Visited	647600824V	A>LR>DVA
44	K.C. Pushpakumari	Visited	687800745V	A>LR>DVA
45	P. R. S.Palihawadana	Visited	701090560V	A>LR>DVA
46	W.K.A.S. Chandrarathna	Visited	640780134V	A>LR>DVA
47	S.H.B. Malkanthi	Visited	673571654V	A>LR>DVA
48	G. Jayarathna	Visited	643581540V	A>LR>DVA
49	U.S.P. Udawatta	Visited	701760263V	A>LR>DVA
50	K.K.Gunarathne	Visited	682050640V	A>LR>DVA
51	D.D.L.Pushpa Kumara	Visited	641860352V	A>LR>DVA
52	K.R.Withanage	Visited	810925116V	A>LR>DVA
53	E.M.R.S.R.Senewirathna	Visited	706251871V	A>LR>DVA
54	W.A.I.Suravimala	Visited	891380410V	A>LR>DVA
55	K.P.D.Karunanayaka	Interviewed	883512951V	A>LR>DVA
56	H.R.D.G.Shanthapriya	Visited	896510860V	A>LR>DVA
57	Dulari Rupasinghe	Visited		A>LR>DVA
58	I.D.L..S. Bandara	Visited	858023114V	A>LR>DVA
59	K.L.I.H.Karandana	Visited	825893741V	A>LR>DVA
60	K.Y.C.D.R.D.Silva	Visited	732802800V	A>LR>DVA
61	I.C.S.B.Rathnayaka	Interviewed	742813231V	A>LR>DVA
62	H.A.K.R.Dayarathna	Visited	642160575V	A>LR>DVA

63	K.G.A.P.Dias	Visited	720880121V	A>LR>DVA
64	K .M. Chandrakanthi	Visited	705800189V	A>LR>DVA
65	W.W. Jayasinghe	Visited	773011036V	A>LR>DVA
66	H.M.C.C.K.Samarasekara	Visited	858622611V	A>LR>DVA
67	N.C.W.Karunaratna	Visited	875441566V	A>LR>DVA
68	D.S.K.Rajarathna	Visited	690750384V	A>LR>DVA
69	P.M.B.Paranagama	Visited	816690307V	A>LR>DVA
70	P.M.B.Paranagama(Q)	Interviewed	816690307V	A>LR>DVA
71	K.I. Samaraweera	Interviewed	910273124V	A>LR>DVA
72	S.H.M.Jayamalaka(Q)	<i>Interviewed</i>		A>LR>DVA
73	K.M.P.G. Dhanawardana	Visited	763501248V	A>LR>DVA
74	M.A.K.P.Munasinghe	Interviewed	762571625V	A>LR>DVA
75	L.A.D.I.Saranasekara(Balangoda)	Visited	197826002810	A>LR>DVA
76	P.K.Udayangani	Interviewed	815773292v	A>LR>DVA
77	M.V.J.K.Chandrasekara	Interviewed	927242010V	A>LR>DVA
78	E.G.D.L. Darmarathna	Interviewed	853414310V	A>LR>DVA
79	K.S.T.D.De Silva	Interviewed	752630585V	A>LR>DVA
80	D.M.D.Premananda	Interviewed	697862328V	A>LR>DVA
81	W.Y.S.Gunawardana	Interviewed	853472328V	A>LR>DVA
82	T.M.N.Thennakoon	Interviewed	842420989V	A>LR>DVA
83	M.V. Piyasena	Interviewed	622860503V	A>LR>DVA
84	R.A. Jayasekara	Interviewed	741102641V	A>LR>DVA
85	D.H.D.K. Hettige	Interviewed	198300803600	A>LR>DVA
86	K.M. Wimalasinghe	Interviewed	633120757V	A>LR>DVA
87	G.S. Sriyakanthi	Interviewed	668081185V	A>LR>DVA
88	House Near WS	Visited		A>LR>FPA
89	Millawitiya Water supply Tank	Visited		A>LR>FPA
90	M.D. Gunathilaka	Visited		A>LR>FPA
91	M. Karunaratna	Visited		A>LR>FPA
92	K G A Kumuduni	Interviewed	906392836V	A>B>DVA
93	Con Punchihewa	Visited		A>B>DVA
94	Dilini	Visited		A>B>DVA
95	Harischandra Liyanage	Visited		A>B>DVA
96	Kumari Madagammana	Visited		A>B>DVA
97	Sarath Madagammana	Visited		A>B>DVA

98	Somasiri Aluthge	Visited		A>B>DVA
99	K.R. Witanage Father	Visited		A>B>DVA
100	Contractor Hettiarachchi	Visited		A>B>DVA
101	Y.M.Tikiribanda	Visited		A>B>DVA
102	Nihal Wasantha	Visited		A>B>DVA
103	Nalaka Katupitiya	Visited		A>B>DVA
104	Ananda Wijesiri	Visited		A>B>DVA
105	N.K. Lionel Kulatunga	Interviewed		A>B>DVA
106	G.S.K.Kariyawasam	Visited	750154026V	A>B>DVA
107	S .H .M. Padmakumara	Interviewed	730214057V	A>B>DVA
108	B.T.N.S.Sugathadasa	Visited	856050904V	A>B>DVA
109	W.S.M.Gunathilaka	Interviewed	806520039v	A>B>DVA
110	G.G.S.P.David	Interviewed	930113930V	A>B>DVA
111	N.P.Nilanthi	Visited	708391913V	A>B>DVA
112	H.K.B.K.Karunanayaka	Visited	720361566V	A>B>DVA
113	D.H. Sepala	Interviewed	681681660V	A>B>DVA
114	House In Kudawa	Google		A>B>FPA
115	M.T. Ariyadasa	Visited		A>B>FPA
116	P.M. Mayadunne	Visited	706860460V	A>B>FPA
117	Kuragala Temple	Visited		A>B>LR>DVA
118	Sanjeewa Ranasinghe- Uncle	Visited		A>B>LR>DVA
119	D.P Ariyadasa	Visited		A>B>LR>DVA
120	H.L. Nimal	Interviewed		A>B>LR>DVA
121	Sanjeewa Batawala	Visited		A>B>LR>DVA
122	Dr Wijeratna	Visited		A>B>LR>DVA
123	Sunil Bandara	Interviewed		A>B>LR>DVA
124	K.E.D. Kulasiri	Interviewed		A>B>LR>DVA
125	Nimal Nakkawita	Visited		A>B>LR>DVA
126	Aravinda Udayakumara	Interviewed		A>B>LR>DVA
127	D.V. Chandrasiri	Visited	710430373V	A>B>LR>DVA
128	P.V.R.Ranasinha	Interviewed	887743029V	A>B>LR>DVA
129	W.M.K.E. Weerasinhe	Interviewed	891511400V	A>B>LR>DVA
130	M.N.N. Diyagama	Interviewed	737752070V	A>B>LR>DVA
131	B.G.J.K.Peter	Interviewed	670832619V	A>B>LR>DVA
132	A .J. Gunarathna	Interviewed	760841536V	A>B>LR>DVA

133	D.G.R.S Chandrasena	Interviewed	871050309V	A>B>LR>DVA
134	D.B.A.De Silva	Interviewed	780640758V	A>B>LR>DVA
135	M.S.K.Mudiyanse	Interviewed	833052128V	A>B>LR>DVA
136	H.S.De Silva	Interviewed	911550512V	A>B>LR>DVA
137	K.V.C.Kumuduni	Interviewed	857930860v	A>B>LR>DVA
138	M.A Jayantha	Interviewed	640993847V	A>B>LR>DVA
139	D Nandasena	Interviewed	690871670V	A>B>LR>DVA
140	M.W.U.P. Pushpakumara	Interviewed	682090820V	A>B>LR>DVA
141	M.K.A. Dilrukshi	Interviewed	707192923V	A>B>LR>DVA
142	K R S Rajapaksha	Interviewed	671711092V	A>B>LR>DVA
143	M.G.C.N. Gamage	Interviewed	771550479V	A>B>LR>DVA
144	W A R N Premathilaka	Interviewed	898353435V	A>B>LR>DVA
145	K.G.A.H.Karangoda	Interviewed	818203500V	A>B>LR>DVA
146	S.P.S.Karunarathna	Interviewed	840654290V	A>B>LR>DVA
147	Sanjeewa Ranasinghe	Visited		A>B>LR>FPA
148	Chandane Munamalpe	Visited		A>B>LR>FPA
149	A .N.Niroshan	Interviewed	821411394V	A>B>LR>FPA
150	A.B. Prasanna Indrajith	Interviewed		A>B>LR>FPA
151	R.A. Sarath Kumara	Interviewed		A>B>LR>FPA
152	P.G.Nimal	Interviewed		A>B>LR>FPA
153	S.A. Manoj Jeewapriya	Interviewed	921991401V	A>B>LR>FPA
154	Wasantha Sri Lal Edirisinghe	Visited		A>B>C>DVA
155	D.M Malani	Visited		A>B>C>DVA
156	A.A.N.Y. Amarakoon	Visited		A>B>C>DVA
157	P.R. Swarna Sandaseeli	Visited		A>B>C>DVA
158	G.H.G.S. Priyalal	Interviewed	832712248V	A>B>C>DVA
159	D.C.M. Gunawardhana	Interviewed	637022237V	A>B>C>DVA
160	M.N.N. Diyagama	Interviewed	737752070V	A>B>C>DVA
161	A .S. K .Dharmasena	Visited	791181844V	A>B>C>DVA
162	K.A.A.Kurupparachchi	Interviewed	686311074V	A>B>C>DVA
163	K.D.P.Chathurika	Interviewed	908401980V	A>B>C>DVA
164	M.A.W.P.Gunarathna	Interviewed	913554370V	A>B>C>DVA
165	L.A.D.I.Saranasekara(Nivitigala)	Interviewed	197826002810	A>B>C>DVA
166	P.D.A.Indumini	Interviewed	887911070V	A>B>C>DVA
167	Ananda Piyasiri	Visited		A>B>C>FPA

168	House in Dehenakanda	Google		A>B>C>FPA
169	G. Thilakasiri	Visited		A>B>C>FPA
170	Nihal Sam Parents	Visited		A>B>C>FPA
171	Omalpe Piyaseli	Visited		A>B>C>FPA
172	Vijithmas Seneviratna	Visited		A>B>C>D>DVA
173	Google Veiw 1-	Google		A>B>C>D>DVA
174	Sumanasiri Thilakaratna	Visited		A>B>C>D>DVA
175	U.D Purasena	Visited		A>B>C>D>DVA
176	R.A. Somapala	Visited		A>B>C>D>DVA
177	Googal view 2	Google		A>B>C>D>FPA
178	Google Veiw 3	Google		A>B>C>D>FPA
179	Google Veiw 4	Google		A>B>C>D>FPA
180	Google Veiw 5	Google		A>B>C>D>FPA
181	W.A. Jawickrama	Visited		A>B>C>LR>DVA
182	D.W.J.Weerananda	Visited	623121143V	A>B>C>LR>DVA
183	Google Veiw 6	Google		A>B>C>LR>FPA
184	Google Veiw 7	Visited		A>B>C>LR>FPA
185	Google Veiw 8	Google		A>B>C>D>LR>DVA
186	Google Veiw 9	Google		A>B>C>D>LR>DVA
187	Google Veiw 10	Google		A>B>C>D>LR>DVA
188	Google Veiw 11	Google		A>B>C>D>LR>DVA
189	Google Veiw 12	Google		A>B>C>D>LR>FPA
190	Mohanjith Panagoda	Visited		A>C>DVA
191	Sitti Anesha	Visited		A>C>DVA
192	E.M.S De Silva	Visited		A>C>DVA
193	Nimal Edirisooriya	Visited		A>C>DVA
194	Kasun Gayan Munasinghe	Visited		A>C>DVA
195	Shiran Deraniyagala	Visited		A>C>DVA
196	Senury	Visited		A>C>DVA
197	M.T. Peries	Visited		A>C>DVA
198	M.T. Sirisena	Visited		A>C>DVA
199	Ven Ambalanpitiya Ganananda	Visited		A>C>DVA
200	Charls Senadeera	Visited		A>C>DVA
201	Asoka Gunaratna	Visited		A>C>DVA
202	Maithreepala Bandara	Visited		A>C>DVA
203	Newil Alwis	Visited		A>C>DVA

204	I.K. Kularatna	Visited		A>C>DVA
205	Fransis Marambe	Visited		A>C>DVA
206	O.B.S. Weerasekara	Visited		A>C>DVA
207	P.R. Swarna Sandaseeli	Visited		A>C>DVA
208	M.M.P.Chandrasena	Interviewed	880420909V	A>C>DVA
209	J.A.P.P.Jayasingha	Visited	868601914v	A>C>DVA
210	M.D.J.S.Athapattu Father	Visited	782753193V	A>C>DVA
211	H M Y G Harishchandra	Visited	888462619V	A>C>DVA
212	E.L. Thilakasiri	Visited	620793345V	A>C>DVA
213	D.C.Anten	Interviewed	671271688V	A>C>DVA
214	Google 13	Google		A>C>DVA
215	Google 14	Google		A>C>DVA
216	Senerath Bandara	Interviewed		A>C>DVA
217	Amarasinghes Brother	Visited		A>C>DVA
218	Rukmal Ananda	Visited		A>C>DVA
219	M.G.R.S Ratnayaka	Visited		A>C>DVA
220	K.A. Upali Sumanadasa	Interviewed		A>C>FPA
221	M.A. Hemachandra	Interviewed		A>C>FPA
222	M.Leelananda	Interviewed		A>C>FPA
223	Jayanthi Perera	Visited		A>C>FPA
224	Pettigala Worker 2	Google		A>C>FPA
225	U.D Purasena	Interviewed		A>C>FPA
226	Gilimale Asapuwa	Visited		A>C>FPA
227	Rathnasiri	Interviewed		A>C>FPA
228	D.M. Ananda	Visited		A>C>FPA
229	Chandraratna Brother	Visited		A>C>FPA
230	M.T.Rupasinghe	Visited		A>C>LR>DVA
231	L.P Nilantha	Visited		A>C>LR>DVA
232	Y.M.Bisomenike	Visited		A>C>LR>DVA
233	T.G. Abeyratna Banda	Visited		A>C>LR>DVA
234	R.P.Jayasinghe	Visited		A>C>LR>DVA
235	Devapriya Wijayaraja	Visited		A>C>LR>DVA
236	Jagath Wijesinghe Brother	Visited		A>C>LR>DVA
237	Pettigala Worker 1	Google		A>C>LR>DVA
238	Pettigala Worker 3	Google		A>C>LR>DVA
239	Sunil Perera	Visited		A>C>LR>DVA

240	W.A.W.L. Hemantha	Visited		A>C>LR>DVA
241	H.V..Priyantha	Visited		A>C>LR>DVA
242	Edral Perirs	Visited		A>C>LR>DVA
243	Susil Bogahawatta	Visited		A>C>LR>DVA
244	M.D Adikaram	Visited		A>C>LR>DVA
245	K.M.S.C. Werahera	Visited	712480858V	A>C>LR>DVA
246	W.G.V.N.Kamalawansa	Visited	832370207V	A>C>LR>DVA
247	Dear Wood Worker 3	Google		A>C>LR>DVA
248	Anura Manamperi	Google		A>C>LR>DVA
249	Chamara Bamunuarachchi	Visited		A>C>LR>DVA
250	D.L.G. Rathnamali	Visited	766600522V	A>C>LR>DVA
251	M.H.S. Jayasooriya	Visited	861753590V	A>C>LR>DVA
252	S.A. Thilakarathna	Visited	692202562V	A>C>LR>DVA
253	E.P.M.Pathirathna	Visited	646341213V	A>C>LR>DVA
254	R.P.Jayasinghe	Visited	640890673V	A>C>LR>DVA
255	G.M.K.N.Kumari	Visited	877533573V	A>C>LR>DVA
256	K.N.H.Tharanga	Visited	868251689v	A>C>LR>DVA
257	M.V.A.Pushpasooriya	Interviewed	847102837v	A>C>LR>DVA
258	A.L.S.Athukorala	Interviewed	652861393V	A>C>LR>DVA
259	K.A. Indika Sandaruwan	Visited	872780718V	A>C>LR>DVA
260	W.P.C.Jayasumana	Interviewed	842864151V	A>C>LR>DVA
261	B.M. Jeewantha Vijaya	Visited	813081458V	A>C>LR>DVA
262	G. Wikum Jananandana	Visited	800812887V	A>C>LR>DVA
263	M.T. Alis	Visited		A>C>LR>FPA
264	Dear Wood Worker 1	Google		A>C>LR>FPA
265	Dear Wood Worker 2	Google		A>C>LR>FPA
266	P.R. Indika Sarath Kumara	Interviewed		A>C>LR>FPA
267	T.K.P.Jayamali	Interviewed	868242124v	A>C>LR>FPA
268	G.R.Chandani	Interviewed	795493026V	A>C>LR>FPA
269	GA-ACD-DVA	Google		A>C>D>DVA
270	GA-ACD-FPA	Google		A>C>D>DVA
271	G.T.Surangani	Interviewed	865102275V	A>C>D>DVA
272	GA-ACD-FPA	Google		A>C>D>FPA
273	Baranduwa Banagoda	Google		A>C>D>FPA
274	M.D.Thamara	Interviewed	816261503V	A>C>D>FPA
275	D.W.R.Kothalawala	Interviewed	852673222V	A>C>D>FPA

276	Dr LalithWilegoda	Interviewed		A>C>D>LR>DVA
277	Keeragala Estate Worker 3	Google		A>C>D>LR>DVA
278	Birty Gunathilaka	Visited		A>C>D>LR>DVA
279	K.H.S.Kumarasinghe	Interviewed	908592514V	A>C>D>LR>DVA
280	H.M.N.Shyamali	Interviewed	885941257V	A>C>D>LR>DVA
281	O.A.G.M.Chandrasiri	Interviewed	895492787V	A>C>D>LR>DVA
282	G.N.Chandima	Interviewed	905743244V	A>C>D>LR>DVA
283	B B L R Rathnasena	Visited	896850261V	A>C>D>LR>DVA
284	P.G.K.N.Pattegama	Visited	707402644V	A>C>D>LR>DVA
285	S.P.Wanniarachchi	Visited	666550064V	A>C>D>LR>DVA
286	S.W.S Jayapala	Visited	666381599V	A>C>D>LR>DVA
287	J L P S R Jayaweera	Visited	696353018V	A>C>D>LR>DVA
288	Keeragala Estate Worker 1	Google		A>C>D>LR>FPA
289	Keeragala Estate Worker 2	Google		A>C>D>LR>FPA
290	W .D. Renuka	Interviewed	748401849V	A>C>D>LR>FPA
291	R .M. D. P. Rajapaksha	Interviewed	787600675V	A>C>D>LR>FPA
292	Googal view 15	Google		
293	Upali Piger	Visited		A>D>DVA
294	Susith Premasiri	Visited		A>D>DVA
295	Ven Mahalle Vipulatissa	Visited		A>D>DVA
296	Delan Karunapala	Visited		A>D>DVA
297	Karunasena	Visited		A>D>DVA
298	Karunasenas Daughter	Visited		A>D>DVA
299	Gayan Wijesooriya	Visited		A>D>DVA
300	K.B. Kalyani Father	Visited		A>D>DVA
301	M.H. Sisira Kumara	Visited	701890086V	A>D>DVA
302	M.M. Pattiya Arachchi	Visited	738040236V	A>D>DVA
303	M.K.J.Nishshanka	Visited	700813320v	A>D>DVA
304	E.M.D.C.Jayasena	Interviewed	847693479V	A>D>DVA
305	H .S. G. Helagedara	Interviewed	721180042v	A>D>DVA
306	H.R.V.Sandamali	Interviewed	198659100746	A>D>DVA
307	P.A.S.Gunaratna	Interviewed	845742590V	A>D>DVA
308	K.A.D.D.N.Jeewanthi	Interviewed	826344105v	A>D>DVA
309	H.M.I.G.Kelumpika	Interviewed	786293480V	A>D>DVA
310	H.H.W.I.Weerasingha	Interviewed	1977603210	A>D>DVA
311	D.M.S.Malkanathi	Interviewed	875032100V	A>D>DVA

312	K.M.D.S.Senevirathna	Interviewed	857280946V	A>D>DVA
313	N.A.S.Premadasa	Interviewed	855084066V	A>D>DVA
314	Pramila Nagahawaththa	Interviewed	845981116v	A>D>DVA
315	K.M.S.S.Samarakoon	Interviewed	825554076V	A>D>DVA
316	H.V.U.Iroshika Vithanage	Interviewed	856473600V	A>D>DVA
317	K.P.A.I.Andadola	Interviewed	865052120V	A>D>DVA
318	G.K.C.Gamage	Interviewed	841260791V	A>D>DVA
319	E.M.R.L.Rathnayaka	Interviewed	855223023V	A>D>DVA
320	D.K.P.Ranjani	Interviewed	197176601214	A>D>DVA
321	E.A.U.C.Basnayaka	Interviewed	686723283V	A>D>DVA
322	W.M.L.M.Walpita	Interviewed	865781458V	A>D>DVA
323	A.M.S.W.Kumari	Interviewed	795383794V	A>D>DVA
324	A.Dasinghege	Interviewed	612021147V	A>D>DVA
325	A. Gunadasa	Interviewed	623023249V	A>D>DVA
326	K.L.S.Kanthilatha	Interviewed	655121021V	A>D>DVA
327	E N Priyangani	Interviewed	855220199V	A>D>DVA
328	K.A.U.K. Kodituwakku	Interviewed	831291575V	A>D>DVA
329	A.W.S.Jayalath	Interviewed	785292995V	A>D>FPA
330	G.K Kithsiri	Visited		A>D>LR>DVA
331	Vijaya Ranasinghe	Visited		A>D>LR>DVA
332	Premasiri Karawita	Visited		A>D>LR>DVA
333	D.M Malani®	Visited		A>D>LR>DVA
334	Non Perial Worker 1	Google		A>D>LR>DVA
335	Non Perial Worker 2	Google		A>D>LR>DVA
336	Non Perial Worker 3	Google		A>D>LR>DVA
337	K.V.J . Bandara	Visited		A>D>LR>DVA
338	Buddika Aluthge	Visited		A>D>LR>DVA
339	S.M.D Senaviratna	Visited		A>D>LR>DVA
340	Maheepala Hearth	Visited		A>D>LR>DVA
341	M.T. Suraweera	Visited		A>D>LR>DVA
342	B.A.M.S.H. Beligaswatta	Visited	760061867V	A>D>LR>DVA
343	G.S. Ajith	Interviewed	682880813V	A>D>LR>DVA
344	C.P.Hettiarachchi	Interviewed	708302490v	A>D>LR>DVA
345	K.G.A.D. Koralage	Interviewed	895481580V	A>D>LR>DVA
346	L.M.C.Janaki	Visited	806704121V	A>D>LR>DVA
347	Y.C.Mihirani	Visited	857780655V	A>D>LR>DVA

348	R.M.A.L.H.Rajapaksha	Interviewed	845862206V	A>D>LR>DVA
349	P.Ranjani Somalatha	Interviewed	756362844V	A>D>LR>DVA
350	P.D.M.K.Nedungamuwa	Interviewed	725273380V	A>D>LR>DVA
351	P.P.C.Lakshini	Interviewed	877280403V	A>D>LR>DVA
352	S.A.S.S.Samarasingha	Interviewed	896222244V	A>D>LR>DVA
353	M.V.P.S.Aberathna	Interviewed	904452976V	A>D>LR>DVA
354	D.W.A.I.Jayasena	Interviewed	908663268V	A>D>LR>DVA
355	W.K.I.L.Swarnathilaka	Interviewed	916563566V	A>D>LR>DVA
356	W. Wellappili	Interviewed	681342869V	A>D>LR>DVA
357	E.P.R.U.Darmasiri	Interviewed	867792635V	A>D>LR>DVA
358	M.D.N.C.Senadhira	Interviewed	805923903V	A>D>LR>DVA
359	P.D.R.B.Gunawardhna	Interviewed	903103922V	A>D>LR>DVA
360	S.H.N.I.silawansa	Interviewed	851791299V	A>D>LR>DVA
361	A.V.N.Darmapala	Interviewed	925732613v	A>D>LR>DVA
362	D.N.R.S.dahanayaka	Interviewed	907922630V	A>D>LR>DVA
363	D.P. Wijesena	Interviewed	681504265V	A>D>LR>DVA
364	W.A. Shanthi	Interviewed	717410939V	A>D>LR>DVA
365	A.K.N.Priyangani	Interviewed	825994173V	A>D>LR>DVA
366	G.Nirupa lakshmi kumari	Interviewed	867622250V	A>D>LR>DVA
367	H.G.Anuja Nilmini	Interviewed	856540430V	A>D>LR>DVA
368	W.M.A.N.Damayanthi	Interviewed	865142005V	A>D>LR>DVA
369	L.A.G.G.Niroshini	Interviewed	888251731V	A>D>LR>DVA
370	S.A.Gayashan	Interviewed	891630158V	A>D>LR>DVA
371	H.K.Dangahadeniya	Interviewed	641051322V	A>D>LR>DVA
372	S.A.N.D.Singhebahu(o)	Interviewed	700332640V	A>D>LR>DVA
373	S.A.N.D.Singhebahu(N)	Interviewed		A>D>LR>DVA
374	W.M. Weerakoon	Visited	632551150V	A>D>LR>DVA
375	Non Perial Worker 4	Google		A>D>LR>FPA
376	Mason Premalal	Interviewed		A>D>LR>FPA
377	G.R.T.R.Senarathna	Interviewed	751192584V	A>D>LR>FPA
378	H.T .N. M. Perera	Interviewed	726722730V	A>D>LR>FPA
379	K.P.R.M.D.Somathilaka	Interviewed	806972240V	A>D>LR>FPA
380	I.R.S.M.Gunasekara	Interviewed	867461779V	A>D>LR>FPA
381	G.A.N.Godage	Interviewed	786991943V	A>D>LR>FPA
382	M.C.D. Menike	Interviewed	905321617V	A>D>LR>FPA
383	W.N. Premasiri	Visited		A>B>D>DVA

384	H.A.M.Yasawardana(H)	Interviewed	708171107V	A>B>D>DVA
385	A.N.P.Alankarage	Interviewed	825753745V	A>B>D>DVA
386	H.S.Niroshani	Interviewed	815621891V	A>B>D>DVA
387	R.D.K.P.Rajapaksha	Interviewed	836621557V	A>B>D>DVA
388	D.R.C. Saman Kumari	Interviewed	826090227V	A>B>D>DVA
389	S.H.M.Jayamalaka	Interviewed	770920302V	A>B>D>DVA
390	M.A.P.S.Mathotaarachchi	Visited	198014602642	A>B>D>DVA
391	Google View	Google		A>B>D>FPA
392	Google View	Google		A>B>D>FPA
393	Google View	Google		A>B>D>LR>DVA
394	Google View	Google		A>B>D>LR>DVA
395	Google View	Google		A>B>D>LR>DVA
396	Google View	Google		A>B>D>LR>FPA
397	Google View	Google		A>B>D>LR>FPA
398	Kumari Madagammana	Visited		NR>PR>NR
399	Sarath Madagammana	Visited		NR>PR>NR
400	B.G.J.K.Peter	Interviewed	670832619V	NR>PR>NR
401	Pushpa Madagammana	Visited		NR>PR>NR
402	M.P.N .S. Somarthna	Interviewed	838574106V	NR>PR>NR
403	W.Darmasena	Interviewed	690681072V	NR>PR>NR
404	J.N.Nisha	Interviewed	197361102760	NR>PR>NR
405	T.R.P.K.Abeykon	Interviewed	857922875V	NR>PR>NR
406	W.C.K.Witharana	Interviewed	797813931V	NR>PR>NR
407	D.W.J.Weerananda	Interviewed	623121143V	NR>PR>NR
408	M.A Jayantha	Interviewed	640993847V	NR>PR>NR
409	M.G.C.N. Gamage	Interviewed	771550479V	NR>PR>NR
410	Contractor Hettiarachchi	Visited		NR>PR & LR>NR
411	Y.M.Tikiribanda	Visited		NR>PR & LR>NR
412	A. P.S. Wimalaweera	Visited	712133015V	NR>PR & LR>NR
413	T.P.M.S.Polwaththage	Interviewed	850673365V	NR>PR & LR>NR
414	H.M.S.G.K.Herath	Interviewed	868422297V	NR>PR & LR>NR
415	G.W.Rupani Kanthi	Interviewed	807844288V	NR>PR & LR>NR
416	D.H.H. V.Kapugedara	Interviewed	876251639v	NR>PR & LR>NR
417	R.S.P.Manohari	Interviewed	196757201521	NR>PR & LR>NR
418	N.P.Thilakarathna	Interviewed	858161932V	NR>PR & LR>NR
419	G.G.S.P.David	Interviewed	930113930V	NR>PR & LR>NR

420	M.W.U.P. Pushpakumara	Interviewed	682090820V	NR>PR & LR>NR
421	Chandanee Munamalpe	Visited		NR>PR & LR>NR
422	K.E.D. Kulasiri	Interviewed		NR>PR & LR>NR
423	W.D.Seetha Ranathunga	Visited	658260057V	NR>PR & LR>NR
424	K.L.S.Kanthilatha	Visited	655121021V	NR>PR & LR>NR
425	Vijithma Senevirathna	Visited		NR>PR & LR>NR
426	D.L.G. Rathnamali	Visited	766600522V	NR>PR & LR>NR
427	G.S.K.Kariyawasam	Visited	750154026V	NR>PR & LR>NR
428	M.H.S. Jayasooriya	Interviewed	861753590V	NR>PR & LR>NR
429	W.S.M.Gunathilaka	Interviewed	806520039v	NR>PR & LR>NR
430	H.S.De Silva	Interviewed	911550512V	NR>PR & LR>NR
431	D Nandasena	Interviewed	690871670V	NR>PR & LR>NR
432	K.N.H.Tharanga	Interviewed	868251689v	NR>PR & LR>NR
433	S.A.G.L.Aberathna	Interviewed	836491750V	NR>PR & LR>NR
434	B.G.Sirani Wijayathunga	Interviewed	746060122 V	NR>PR & LR>NR
435	W.T.R.I.Werasinghe	Interviewed	732721584V	NR>PR & LR>NR
436	A.S.P.Karunaratna	Interviewed	866660344V	NR>PR & LR>NR

## A.2 Detail of the selected road Sample

Table A.1 2: Details of the selected road sample

Serial No	Name of the Road	Actual length	Length Curtailed/Extended/
C001	Bateyyaya Teppanawa road	3.0	3.0
C002	Kuruwita- Pathagama Gorkaela Road	8.40	9.0
C004	Kadangoda Theppanawa Gorakaela Rd	9.2	9.0
C005	Kuruwita Erathna Rd	11.20	12.0
C017	Galabada Rathganga Road	10.4	10.0
C036	Lellopitiya Hettikanda Road	14.00	14.00
C049	Morahela Amupitiya Road	5.2	5.0
C055	Balangoda Pettigala Road	5.50	6.0
C069	Dela Noragalla Road	4.0	4.0
C079	Pallebedda Buluthota	22.6	23.0

Serial No	Name of the Road	Actual length	Length Curtailed/Extended/
C083	Udagama Court Road & New Town	4.0	4.0
C093	Kella Urubokka Road	9.6	9.0
C097	Hettimulla Dewattha Ussapitiya Rd	12.1	12.0
C101	Higgoda Gantuna Rd	5.25	5.0
C133	Yattogoda Beligala Batuwatta Road	11.0	11.0
C 154	Maniyangama Panawala Road	10.02	10
C176	Galapitamada Dunumala Athaudakanda Rd	5.31	6.00
C179	Ambalanpitiya Imbulpitiya Dikdeniya Rd	12.70	13
C182	Deraniyagala Kosgahakanda via yatiwala Rd	15.10	15.0
C189	Aranayaka Keli Rd	10.78	11.0
C198	Daluggala Madawala Mahaoya Rd	4.77	5.00
D005	Kuruwita Udakada BopathElla Road	3.1	3.0
D009	Eheliyagoda Paleegala Road	3.0	3.0
D012	Paradise Molekele Road	3.0	3.0
D018	Bevila Diddeniya Anandapura Rd	6.9	7.0
D049	Keppetiyamandiya Wewagama Rd	5.1	5.0
D068	Ayagama Palawela	12.0	12.0
D068R	Ayagama Palawela	12.0	12.0
D072	Manandoala Junction to Pengirikanda	3.0	3.0
D076	Godakawela Bibilegama Road	5.0	5.0
D083	Kahawatta Watapotha Road	10.0	10.0
D 107	Pudukatuwa Waleboda Road	11.9	12
D120	Non Perial Estate Raod	16.2	16.0
D147	99 Gangeyaya Road	2.0	2.0
D151	Kolombage ara Panahaduwa Rd	8.1	8.0
D160	Hagala 12 Ela Rd	3.0	3.0
D194	Galigamuwa Rideekotuwa Weragoda Rd	5.9	6.0
D204	Fransis Molamure Mawatha	1.1	1.0
D237	Undugoda Ihala Uduwa road	8.0	8.0
D275	Nakkawita Maliboda Rd	9.0	9.0
D276	Nooriya Polgaswatta Road	7.0	7.0

## APPENDIX : B

### B.1 Non peril estate road

C..3.1 1 Non-perils estate road (0 to 18 km) considered for the worst case scenario analysis provides an alternative access path to the famous World end with 2 km long footpath. Starting from the A4 main road 0+00 km to 8+00 km distance is gazette under the provincial road. 8+00 km to 18+00 km distance is managed by using provincial council funds. However, vehicle movements are restricted by the Balangoda plantations mainly due to the poor condition prevailing in the road and some other reasons. This Photograph shows the world-famous Bakers bend in this road. In this location curve radius of the center line is exactly 4.5 m and speed is mainly controlled by the substandard curves, insufficient carriageway width, steep slopes, and finally very high IRI values in the remaining sections.



## B.2 Kuruwira Erathna Road

Googal Maps can be effectively used for determining the pavement conditions, width of the carriageway ,shoulders and ROW , approximate Elevation and Gloable Coordinates.

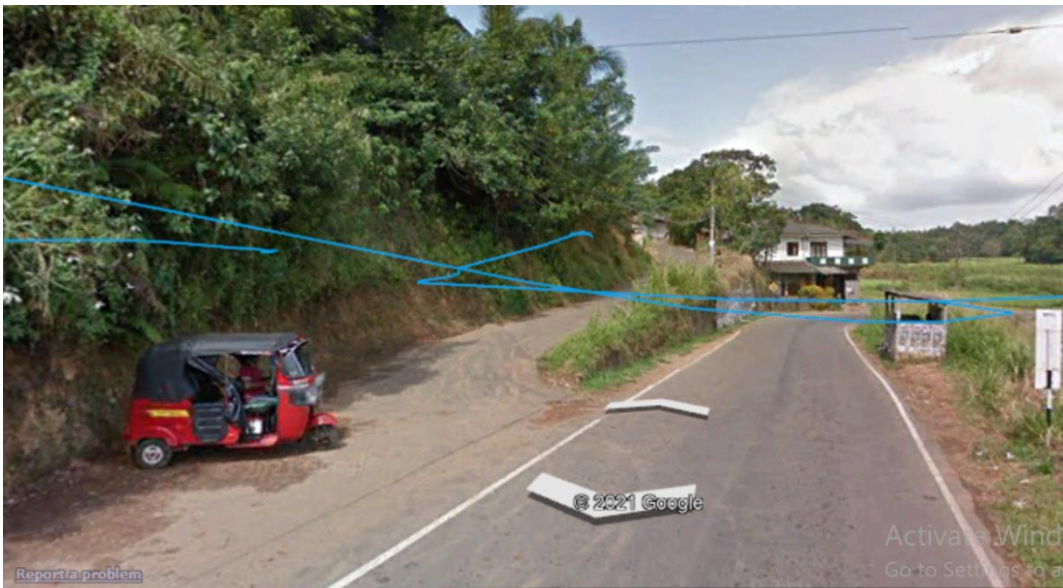
Kuruwita Erathna Road Chainage 6 km+500



IRI Score =85, Carrage Way Width=4 m, Shoulder width= 1.25 m on either side  
ROW=8 m approximately.

## B.3 Morahela Amupitiya road junction.

Morahela -Amupitiya road will be be improved under the Transport Connectivity Assests management project[TCAMP] . (Curve radius is less than 5 m.)



### **B.4 Eheliyagoda –Palegala road D009**

This area of the road undergoes water after heavy rains. This road cannot be considered as all season road.



### **B.5 Padawigampoal Gal Messa**

– Provincial Roads provides access to this location with tourist attraction- Rambukkana a



## **B.6 Higgassena via Devipahala Demeda road - Bopath Ella Approach road**

This road provides access path to the famous Bopath Ella falls in photograph B.6.. In this location ROW is as low as 4.2 m . Land acquisition is not permitted under the prevailing legal and

Only possible solution is to open this road segment for one way traffic. This road section was marginally improved fifty years ago by using the donated lands.



## **B.7 Restricted ROW in Udawela- Akarella-Ambawila Road**

- ROW is less than 6 m. Land value of this area is around 500,000 LKR per purchase.

Land value gradually reduced to 100,000 LKR at the change of 0+500m and at the

distance of 1 km+00m land prices as low as 50,000 LKR per purchase.



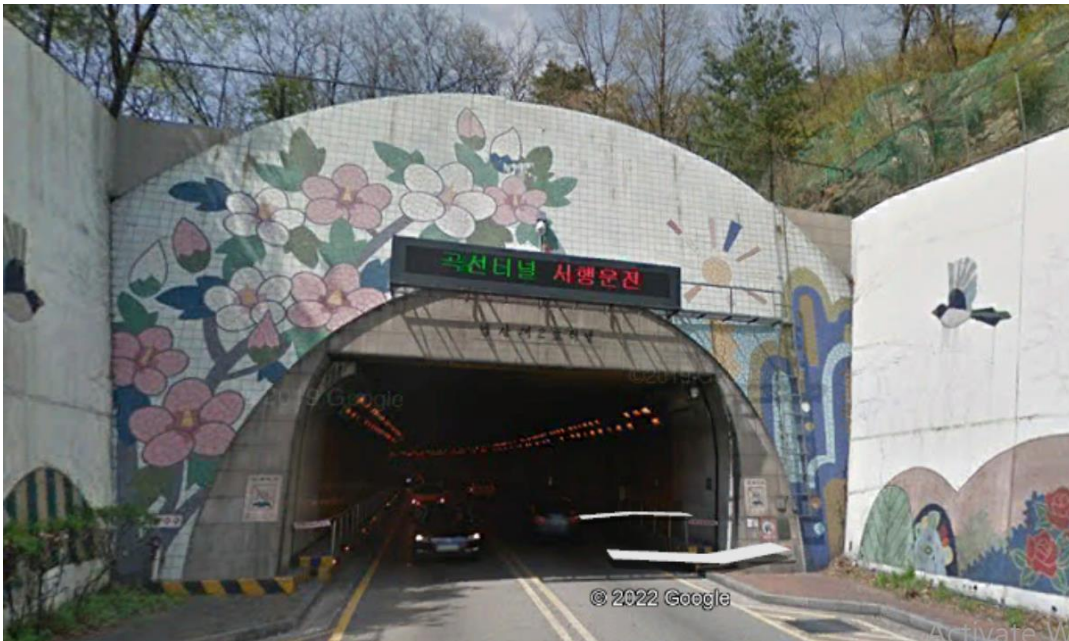
### **B.8 Embilipitiya concrete yard road**

Embilipitiya town internal roads network is properly planned with required ROW in most of the places. This road is in a flat terrain and it is possible to construct 1.2 m wide bicycle lanes on either sides of the road.



## **B.9 Road Tunnel in South Korea Example for the most effective land use planning.**

South Korea is one of the countries with 65% forest reserves. Underground tunnels are used to minimize the damages caused to the environment. In Sri Lanka there is only one



## APPENDIX : C

### C.1 IRI Value measurement of the Provincial roads

Table C: 1 IRI value measurements in Kuruwita Gorakaela road

Mobilile App IRI Measurnment in Kuruwita- GorakaEla Road via Pathagama ( C002 )Road					
Date : October 28,2018			Time : 3.57 PM-4.15 PM		
Longitude	Latitude	On the Spot Estimated IRI	Speed In Kmph	Distance km	Accumulated IRI
80.36778	6.774124	5.2	33	-	0.02
80.36784	6.774082	4.0	22	0.008	0.05
80.36788	6.774064	4.0	12	0.013	0.06
80.3679	6.774054	4.0	6	0.016	0.07
80.36791	6.774044	4.0	6	0.017	0.07
80.3679	6.774025	4.0	7	0.019	0.09
80.36789	6.773999	4.0	10	0.022	0.10
80.36787	6.773959	4.0	17	0.028	0.12
80.36784	6.773918	4.0	19	0.033	0.15
80.36781	6.773862	1.9	24	0.041	0.16
80.36775	6.7738	1.6	28	0.050	0.18
80.36771	6.773744	1.6	26	0.058	0.19
80.36767	6.773693	1.5	24	0.065	0.20
80.36763	6.773651	2.0	20	0.071	0.21
80.3676	6.773612	2.0	18	0.076	0.22
80.36758	6.77359	2.0	15	0.080	0.23
80.36755	6.77358	2.0	8	0.083	0.23
80.36746	6.773575	2.0	8	0.093	0.24
80.36743	6.773569	2.0	12	0.097	0.25
80.36738	6.773566	2.0	20	0.103	0.26
80.36731	6.773565	4.5	23	0.110	0.30

Mobilile App IRI Measurnment in Kuruwita- GorakaEla Road via Pathagama ( C002 )Road					
Date : October 28,2018			Time : 3.57 PM-4.15 PM		
Longitude	Latitude	On the Spot Estimated IRI	Speed In Kmph	Distance km	Accumulated IRI
80.36724	6.773558	6.8	25	0.118	0.35
80.36718	6.773553	2.4	23	0.125	0.37
80.36712	6.773548	7.0	21	0.131	0.40
80.36708	6.773543	7.0	18	0.136	0.44
80.36704	6.773539	7.0	15	0.140	0.46
80.36701	6.773538	7.0	13	0.144	0.49
80.36698	6.773533	7.0	14	0.147	0.52
80.36693	6.773525	7.0	19	0.153	0.56
80.36688	6.773513	2.1	22	0.159	0.57
80.3668	6.773508	3.0	29	0.167	0.60
80.36673	6.773505	1.4	34	0.176	0.61
80.36664	6.773503	1.4	35	0.185	0.62
80.36655	6.773505	1.6	35	0.195	0.64
80.36646	6.773513	1.9	35	0.205	0.66
80.36636	6.773524	1.9	39	0.216	0.68
80.36626	6.773529	4.9	40	0.227	0.74
80.36615	6.773531	2.8	42	0.240	0.77
80.36604	6.773532	6.6	43	0.252	0.85
80.36594	6.773531	2.4	42	0.263	0.88
80.36584	6.773529	6.4	40	0.275	0.95
80.36574	6.773527	2.2	37	0.286	0.97
80.36565	6.773527	11.4	35	0.296	1.09
80.36556	6.773526	9.2	34	0.305	1.17
80.36548	6.773524	3.3	32	0.314	1.20
80.3654	6.773516	3.1	34	0.324	1.23

Mobilile App IRI Measurnment in Kuruwita- GorakaEla Road via Pathagama ( C002 )Road					
Date : October 28,2018			Time : 3.57 PM-4.15 PM		
Longitude	Latitude	On the Spot Estimated IRI	Speed In Kmph	Distance km	Accumulated IRI
80.36531	6.773502	3.5	36	0.333	1.27
80.36522	6.773484	1.9	36	0.343	1.28
80.36522	6.773484	2.1	36	0.343	1.30
80.36504	6.773443	4.5	34	0.364	1.37
80.36496	6.773419	3.0	34	0.374	1.40
80.36487	6.773385	1.5	36	0.384	1.41
80.36479	6.773346	2.1	37	0.394	1.43
80.36471	6.773299	1.9	37	0.405	1.45
80.36463	6.77325	1.6	37	0.415	1.47
80.36455	6.773203	2.0	37	0.426	1.49
80.36446	6.773155	3.3	40	0.437	1.53
80.36436	6.773105	1.8	43	0.449	1.55
80.36427	6.773053	1.9	43	0.460	1.57
80.36418	6.773002	2.0	41	0.472	1.60
80.36409	6.772955	4.1	39	0.484	1.64
80.36401	6.772918	2.0	33	0.493	1.66
80.36395	6.772893	1.6	23	0.500	1.66
80.36392	6.772884	1.6	13	0.504	1.67
80.36392	6.772866	1.6	5	0.506	1.67
80.36392	6.772858	1.6	6	0.507	1.67
80.36391	6.772843	1.6	11	0.509	1.68
80.36387	6.772817	1.8	22	0.514	1.69
80.36382	6.772778	1.8	30	0.521	1.70
80.36375	6.772731	1.4	33	0.531	1.72
80.36367	6.772681	1.6	36	0.541	1.73

Mobilile App IRI Measurnment in Kuruwita- GorakaEla Road via Pathagama ( C002 )Road					
Date : October 28,2018			Time : 3.57 PM-4.15 PM		
Longitude	Latitude	On the Spot Estimated IRI	Speed In Kmph	Distance km	Accumulated IRI
80.36358	6.772628	1.9	35	0.552	1.75
80.3635	6.772581	1.6	33	0.563	1.77
80.36343	6.772536	1.6	32	0.572	1.79
80.36336	6.772491	1.9	31	0.582	1.80
80.36329	6.772449	2.1	31	0.591	1.82
80.36321	6.772407	1.7	33	0.600	1.84
80.36314	6.772362	1.9	35	0.610	1.86
80.36306	6.772313	2.0	35	0.620	1.88
80.36299	6.772264	1.8	34	0.630	1.90
80.36292	6.772214	3.1	33	0.640	1.93
80.36285	6.772165	1.9	32	0.649	1.94
80.36278	6.772119	2.7	32	0.658	1.97
80.36271	6.772076	1.7	32	0.667	1.98
80.36264	6.772033	1.9	31	0.676	2.00
80.36257	6.771988	2.1	31	0.685	2.02
80.3625	6.771946	2.1	34	0.695	2.04
80.36242	6.771902	3.7	37	0.705	2.08
80.36233	6.771856	3.0	39	0.716	2.11
80.36224	6.77181	3.1	41	0.728	2.15
80.36214	6.771765	5.5	40	0.739	2.21
80.36205	6.771732	10.4	40	0.751	2.33
80.36195	6.771706	4.0	41	0.762	2.38
80.36184	6.771683	6.3	42	0.774	2.45
80.36174	6.771661	2.3	42	0.786	2.48
80.36163	6.771645	2.2	41	0.798	2.51

Mobilile App IRI Measurnment in Kuruwita- GorakaEla Road via Pathagama ( C002 )Road					
Date : October 28,2018			Time : 3.57 PM-4.15 PM		
Longitude	Latitude	On the Spot Estimated IRI	Speed In Kmph	Distance km	Accumulated IRI
80.36153	6.771632	5.7	39	0.809	2.57
80.36143	6.771625	2.9	39	0.821	2.61
80.36133	6.771621	4.5	38	0.832	2.65
80.36123	6.77162	5.0	38	0.842	2.71
80.36114	6.771618	1.9	37	0.853	2.73
80.36106	6.771614	2.1	35	0.862	2.75
80.36097	6.771611	2.8	33	0.871	2.77
80.36089	6.771607	2.3	33	0.880	2.79
80.36081	6.771601	2.1	34	0.890	2.81
80.36072	6.771594	2.0	34	0.899	2.83
80.36065	6.771587	1.9	31	0.908	2.85
80.36057	6.771581	1.7	30	0.917	2.86
80.36049	6.771576	1.5	31	0.925	2.87
80.36041	6.77157	7.5	33	0.934	2.94
80.36033	6.771566	7.8	34	0.943	3.02
80.36025	6.771559	1.7	31	0.952	3.03
80.36017	6.77155	1.4	27	0.961	3.04
80.36011	6.771541	1.6	25	0.968	3.05
80.36005	6.771538	1.9	24	0.975	3.07
80.35998	6.771535	2.6	28	0.982	3.09
80.3599	6.771528	2.8	33	0.991	3.11
80.3598	6.771516	2.1	40	1.002	3.16

## C.2 Driving Cycle

A driving cycle is a series of data points representing the speed of a vehicle versus time.

Driving cycles normally use to assess the level of service and other parameters of a road segment. Instance fuel consumption, electric vehicle autonomy and polluting emissions, value of time saving etc.

This is a very useful tool which can be used for analyzing the behavior of a road segment under the different conditions. Value of time saving, and fuel saving has a complex relationship with the driving cycle.

In the case of Provincial roads, driving cycle shall be used to determine the degree of road improvement. There are three options available for the class C roads with AADT more than 1000 PCU

Driving Cycle Kuruwita- Erathna Road 0-4 km Going Up

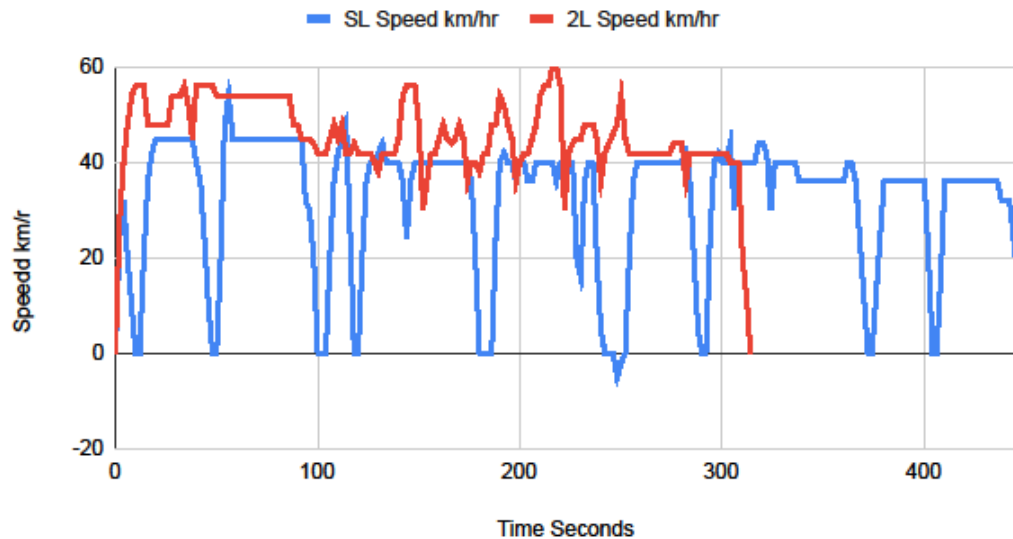


Figure C.2 1 Kuruwita- Erathna Road -Driving cycle for climbing up (0-4 km)

### Kuruwita- Erathna Road Climbing Up fuel consumption

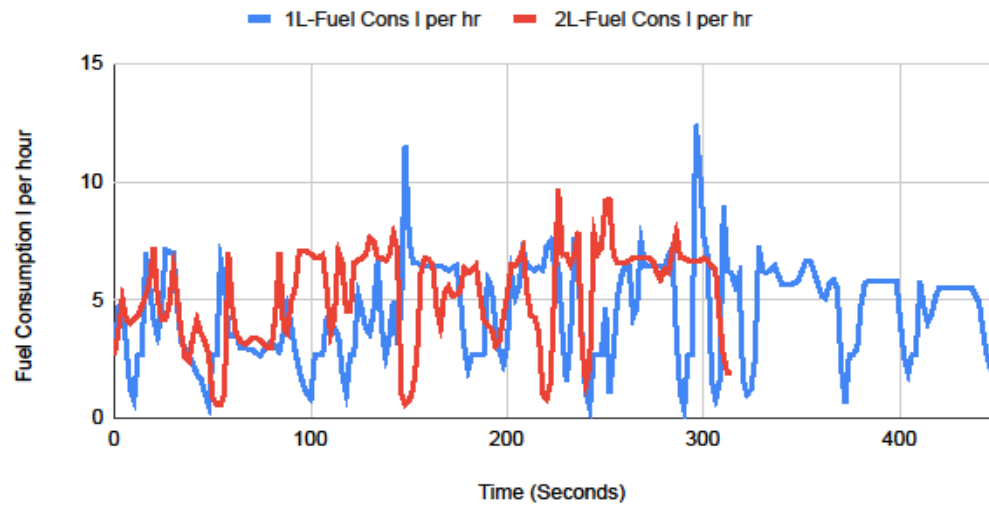


Figure C.2 2 Kuruwita-Erathna Road –Fuel consumption Climbing up (0-4 km)

### Kuruwita-Erathna Going Down-Speed Vs Time

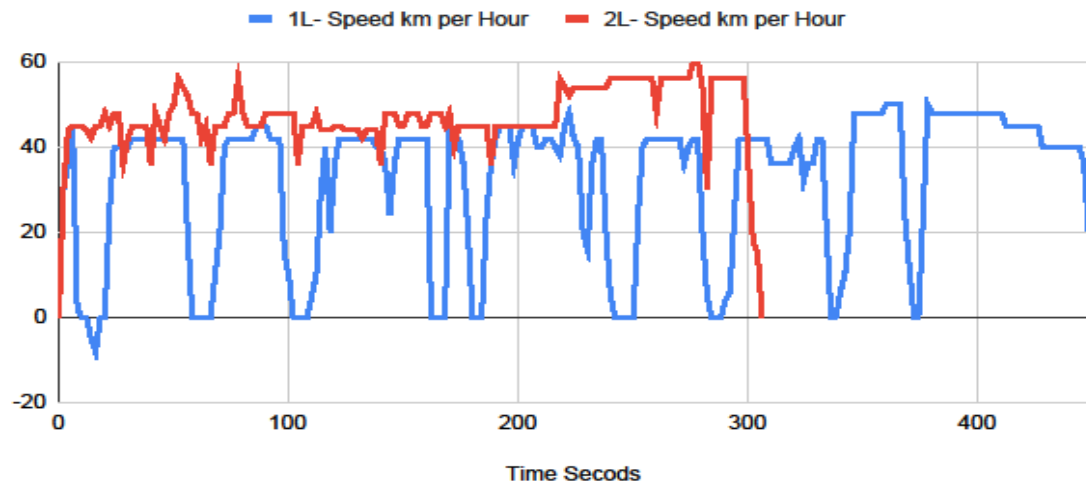


Figure C.2 3 Kuruwita-Erathna road Going down-Driving cycle (4 km-0)

## Kuruwita-Erathna Going Down -Fuel Consumption

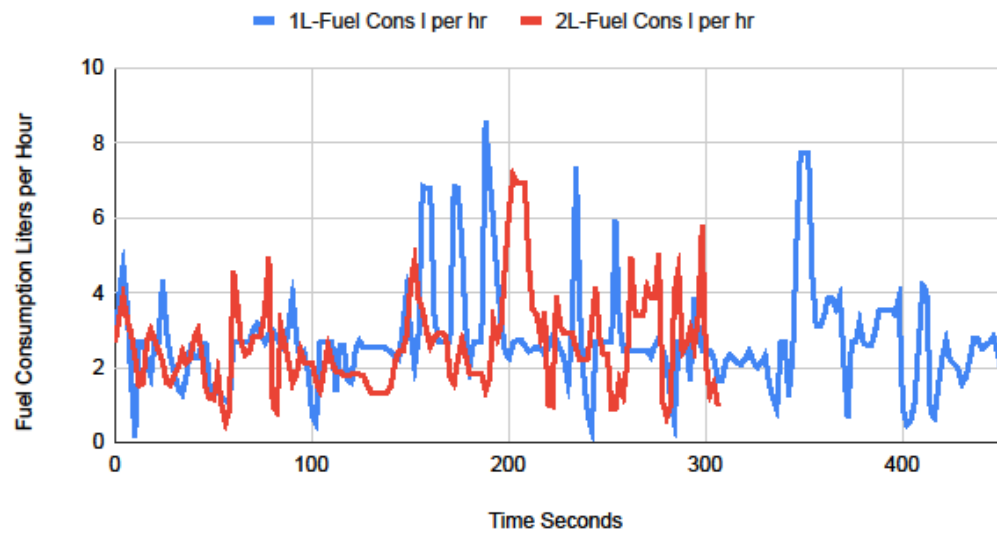


Figure C.2 4 Kuruwita-Erathna road-Going down fuel consumption (4 km-0)