Democratic Socialist Republic of Sri Lanka

Ministry of Transport and Civil Aviation

Colombo Suburban Railway Project
Project Preparatory Technical Assistance

Kelani Valley Line

Alternatives Studies

July 2017

egis

RDC Resources Development Consultants

ADB

REPORT COVER PAGE

Project Title:	Colombo Suburban Railway Project Project Preparatory Technical Assistance (PPTA)
Project Owner	Asian Development Bank
Contractor	Egis International / Resources Development Consultants (Pvt) Ltd
Project Office Address:	Ministry of Transport, 1 D. R. Wijewardena Mawatha, Colombo – 10, Sri Lanka.
Telephone:	++ 94 011 2689 243
Head Office Address:	Egis International 15, Avenue du Centre – CS 20538 Guyancourt 78286 Saint-Quentin-en-Yvelines Cedex - France
Telephone:	++ 33 1 39 41 42 75
Fax:	++ 33 1 39 41 57 29
E-mail:	Pascal.ROUSSEL@egis.fr
Contact Person:	Mr. Pascal Roussel

Document quality information

General information

Author(s)	Project Team
Project name	**Colombo Suburban Railway Project – Project Preparatory Technical Assistance (PPTA)**
Document name	**Initial Report** **Kelani Valley Line – Alternative Study** **Volume 1**
Date	**7th of July, 2017**
Reference	**49111-02/CSR PPTA/FRIFS/001**

Addressee(s)

Sent to (hard copy / electronic):		
Name	**Organisation**	**Sent on (date):**
Aruna Nanayakkara	ADB	28 Jul 2017

Copy to (electronic):		
Name	**Organisation**	**Sent on (date):**
Markus Roesner	ADB	28 Jul 2017
Johan Georget	ADB	28 Jul 2017
Palitha Samarasinghe	MOT	28 Jul 2017
Pascal Roussel	Egis International	28 Jul 2017
S. Jegasothy	RDC	28 Jul 2017

History of modifications

Version	Date	Written by	Approved by:
1	28 Jul 2017	Xavier Zubillaga, Damien Mangeas, Frédéric Birer, Vincent Vanhede, Benoit Guillot	Pascal Roussel
2	23 Oct 2017	Xavier Zubillaga, Damien Mangeas, Frédéric Birer, Vincent Vanhede, Benoit Guillot, Lorène Honoré	Pascal Roussel
3	22 Dec 2017	Xavier Zubillaga, Damien Mangeas, Frédéric Birer, Vincent Vanhede, Benoit Guillot, Lorène Honoré	Pascal Roussel

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

ADB's Country Partnership Strategy 2012-2016 aims at supporting sustainable economic growth by developing viable multimodal transport systems, including railways and the public transport system.

The ensuing project will be processed as a project loan; the scope being defined by a project preparatory technical assistance (PPTA) and project preparation including design and support for procurement and safeguards which will be provided under a proposed technical assistance loan (TA loan).

EGIS International in association with Resources Development Consultants (the Consultant), where selected to carry out the PPTA.

During the course of preparing the PPTA, the Consultant identified the need to prepare a specific alternative analysis for the Colombo Suburban Railway Kelani Valley Line. This Line serves rapidly developing areas of Colombo in the southeast of the city. However, it is a single track curvy line and Sri Lankan Government has identified the priority need to improve its effectiveness and efficiency.

Expected benefits include positive impacts on economic activities, the environment, and health of residents of Colombo Metropolitan Region (CMR), aligned with the Government of Sri Lanka's Strategic Plan for Transport Management in the CMR. The outcome will be improved transport capacity and service quality in the suburban railway network of Sri Lanka Railways (SLR).

The present report sums-up all data related to the Alternative study of the Kelani Valley line, as a part of Colombo Suburban Railway Project (Preparatory Technical Assistance), into 4 parts:

- Demand forecast and diagnosis of the existing line, after having reviewed previous studies and additional data collection;
- Definition of the corridor and alignment alternatives and definition of various technology alternatives;
- Operating scenarios, costing and assessment of the alternatives
- Recommendations

55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

2 PROJECT CONTEXT AND STUDY OBJECTIVE

2.1 THE COLOMBO SUBURBAN RAILWAY LINES

The Western Province, which is also identified as the CMR, is on the western seaboard of Sri Lanka and includes the capital, Colombo. It extends over 3,684 km2 with a population of 5.8 million (29% of the country), leading to the highest population density of 1,581 persons/km2. Western provincial share of the national gross domestic product (GDP) is around 43.4% and has recorded the highest per capita income of Rs 372,814 (approx. $2,922) in 2012.

The Colombo Suburban Railway (CSR) network is developed along four major corridors, namely Main Line, Coastal Line, Kelani Valley Line and Puttlam Line totalling around 230 km. Figure 1 shows Colombo Suburban railway lines.

For the Colombo suburban rail strategic plan, the PPTA encompass the study area covering the four major corridors, Main Line, Coastal Line, Kelani Valley Line and Puttlam Line, including:

- Main line: Colombo Fort to Veyangoda and to Polgahawela (for possible signalling and communications improvements);
- Coastal line: Colombo Fort to Kalatura South;
- Puttalam line, that diverts from the Main line at Ragama and goes to Negombo;
- Kelani Valley line, that diverts from the Main line at Maradana and goes to Homagama.

Figure 2-1: Colombo Suburban Railway Lines

egis
Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

2.2 THE KELANI VALLEY LINE SITUATION

The Kelani Valley Line is a single track line with few passing loop. The line is serving a highly populated area and has a high ridership potential. Yet, PPTA Interim Report concluded that the single track layout does not provide the necessary capacity required to transport the estimated number of passengers. Even if all stations were equipped with passing loops, this would still not be enough. The report concluded that KV Line would need to be converted to double track to allow a greater number of services.

The above conclusion is consistent with the Sri Lankan Government interest in double tracking the KV Line.

However, because the line geometry, the PPTA Interim Report also concluded that the dualling of the tracks should not bring significant improvement in journey times. In addition, it concluded that, the laying of double track will not bring a solution in regard of traffic road with numerous level crossings staying closed too long and the train speed will be limited due to sharp curves and the difficulties to rectify these curves at level. The recommendation was to conduct a special study to further analyse alternative for overall improvement of the line, studying layout improvement, and reducing rail – road conflicts.

2.3 OBJECTIVE

The purpose of the alternative study is to conduct a study of feasible alternative improvements to the KV Line, and to carry out a detailed appraisal and comparison of these alternatives in order to provide decision makers with the required information to select the best alternative and continue its preparation in future phases with more detailed studies and implementation.

3 TRAFFIC FORECAST AND DIAGNOSIS OF THE EXISTING LINE

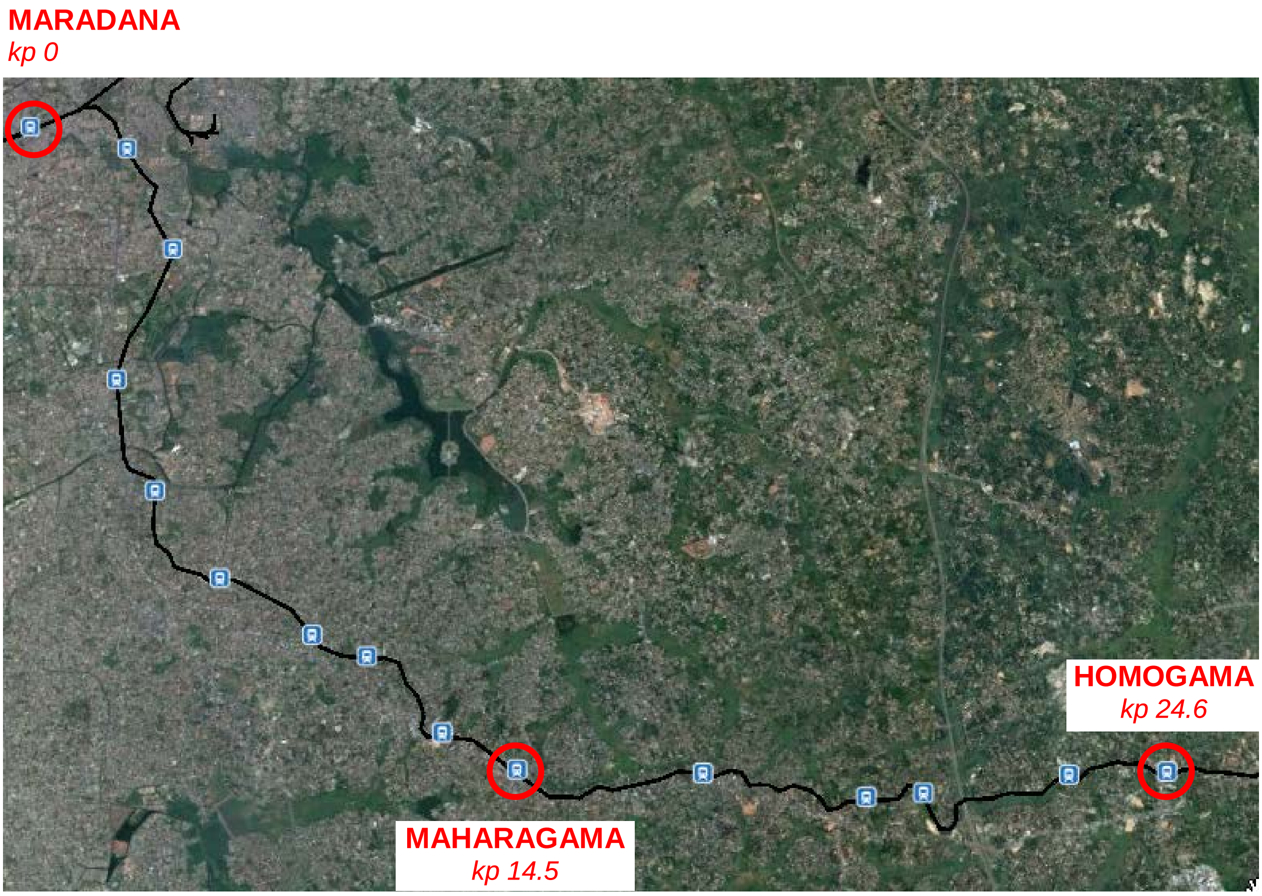
3.1 OVERALL INSERTION

The Kelani Valley line diverts from Main line at the level of Maradana station. It immediately benefits from its own single track. As a consequence, trains running on that corridor are currently rarely mixed with other traffics (Puttalam and Main line).

Before reaching Locomotive Yard, the single track line heads toward the South and South-eastern sections of the metropolitan area, until Maharagama station.

At this point, the line orientation change: it shifts to the East until Homogama station, last point to consider in this alternative study.

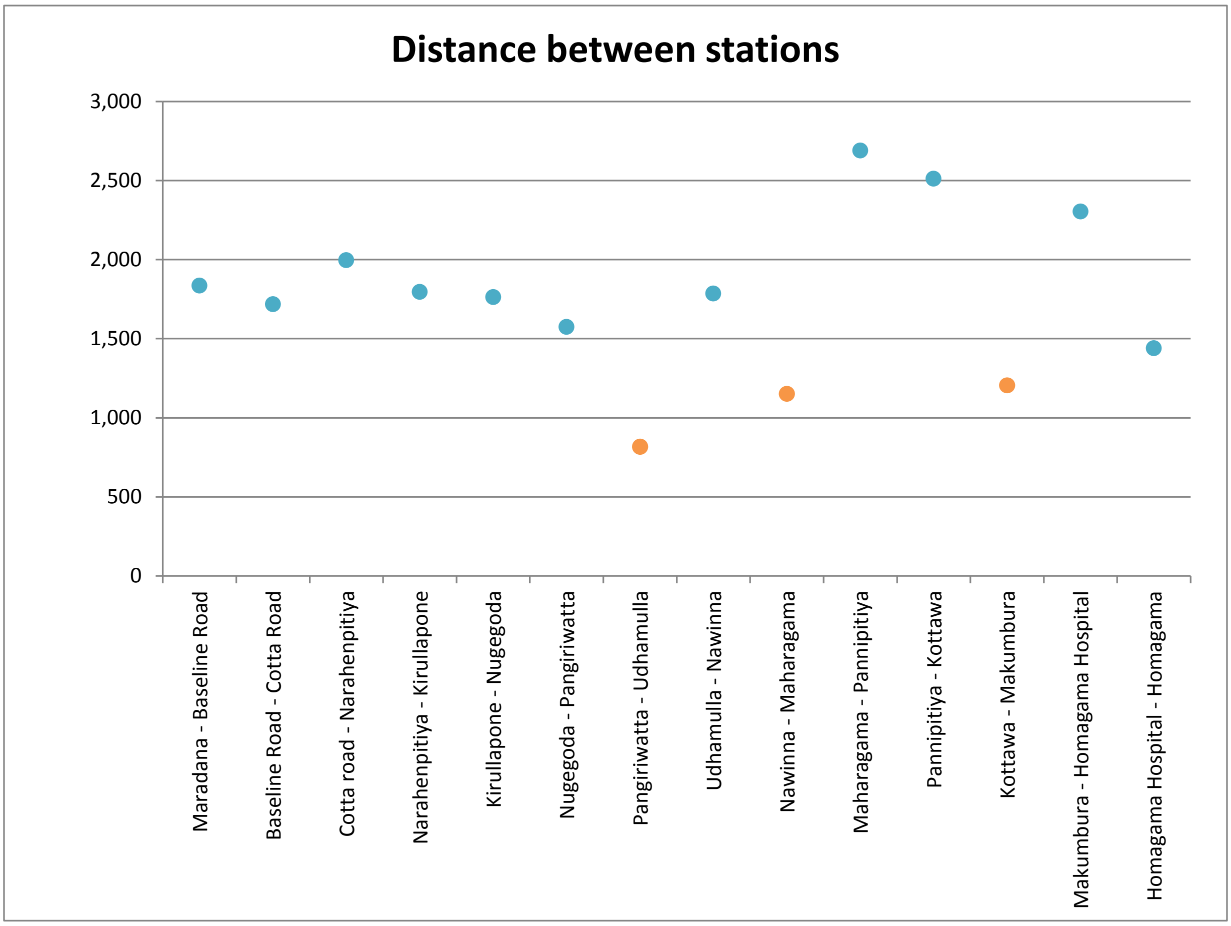
Figure 3-1: Maradana – Homogama section



A total of 24.6 km are recorded between Maradana and Homagama. The distance between stations is uneven with some very short interdistance (only 800 m between Pangiriwatta and Udhamulla) to the longest one which is 2.7 km long between Maharagama and Pannipitiya.

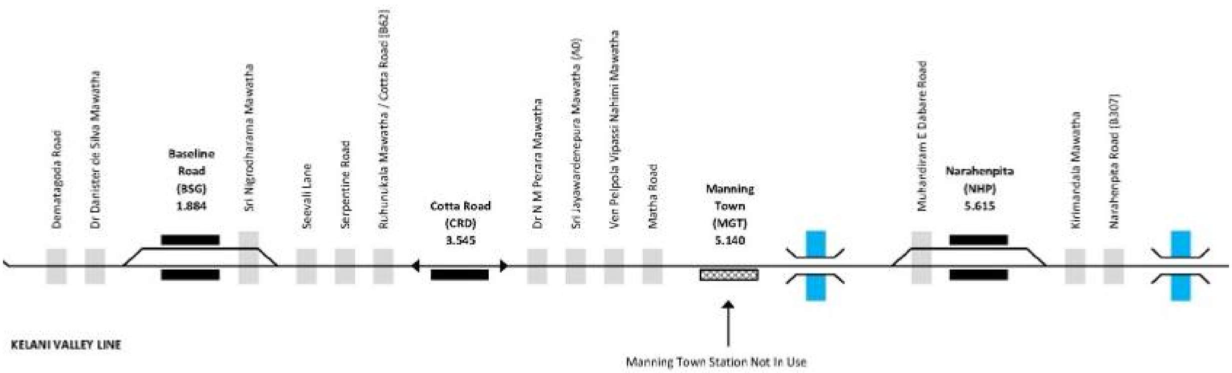
A short interdistance has a high impact on the commercial speed as the train does not have enough length to get to full speed. It is also less efficient in term of attractiveness as close stations are attracting the same passenger.

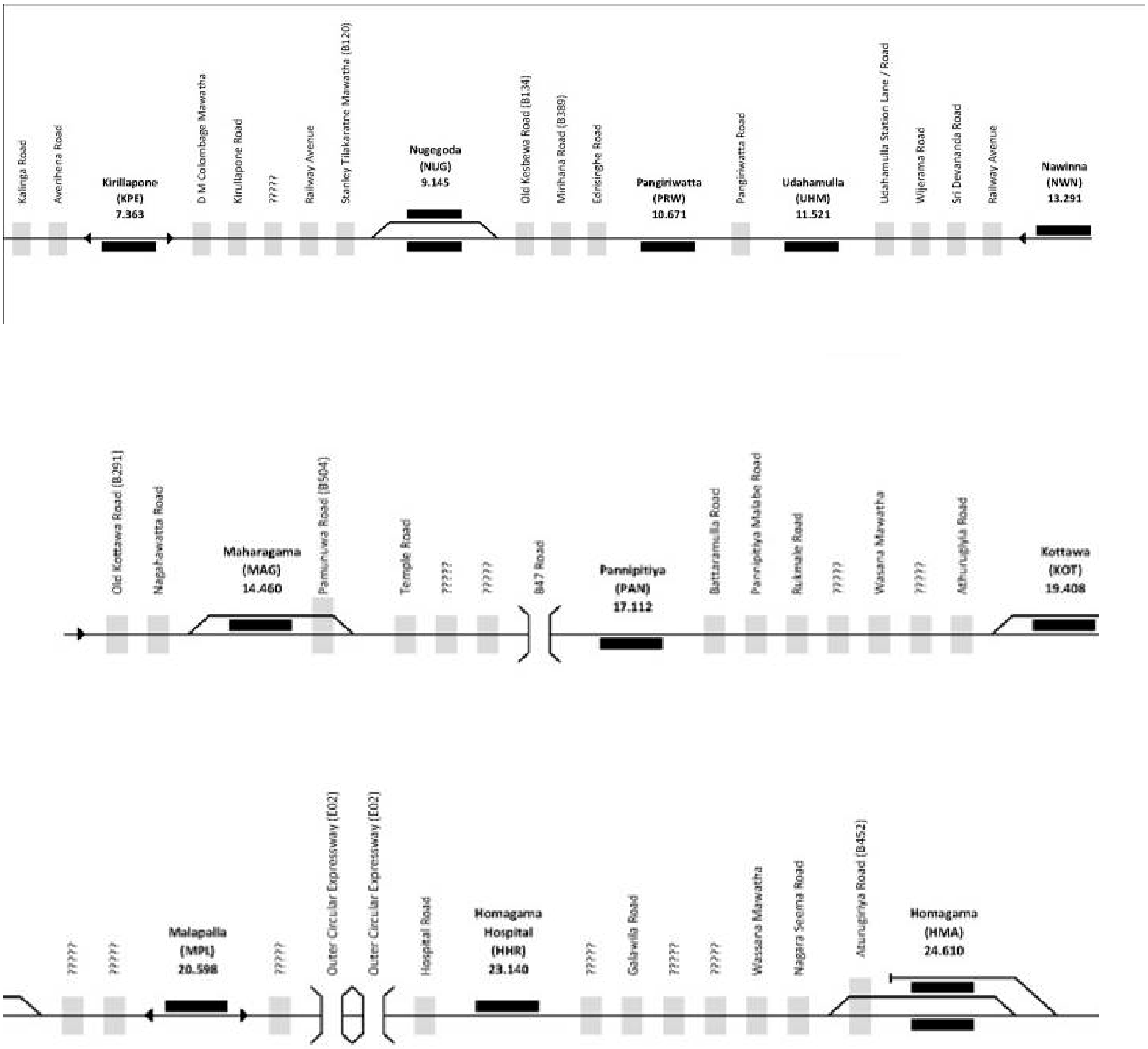
Figure 3-2: Distribution of distance between stations



The following diagrammatic track layout gives the overall distribution of stations, as well as location of passing loops (x6).

Figure 3-3: Diagrammatic track layout KV Line



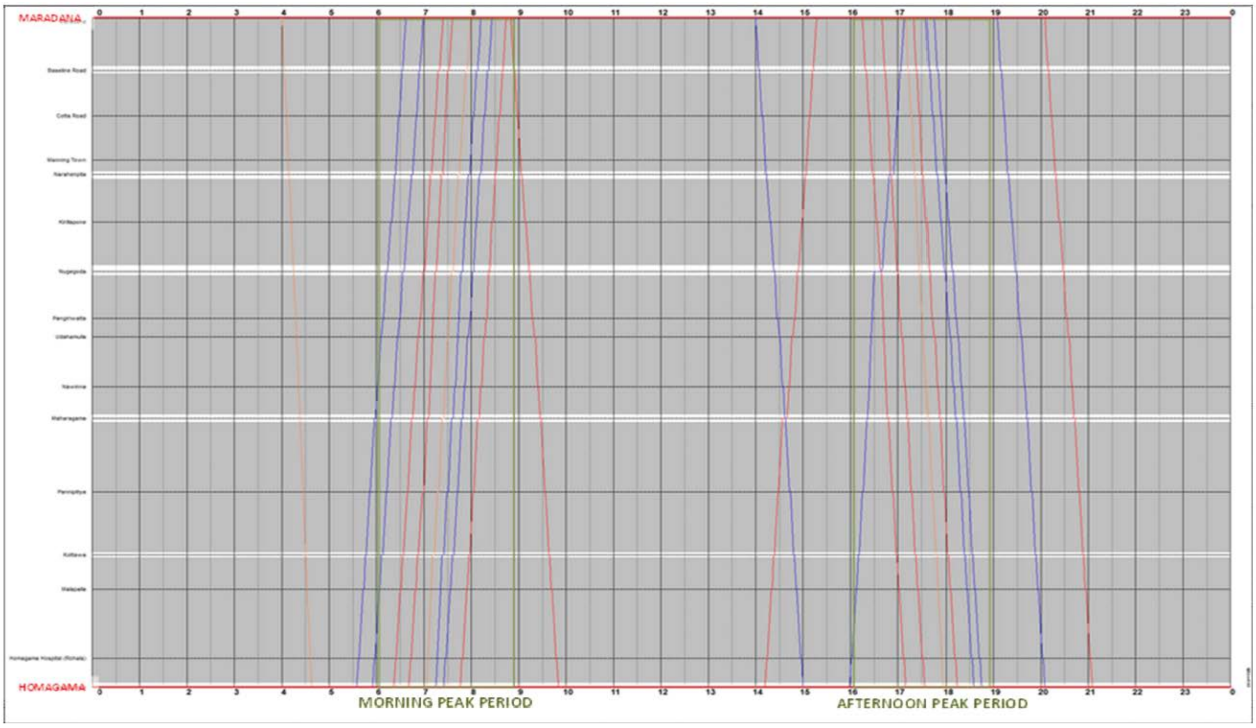


3.2 CURRENT OPERATION

The current operation program (2016) unveils oriented paths according to time period: on morning peak, most trains are converging toward Maradana station (8 out of 10). On the other hand, on evening peak period, a large number of trains is also leaving Colombo central station, running toward end of line (9 out of 11).

The following figure shows the current timetable distance-time graph for the Kelani Valley Line, from Colombo Fort to Homagama (the line continues until Avissawella), for the 00h-24h period.

Figure 3-4: Distance – Time Graph – 00h-24h – Maradana to Homogama



General comments are the following:

- Almost all trains run during the peak periods,
- All train paths run in the same direction
  - Down Line during morning peak.
  - Up Line during evening peak.
- A maximum of 4 trains per hour at peak hour
- Travel time is around 62 minutes between Maradana and Homogama
- According to *Working Time Table (Part 1)*, the maximal authorized speed due to the state of the track is 32 kmph
- Commercial speed is 23.5 kmph
- Capacity is very limited due to single track sections and limited number of stations with a passing loop.
- The potential to add additional trains is also very limited.

3.3 HORIZONTAL ALIGNMENT

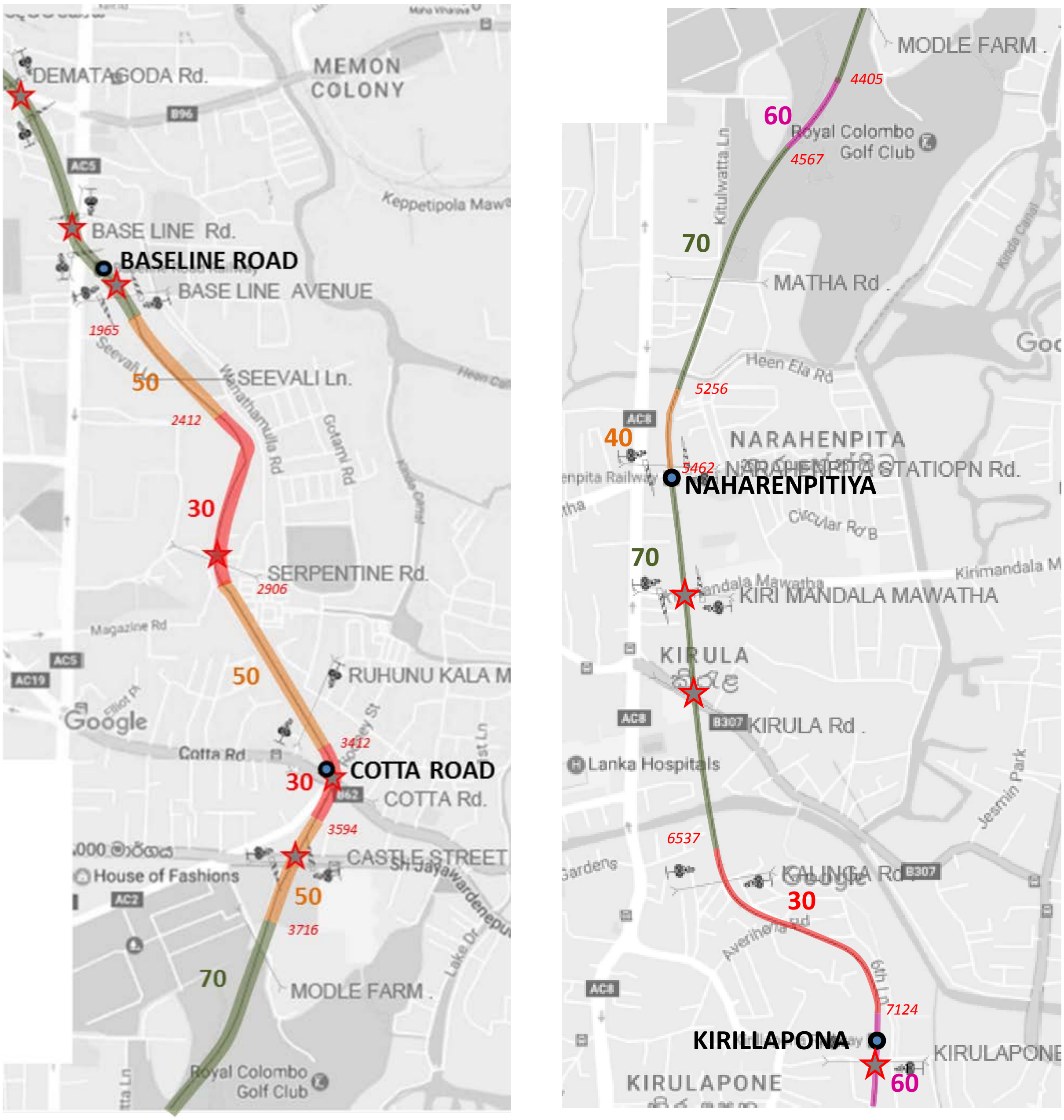
As a first look, we must mention that the line is very winding, with a large variety of curves throughout the path.

- 37% of the alignment is composed of curves with radius < 150 m,
  The maximum speed is reduced under 30 km/h
- 70% of the alignment is made of curves with radius < 300 m,
  The maximum speed is reduced under 70 km/h

The following pictures show the horizontal alignment breakdown, between straight sections and curves. It also gives indications on maximum speed allowed by the infrastructure.

This is to note that the real maximum speed (the operating speed), is always behind the one provided by the track.

Figure 3-5: Horizontal alignment Dematagoda Road – Kirillapona station



Left: from KP 1000 to KP 4000 Right: from KP 4000 to KP 7000

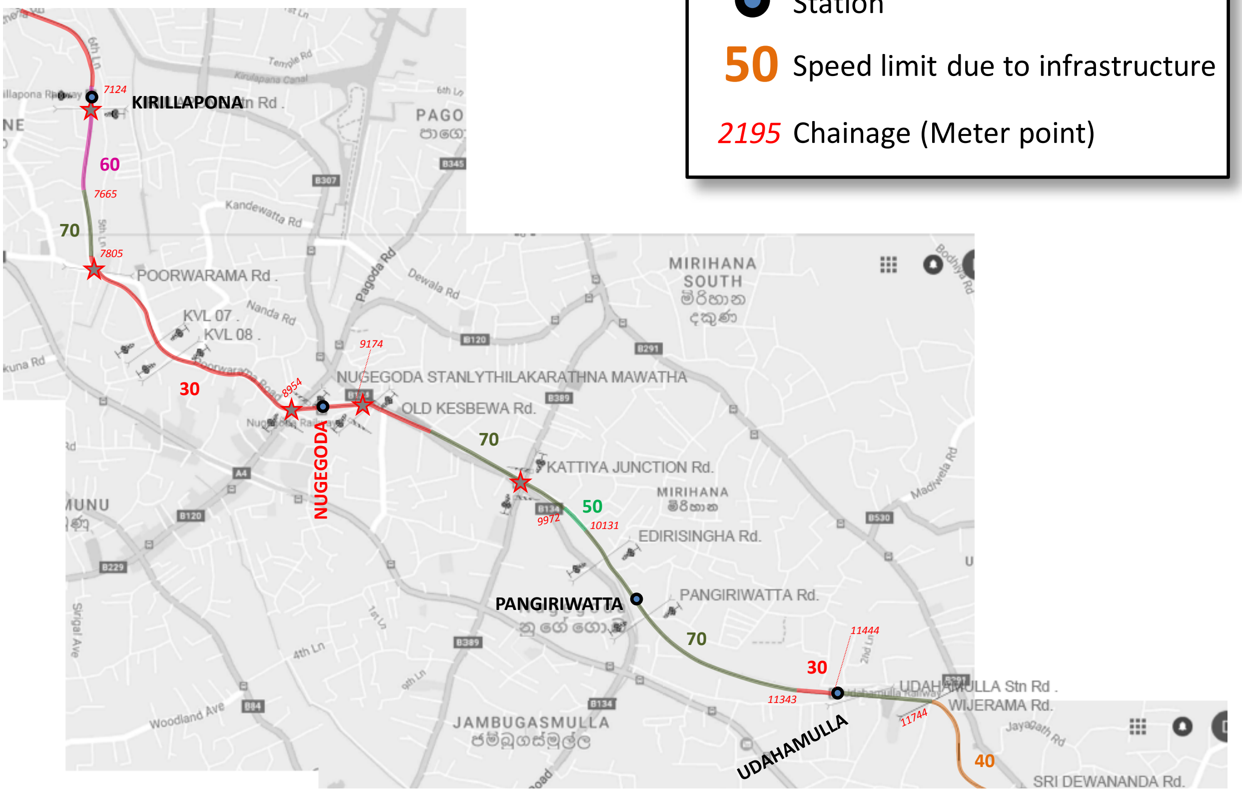
KEYS

- Major crossroads
- Station
- **50** Speed limit due to infrastructure
- *2195* Chainage (Meter point)

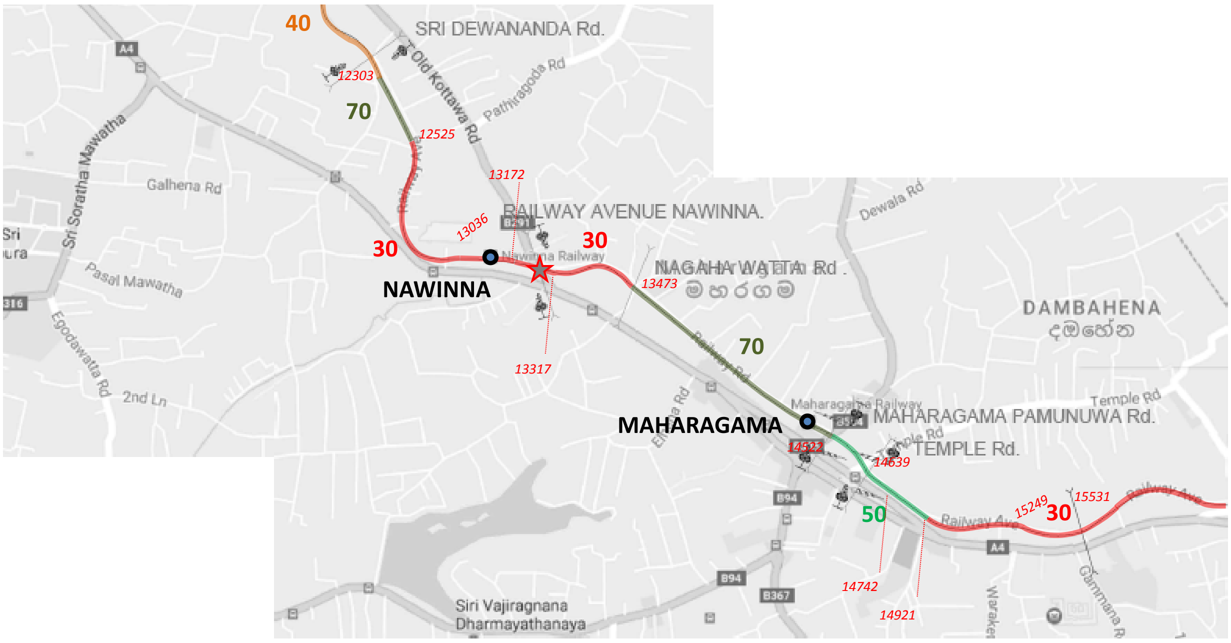
Figure 3-6: Horizontal alignment Kirillapona station – Maharagama station

KEYS

- Major crossroads
- Station
- **50** Speed limit due to infrastructure
- *2195* Chainage (Meter point)

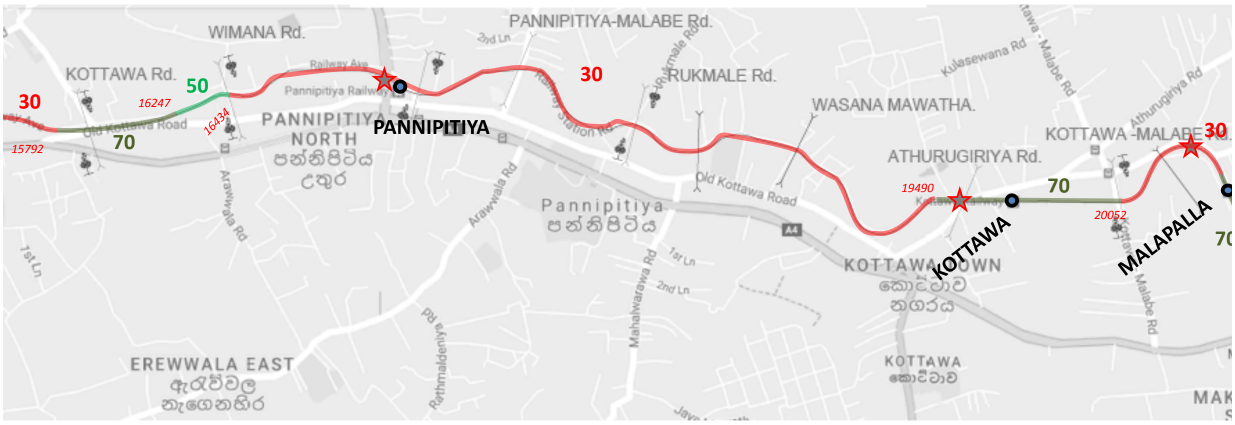


egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council



Top: from KP 7000 to KP 12000 Down: from KP 12000 to KP 15000

Figure 3-7: Horizontal alignment Maharagama station – Homagama station



KEYS

- Major crossroads
- Station
- 50 Speed limit due to infrastructure
- *2195* Chainage (Meter point)

Top: from KP 15000 to KP 21000 Down: from KP 21000 to KP 25000

3.4 VERTICAL ALIGNMENT

The line remains almost all the time at same elevation between Maradana and Nugegoda. As a result, few gradients are to be noticed.

A more hilly topography is encountered after Nugegoda.

Figure 3-8: Existing line deeply excavated near Kesbewa road, just after Nugegoda station

Relevant altitudes are compiled in the following chart.

Station	Geographical status		Altitude (m)
	Longitude	Latitude	
Colombo Fort	6° 55’ 59.5”	79° 50’ 58.1”	12
Maradana	6° 55’ 43.1”	79° 51’ 56.8”	01
Narahenpita	6° 53’ 48.8”	79° 52’ 40.8”	38
Nuggegoda	6° 52’ 21.7”	79° 53’ 26.9”	38
Maharagama	6° 50’ 47.7”	79° 55’ 37.1”	38
Kottawa	6° 50’ 37.7”	79° 58’ 01.7”	38
Homagama	6° 50’ 43.4”	80° 00’ 13.0”	38

3.5 STATIONS

The line is served by a total of 14 stations, which make an average distance between stations of 1800m. Among them, 6 have a passing loop, enabling trains to cross themselves in opposite direction.

Figure 3 2: Typical station, without passing loop

Figure 3 2: Typical station, with passing loop

They all benefit from a shed, protecting passengers from sun and rain. The access is mostly made by walking. Nugegoda station is equipped with park lot.

The platform lengths at the stations of KV line are the following:

STATION NAME	PLATFORM LENGTHS (m)	
	SIDE 1	SIDE 2
BASE LINE	77,5	119,1
COTTA ROAD	86,4	
NARAHENPITA	107,3	105,8
KIRULAPANE	92,9	
NUGEGODA	124	154,9
PENGIRIWATTE	75,6	
UDAHAMULLA	109,2	
NAWINNA	93,94	
MAHARAGAMA	103,4	
PANNIPITIYA	101,8	
KOTTAWA	100,6	
MALAPALLA	116,35	
HOMAGAMA ROHALA	83,8	
HOMAGAMA	146.71	104,5

The platform lengths vary between 75m and 150m. Currently many stations can only correctly host short trains.

3.6 LEVEL CROSSINGS

A total of 53 level crossings are spotted all through the line. As an average, there is a level crossing every 2.15 km.

Figure 3 2: Train at level crossing on Baseline road

There are of four categories, based upon the devices and manned supervision:

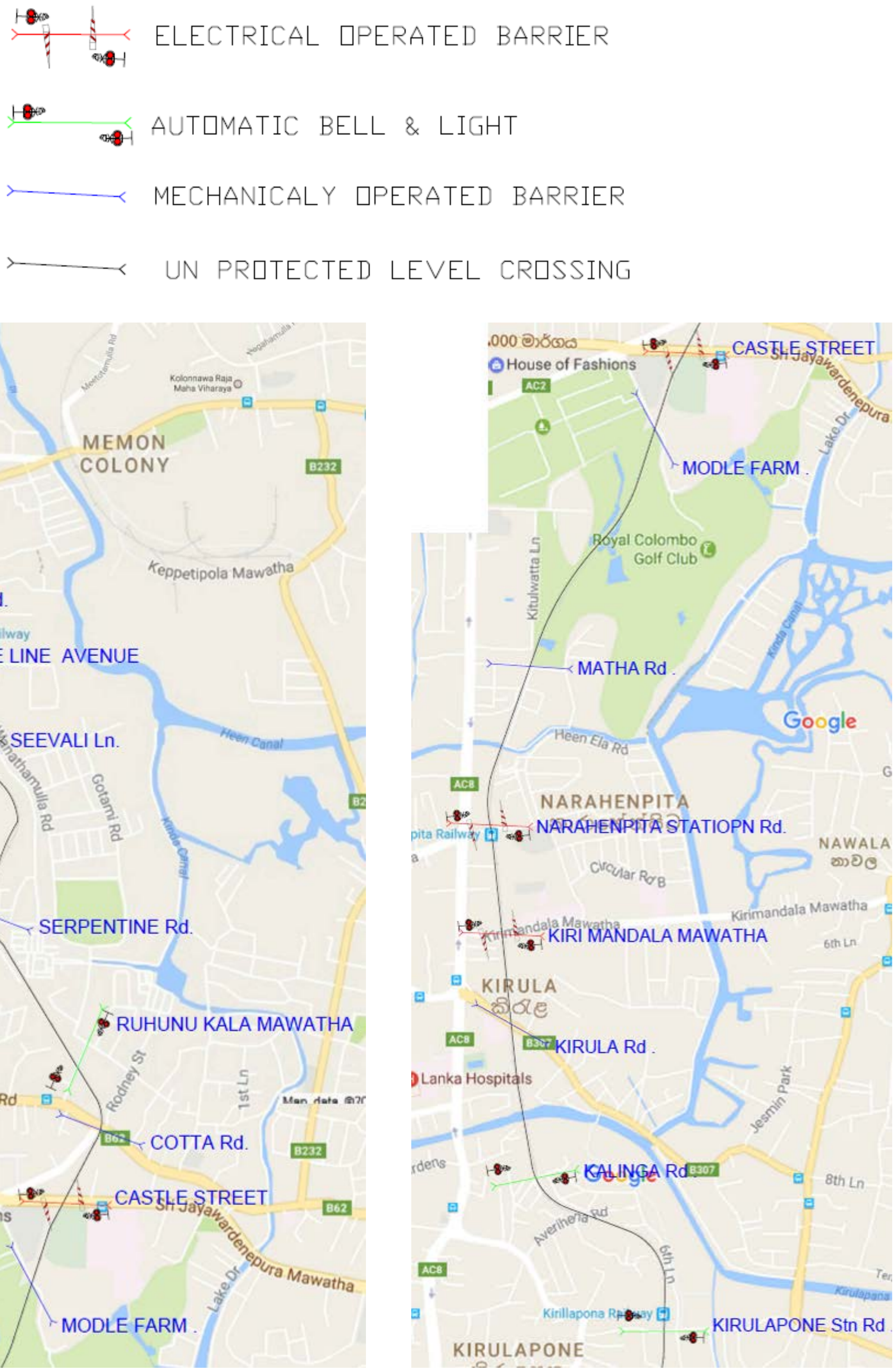
- Electrical operated barrier,
- Automatic bell and light, without barrier
- Mechanically operated barrier, manipulated by a railway agent
- Unprotected level crossing

According to SLR, for an electrical operated barrier level crossing, the duration of the sequence in which road traffic is stopped is around 60 seconds, split into:

- 10s for announcement
- 7s for barriers closing
- 20s for time of train to reach the level crossing
- 5s for train passing
- 10s for train releasing pedal / barrier starting opening
- 7s for barrier opening

In practice, this duration may be longer. The following maps are showing the locations of KV line level crossings:

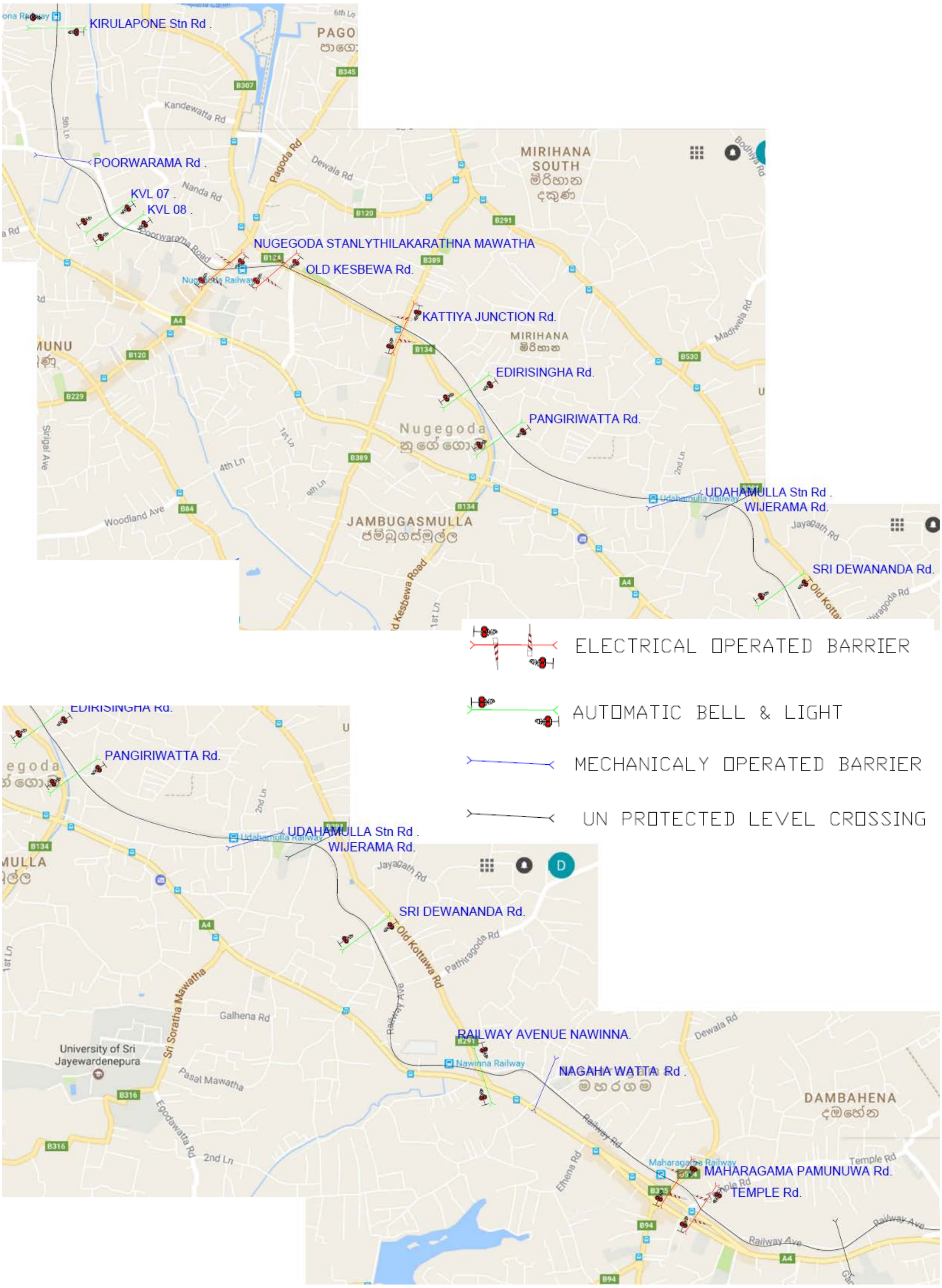
Figure 3-9: Location of level crossings on section Dematagoda Road – Kirillapona station



Left: from MP 1000 to MP 4000

Right: from MP 4000 to MP 7000

Figure 3-10: Location of level crossings on section Kirillapona station – Tenple road

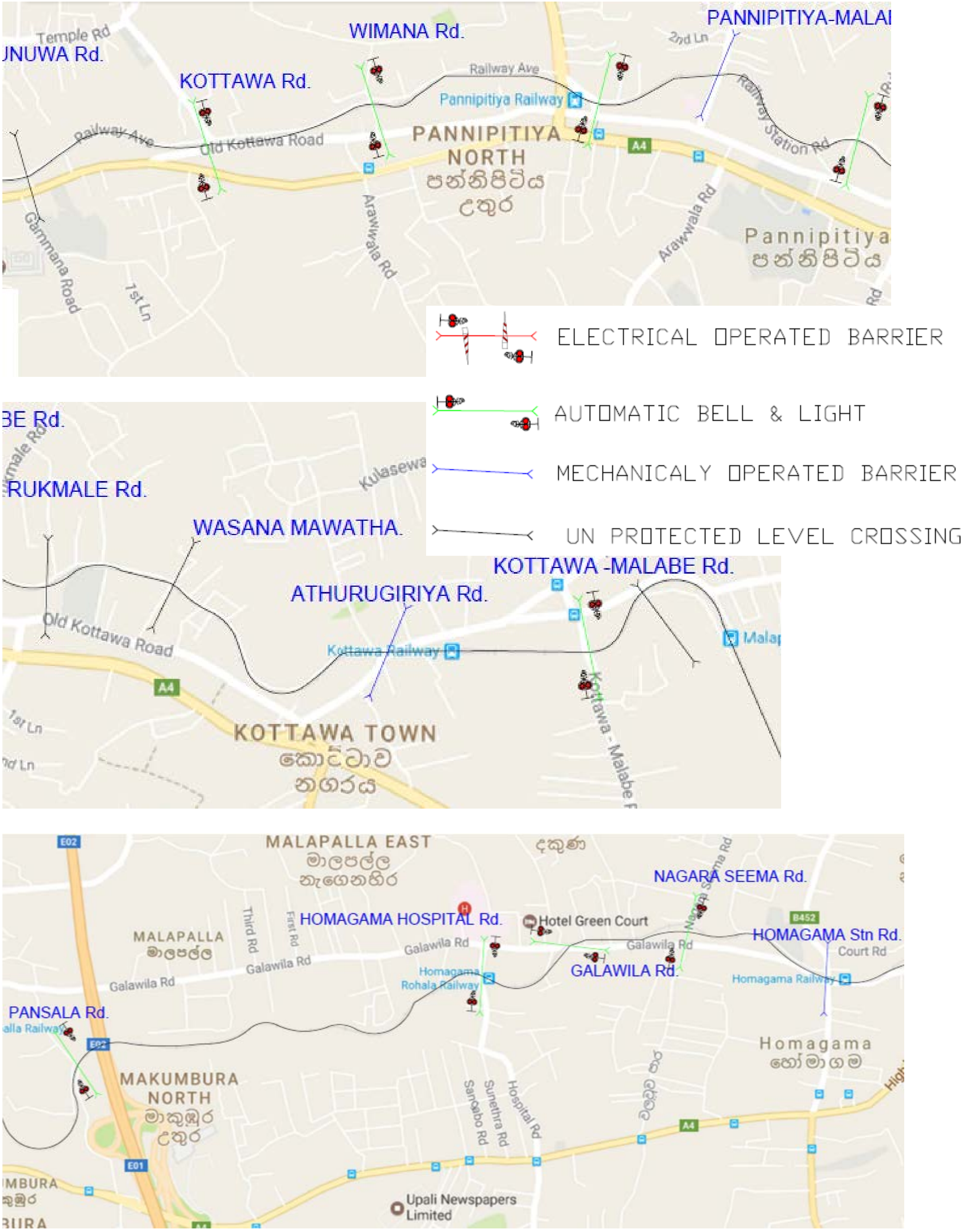


Top: from MP 7000 to MP 12000

Down: from MP 12000 to MP 15000

egis RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road, Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

Figure 3-11: Location of level crossings on section Kirillapona station – Tenple road



Top: from MP 18000 to MP 21000

Center: from MP 18000 to MP 21000

Down: from MP 21000 to MP 25000

The road traffic can be punctually quite high on major corridors, causing congestion. As a result, the road congestion may interfere with rail traffic when vehicles remain in the middle of the rail-track (as seen on below picture).

Figure 3-12: Frequent situation of congested roads

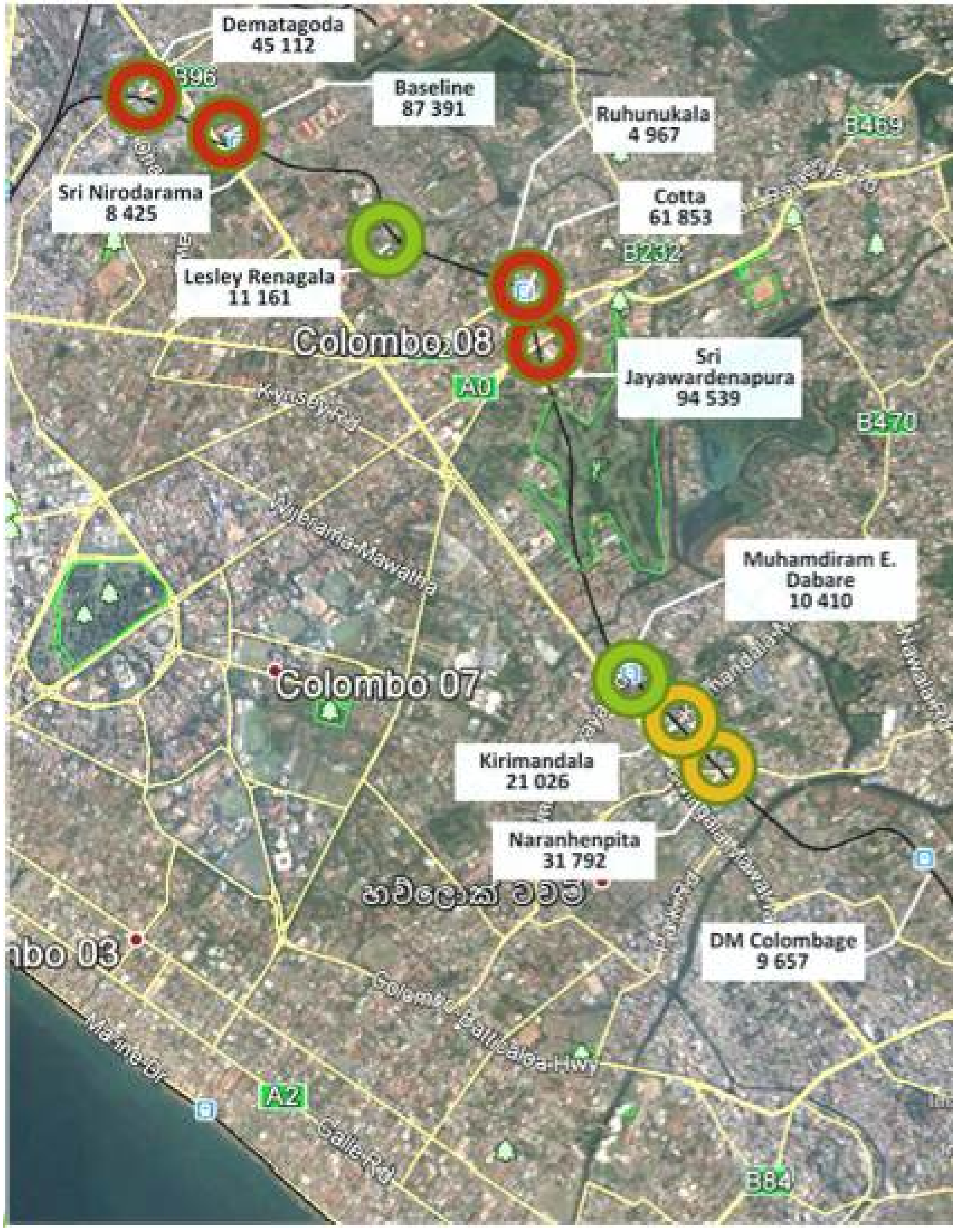
In case of rail traffic increase on KV line, measures will have to be taken to prevent such difficulties, with cars preventing train from running on line. Such situation may cause serious accidents, as trains may not have enough time to brake before a possible impact.

The following maps give an overview of major crossroads and related traffics, with most updated data available (traffic counts May 2017).

There are 3 highlighted categories, based upon the counted road ADT (Average Daily Traffic):

- Road traffic > 40 000 ADT (red). The road is presently highly congested
- Road traffic > 20 000 ADT (yellow). The road is presently heavily circulated and regularly congested
- Road traffic > 10 000 ADT (green). The road is well circulated, and risk of congestion will be increasing within the next years

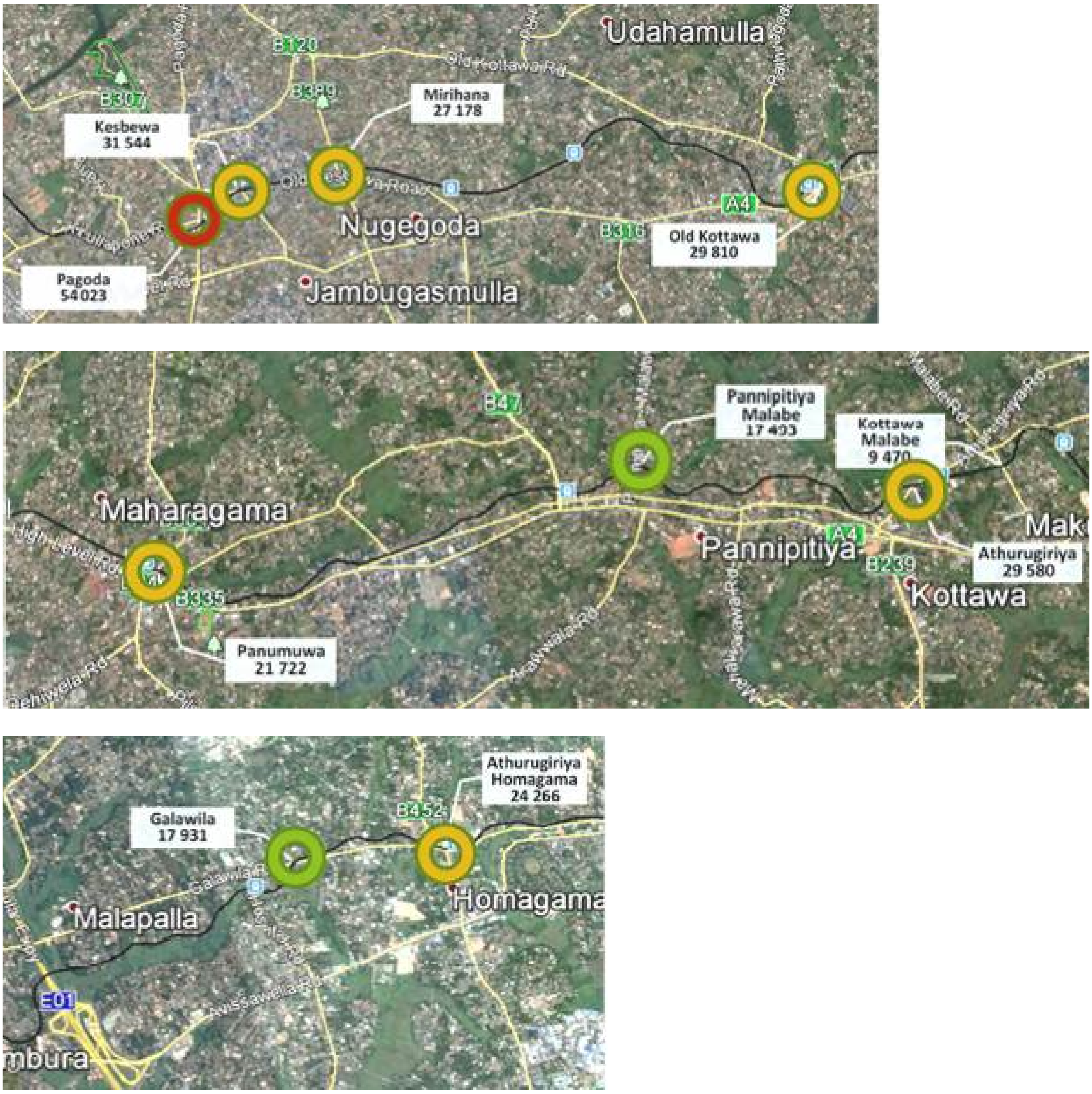
Figure 3-13: Road traffic counts (May 2017) on section Dematagoda road - Kirillapona station



From MP 1000 to MP 7000

- Road traffic > 40 000 ADT (red): 4 units
- Road traffic > 20 000 ADT (yellow): 2 units
- Road traffic > 10 000 ADT (green): 2 units

Figure 3-14: Road traffic counts (May 2017) on section Kirillapona – Homogama station



Top: from MP 7000 to MP 12000

Center: from MP 12000 to MP 21000

Down: from MP 21000 to MP 25000

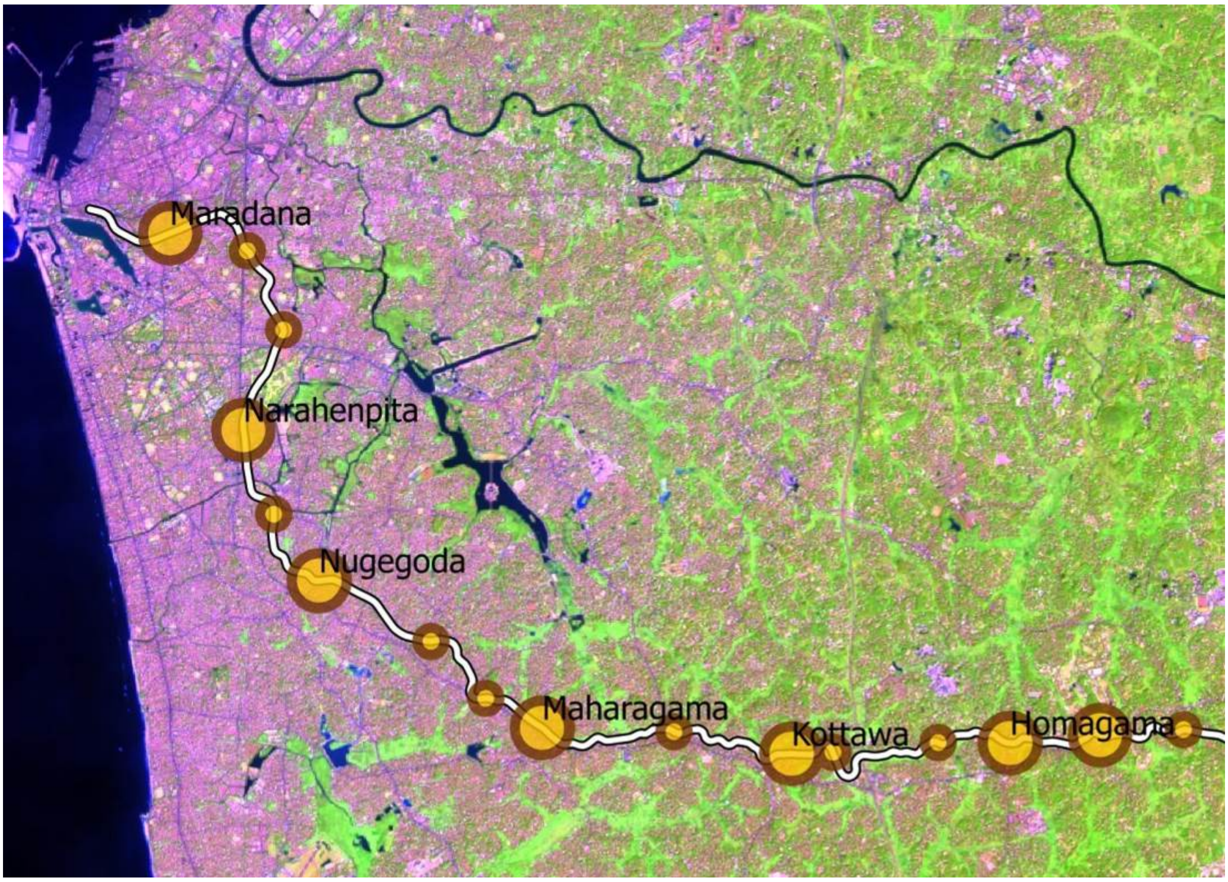
- Road traffic > 40 000 ADT (red): 1 unit (before Nugegoda station)
- Road traffic > 20 000 ADT (yellow): 6 units (2 before Nugegoda station)
- Road traffic > 10 000 ADT (green): 2 units

3.7 URBANIZATION

The line crosses a heavy populated zone, mostly between Maradana and Maharagama. The immediate surroundings of the line are densely urbanized. The minimum width available between houses is around 4 to 5 meters (the rail-track in-between).

The following figure shows the urbanization density in Colombo Metropolitan Region and the location of KV Line.

Figure 3-15: Urbanization and KV Line



Source: UN Habitat, 2017

Figure 3-16: Dense urbanization along the tracks

4 FORECAST SITUATION

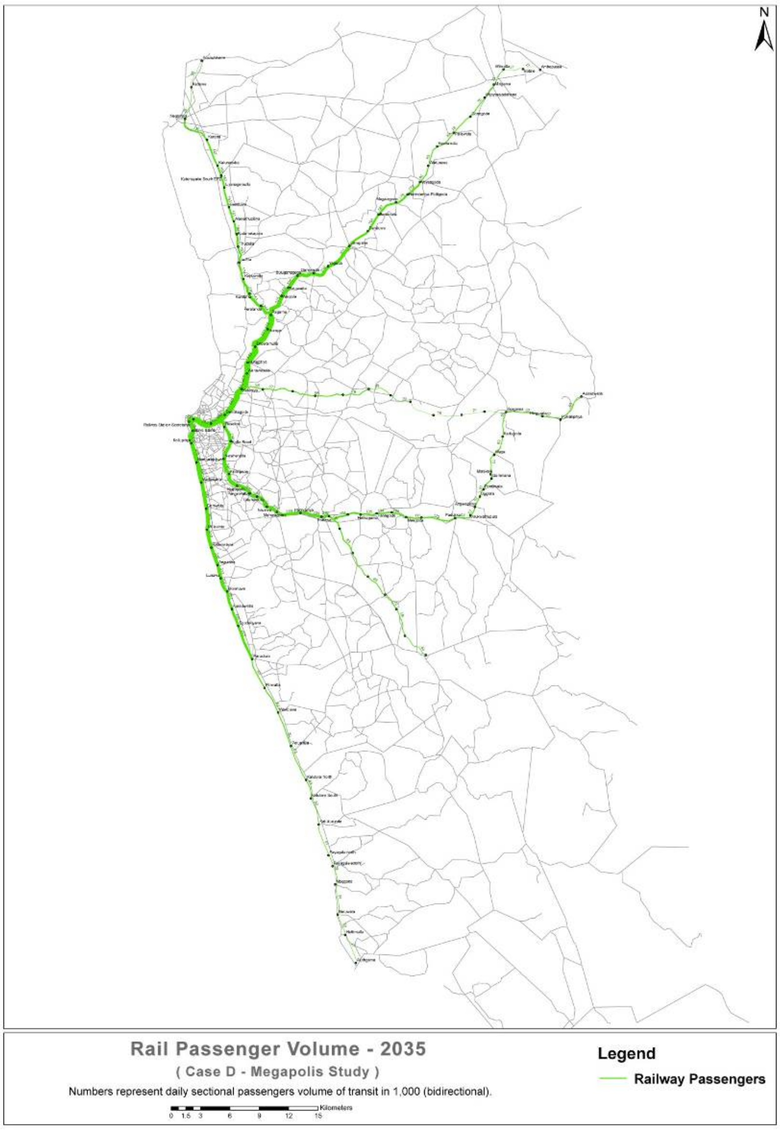
4.1 TRAFFIC FORECAST

4.1.1 Daily passenger ridership

The passenger ridership estimation is based upon previous available data, named as “Megapolis Study (Case D), providing forecast on boarding and alighting at any station of the suburban area for the year 2035. An assumption is made to obtain the same boarding and alighting figures for 2025.

The following diagram shows the estimated daily ridership for 2035, in-between stations, in thousands (000s) of passengers (both directions counted).

Figure 4-1: Rail Passenger Volume on CSR network, year 2035



egis
Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

A patronage forecast is made for both year 2025 and year 2035. These data are taken from the output of the Megapolis Study (Case D), giving an estimated ridership for KV line on year 2035.

Table 4-1: Daily Riderships and Traffic loads per section on peak period

		Riderships daily (both directions)				Peak Period			
From	To	2016	2020	2025	2035_D	2016	2020	2025	2035_D
KELANI VALLEY LINE									
	Maradana	17,000	238,000	244,000	303,000	1,210	16,946	17,373	21,574
Maradana	Baseline Road	17,000	238,000	244,000	303,000	1,210	16,946	17,373	21,574
Baseline Road	Cotta Road	18,000	238,000	241,000	296,000	1,282	16,946	17,159	21,075
Cotta Road	Narahenpita	20,000	259,000	261,000	318,000	1,424	18,441	18,583	22,642
Narahenpita	Kirillapone	23,000	269,000	289,000	349,000	1,638	19,153	20,577	24,849
Kirillapone	Nugegoda	23,000	249,000	297,000	358,000	1,638	17,729	21,146	25,490
Nugegoda	Pangiriwatta	24,000	227,000	289,000	340,000	1,709	16,162	20,577	24,208
Pangiriwatta	Udahamulla	24,000	208,000	271,000	320,000	1,709	14,810	19,295	22,784
Udahamulla	Nawinna	23,000	189,000	259,000	304,000	1,638	13,457	18,441	21,645
Nawinna	Maharagama	23,000	172,000	248,000	291,000	1,638	12,246	17,658	20,719
Maharagama	Pannipitiya	20,000	142,000	223,000	260,000	1,424	10,110	15,878	18,512
Pannipitiya	Kottawa	17,000	132,000	222,000	259,000	1,210	9,398	15,806	18,441
Kottawa	Malapalla	14,000	119,000	214,000	246,000	997	8,473	15,237	17,515
Malapalla	Homagama Hospital	13,000	25,000	133,000	154,000	926	1,780	9,470	10,965
Homagama Hospital	Homagama	13,000	22,000	110,000	135,000	926	1,566	7,832	9,612
Homagama	Panagoda	11,000	22,000	111,000	135,000	783	1,566	7,903	9,612
Panagoda	Godagama	10,000	22,000	109,000	134,000	712	1,566	7,761	9,541
Godagama	Migoda	9,000	21,000	103,000	128,000	641	1,495	7,334	9,114
Migoda	Watareka	8,000	16,000	87,000	111,000	570	1,139	6,194	7,903
Watareka	Padukka	7,000	17,000	87,000	110,000	498	1,210	6,194	7,832
Padukka	Arukwatte	3,000	15,000	74,000	93,000	214	1,068	5,269	6,622
Arukwatte	Anganpitiya	3,000	17,000	69,000	87,000	214	1,210	4,913	6,194
Anganpitiya	Ugalla	3,000	15,000	66,000	82,000	214	1,068	4,699	5,838
Ugalla	Pinnawala	3,000	15,000	65,000	81,000	214	1,068	4,628	5,767
Pinnawala	Gammana	2,000	16,000	66,000	81,000	142	1,139	4,699	5,767
Gammana	Morakelle	2,000	12,000	59,000	73,000	142	854	4,201	5,198
Morakelle	Waga	2,000	12,000	60,000	73,000	142	854	4,272	5,198
Waga	Kadugoda	1,000	11,000	56,000	69,000	71	783	3,987	4,913
Kadugoda	Kosgama	1,000	10,000	55,000	68,000	71	712	3,916	4,842
Kosgama	Hingurala	1,000	7,000	47,000	62,000	71	498	3,346	4,414
Hingurala	Puwakpitiya	1,000	6,000	51,000	67,000	71	427	3,631	4,770
Puwakpitiya	Avissawella	1,000	4,000	46,000	63,000	71	285	3,275	4,486

4.1.2 Peak hour ridership

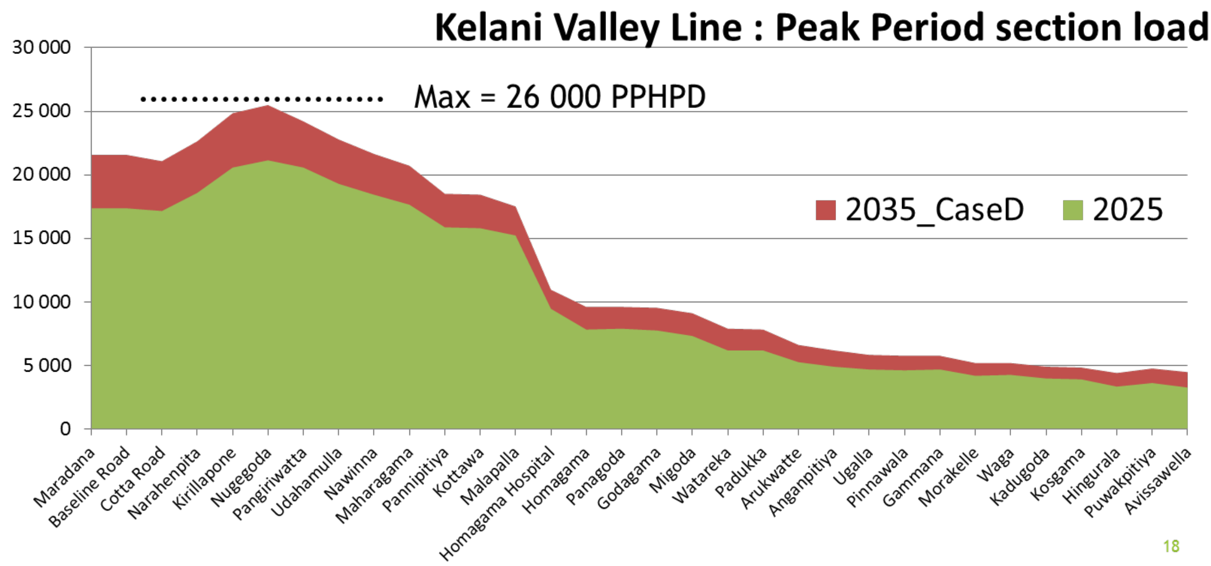
The transformation of daily ridership in both directions to peak hour ridership per direction has been achieved based on the following assumptions:

- Ratio peak hour to daily passenger flows : 8.9% / (ComTrans / Megapolis estimation)
- Ratio peak hour boardings / alightings,
  - Morning; 80% alighting, 20% boarding,
  - Evening; 20% alighting, 80% boarding.

Evening peak hour services will be the same as for the morning peak hour services, but with directions reversed.

The following picture is the train load diagram, giving the maximum load on the whole line, at peak period.

Figure 4-2: Chart of traffic loads per section on peak period



According to these values, 3 different sections can be identified:

- A heavily loaded section between Cotta Road and Maharagama (up to 20,000 passengers per hour per direction in 2025, up to 26,000 pphpd in 2035),
- A sudden fall of traffic between Malapalla and Homagama (from 15,000 / 17,000 to 7,000 / 9,000 pphpd according to horizon),
- A slow and progressive decrease of passenger load from Homagama until end of line (Avissawella).

4.1.3 Sensitivity of the traffic forecast regarding population growth and public transport network development

In addition, an alternative scenario was also estimated with different hypothesis concerning population growth and public transport network development. This “mid-growth” scenario as developed with ADB to estimate the impact of the population growth and the development of the transit network. This alternative scenario is based on:

- JICA’s mid-growth scenario hypothesis (from the ComTrans study)
- The hypothesis that only RTS[1] 1 and RTS 4 are built by 2035.

[1] RTS: Rapid Transit System as developed in the ComTrans study

egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

- More importantly for the KV Line, the mid-growth scenario assumes that in 2025 the KV Line improved only from Maradana to Homagama and there is no Kottawa-Horana extension. In 2035 it assumes that KV Line is improved up to Avissawella and the Kottawa-Horana extension has been built.

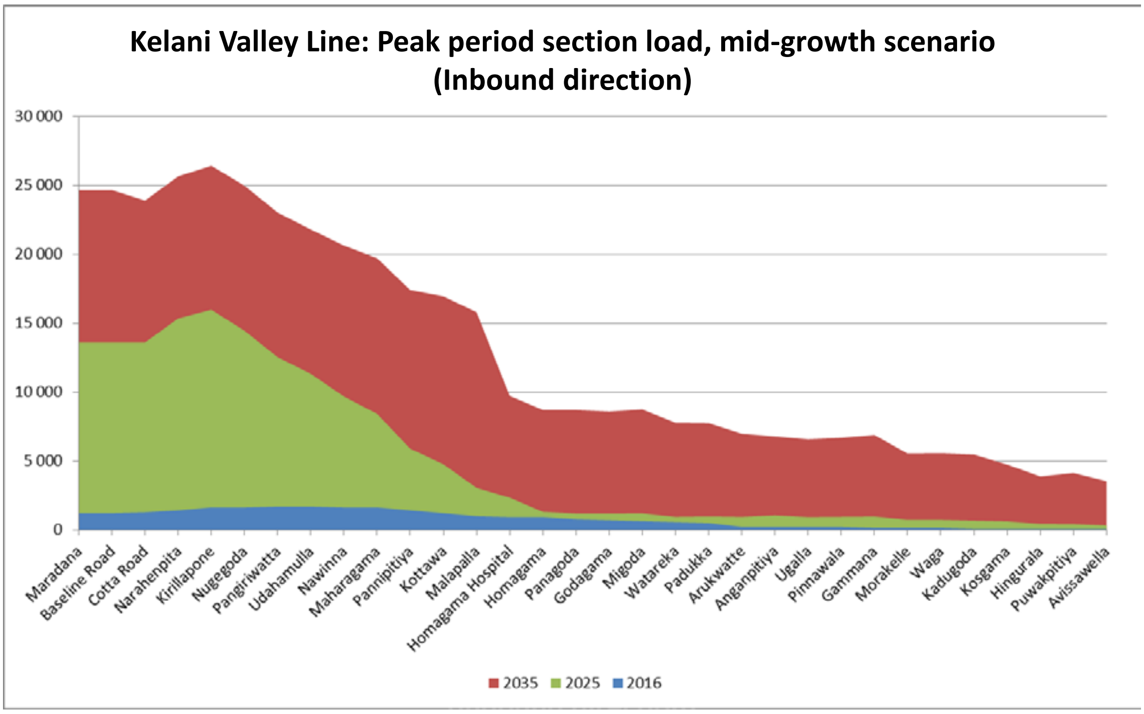
The following table present the traffic load per section for the mid growth scenario for the daily traffic and for the peak hour in the peak direction at the different forecasted years.

Table 4-2: Traffic load per section on KV line for the mid-growth scenario

		Traffic load (daily both directions) Mid Growth scenario			Traffic load (peak hour, peak direction) Mid Growth scenario		
From	To	2016	2025	2035	2016	2025	2035
KELANI VALLEY LINE							
Maradana	Baseline Road	17,000	191,167	346,545	1,210	13,611	24,674
Baseline Road	Cotta Road	18,000	191,205	335,852	1,282	13,614	23,913
Cotta Road	Narahenpita	20,000	215,654	360,486	1,424	15,355	25,667
Narahenpita	Kirillapone	23,000	224,508	371,318	1,638	15,985	26,438
Kirillapone	Nugegoda	23,000	203,114	350,907	1,638	14,462	24,985
Nugegoda	Pangiriwatta	24,000	176,191	323,603	1,709	12,545	23,041
Pangiriwatta	Udahamulla	24,000	159,231	306,347	1,709	11,337	21,812
Udahamulla	Nawinna	23,000	136,064	289,984	1,638	9,688	20,647
Nawinna	Maharagama	23,000	118,427	276,985	1,638	8,432	19,721
Maharagama	Pannipitiya	20,000	82,847	244,643	1,424	5,899	17,419
Pannipitiya	Kottawa	17,000	67,092	238,189	1,210	4,777	16,959
Kottawa	Malapalla	14,000	42,950	221,968	997	3,058	15,804
Malapalla	Homagama Hospital	13,000	32,971	136,663	926	2,348	9,730
Homagama Hospital	Homagama	13,000	18,461	122,421	926	1,314	8,716

The maximum traffic load in 2035 is reached between Cotta Road and Kirillapone with around 26 000 passengers per hour in the peak direction. The traffic remains above 20 000 pphpd until Maharagama. Then it slowly decreases to 15 800 pphpd in Malapalla.

Figure 4-3: Traffic load per section on KV line for the mid-growth scenario

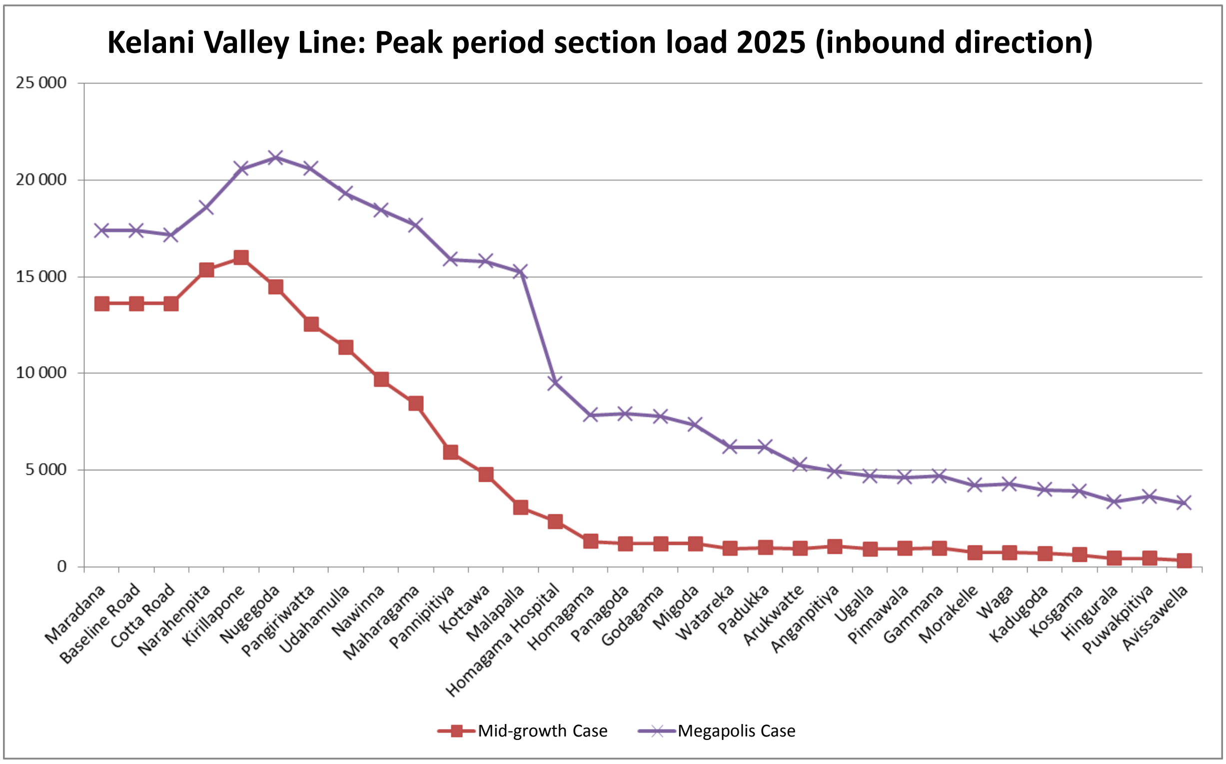


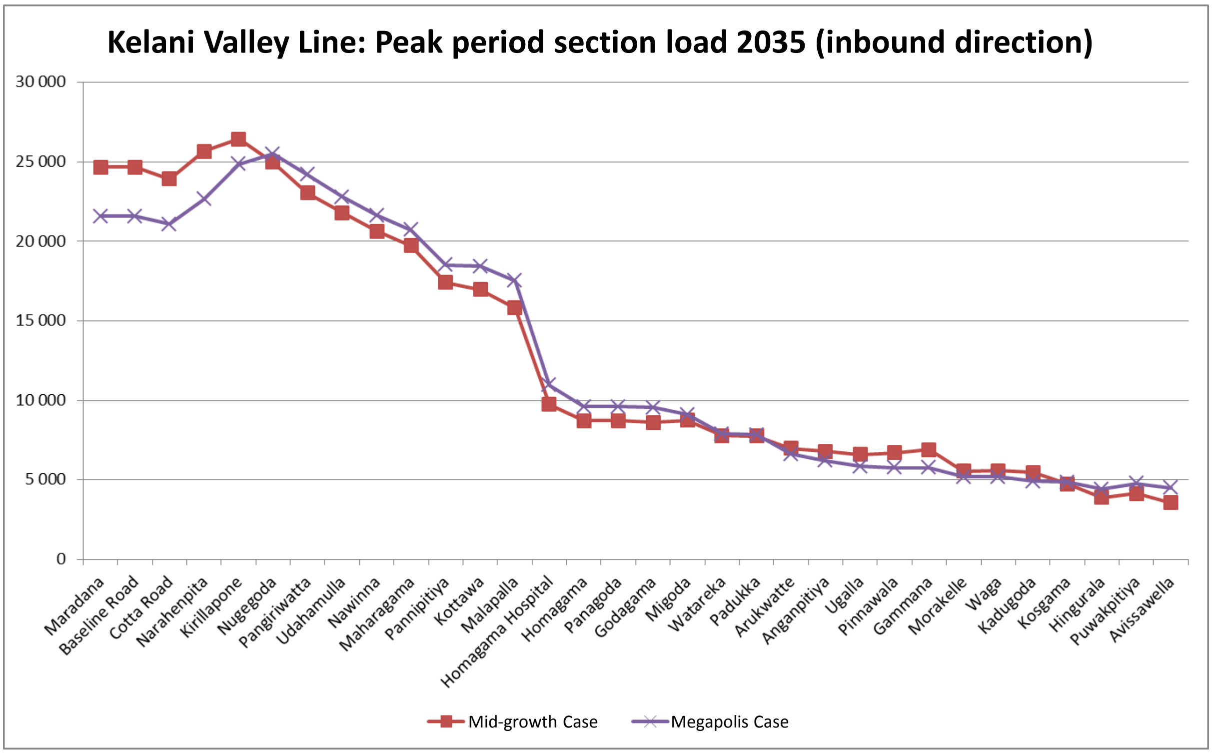
The comparison between the Megapolis case and the Mid-growth scenario is shown in the following table (for the peak hour in the peak direction) as well as is the following chart.

Table 4-3: Traffic load per section on KV line - Megapolis case and mid-growth scenario (peak hour traffic in the peak direction)

		Megapolis case		Mid-growth Case		*Delta 2025*	*Delta 2035*
From	To	2025	2035	2025	2035		
KELANI VALLEY LINE							
Maradana	Baseline Road	17,373	21,574	13,611	24,674	*-22%*	*14%*
Baseline Road	Cotta Road	17,159	21,075	13,614	23,913	*-21%*	*13%*
Cotta Road	Narahenpita	18,583	22,642	15,355	25,667	*-17%*	*13%*
Narahenpita	Kirillapone	20,577	24,849	15,985	26,438	*-22%*	*6%*
Kirillapone	Nugegoda	21,146	25,490	14,462	24,985	*-32%*	*-2%*
Nugegoda	Pangiriwatta	20,577	24,208	12,545	23,041	*-39%*	*-5%*
Pangiriwatta	Udahamulla	19,295	22,784	11,337	21,812	*-41%*	*-4%*
Udahamulla	Nawinna	18,441	21,645	9,688	20,647	*-47%*	*-5%*
Nawinna	Maharagama	17,658	20,719	8,432	19,721	*-52%*	*-5%*
Maharagama	Pannipitiya	15,878	18,512	5,899	17,419	*-63%*	*-6%*
Pannipitiya	Kottawa	15,806	18,441	4,777	16,959	*-70%*	*-8%*
Kottawa	Malapalla	15,237	17,515	3,058	15,804	*-80%*	*-10%*
Malapalla	Homagama Hospital	9,470	10,965	2,348	9,730	*-75%*	*-11%*
Homagama Hospital	Homagama	7,832	9,612	1,314	8,716	*-83%*	*-9%*

Figure 4-4: Comparison between Megapolis scenario and mid-growth scenario in 2025 & 2035





In 2025, the traffic for the mid-growth scenario is significantly lower than the Megapolis scenario (-46% in average on all sections).

- From Maradana to Kirillapone, the traffic is 20% lower than for the Megapolis Case;
- After Kirillapone, the traffic is dropping by 80%;
- Then, after Homagoma, the traffic for the mid-growth scenario is almost null compared to the Megapolis scenario.

All these differences can be explained by the absence of Kottawa – Horana extension and the non-improvement of KV line after Homagama.

Whereas in 2035, the traffic loads per section are very similar between the two scenarios. Indeed, the mid-growth scenario in 2035 includes the Kottawa – Horana extension as well as the improvement of KV line after 2025. The traffic is even higher on some sections with the mid-growth scenario than with Megapolis one:

- From Maradana to Kirillapone, the traffic is higher with the mid-growth scenario (from +6% to +14%),
- After Kirillapone, a decrease in the traffic is noticed for the mid-growth scenario compared to the Megapolis one.

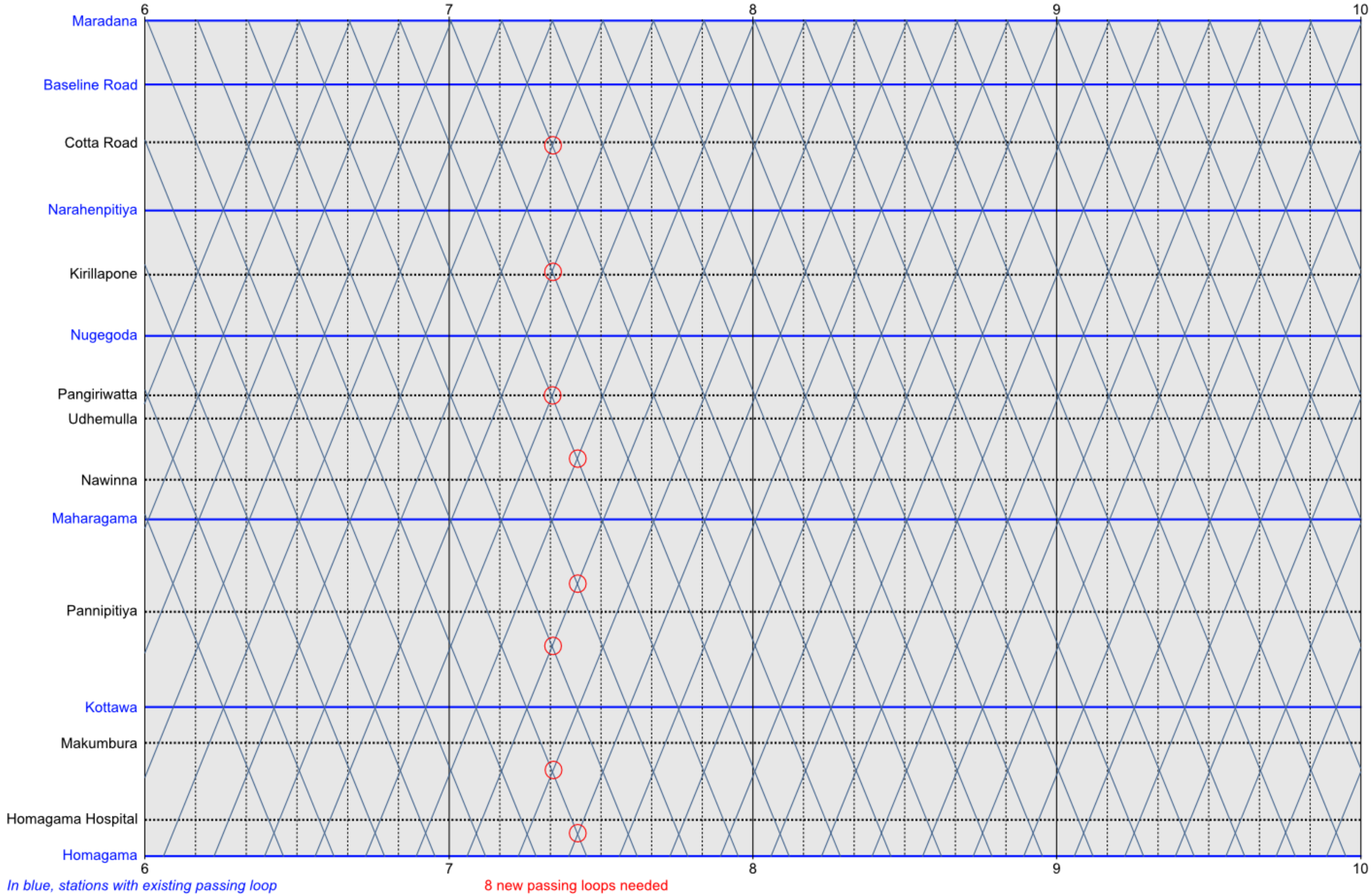
This slightly higher ridership for the mid-growth scenario in 2035 can be explained by the absence of some RTS lines in the mid-growth scenario. Passengers of KV line are shifting to other RTS lines in the Megapolis scenario.

4.2 ACCOMODATING THE FORECAST TRAFFIC

The traffic analysis shows a high potential for KV line and a need to increase the line capacity to handle the demand. Traffic forecasts estimate the minimum need of a 5 minutes headway, with possibly an even higher headway. Yet, increasing the frequency with the existing rolling stock fleet means trains need to run both directions during peak hour. However, developing both direction services in peak hour can prove to be difficult as there are only 6 passing loops at station.

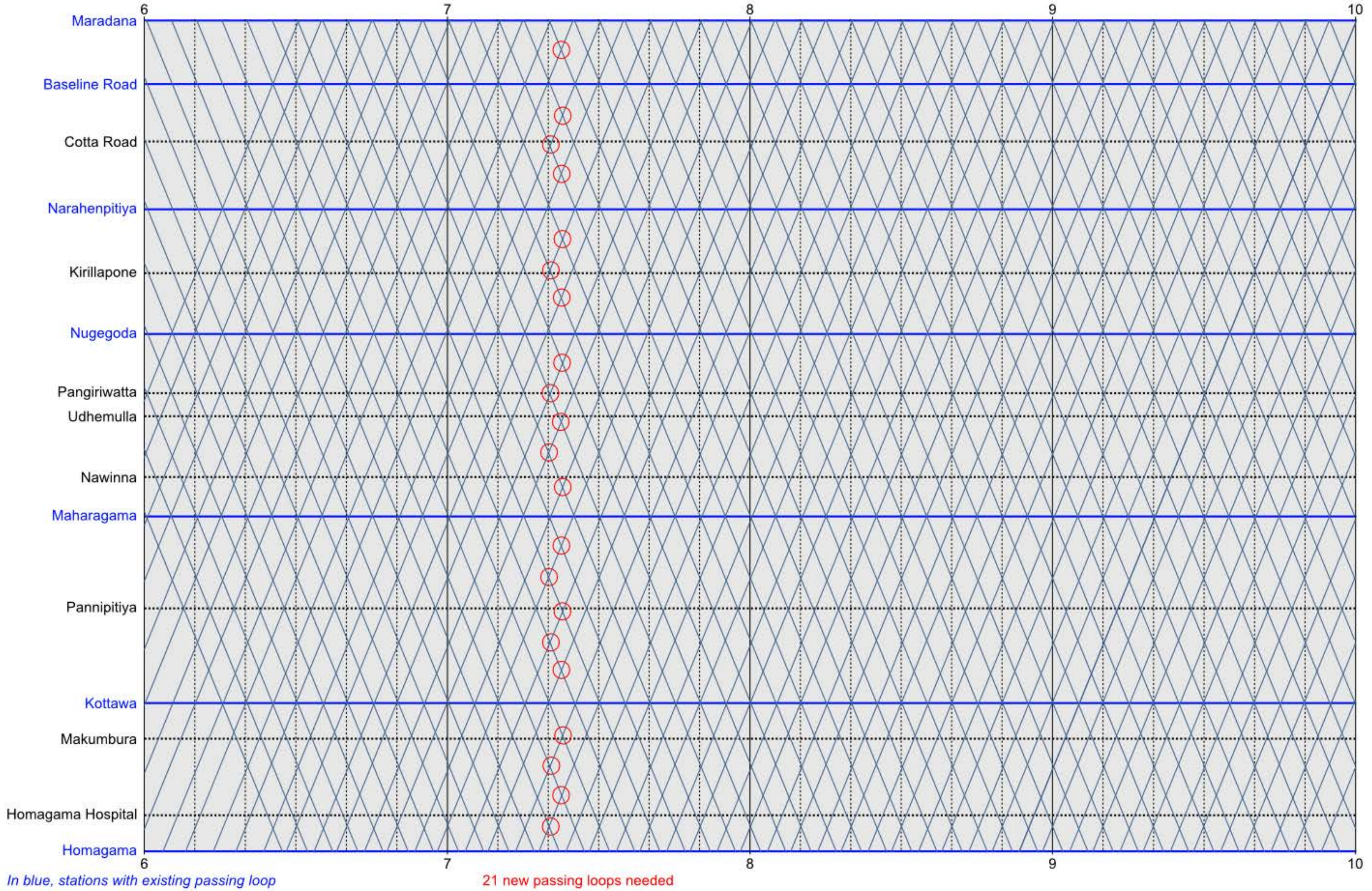
Using a theoretical headway of 10 min per direction, the train graph defines the needs of several additional passing loops, as shown below.

Figure 4-5: Need for additional passing loop for a 10 min headway service, both directions between 6:00 and 10:00am



egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

Figure 4-6 Need for additional passing loop for a 5 min headway service, both directions between 6:00 and 10:00am



egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

When the lines are crossing, this means the trains need to cross each other and thus a passing loop needs to be provided. Therefore 8 new passing loops may be justified to increase the headway to 10 minutes and 21 new ones for a 5 minutes headway. Even though, operations with such a track layout can be considered highly unstable as all delay from one train impacts all the other trains of the line.

For the 5 minutes headway, several passing loop need to be between stations, which means one train has to stop to let the other train pass. Commercial speed will therefore be reduced. Then, this hypothesis would lead to more than one passing loop per kilometre, which is more costly than double tracking as each passing loop requires two railroad switches..

4.3 KV LINE MAIN CONSTRAINTS AND OPPORTUNITIES

The diagnosis has highlighted several constraints limiting the development of the KV Lines:

- The line is with single track with few passing loops, and there is no room for dualling the track due to high urbanization / encroachment next to the existing line;
- The line geometry is really winding with short radius curves limiting the maximum authorised speed and thus affecting the operating speed which average 25 kmph;
- Numerous level crossing with 17 level crossing on high to very high traffic roads;
- Station platform lengths are short and can't accommodate long and more capacitive trains.

To develop the services on KV Line with increased headways and reduced travel time, several options have been considered:

- Dualling of the tracks, as the base case scenario;
- Improving the line geometry to ensure greater authorized speed at ground level;
- Eliminating level crossing;
- Introducing new technologies allowing higher speed with sharper curves;
- Increasing platform length. This option will be considered as a base case scenario.

The following paragraphs detail the different options and a multicriteria analysis is provided in Chapter 6.

egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

5 OPTIONS TO IMPROVE KV LINE OPERATIONS

5.1 REALIGNMENT TO INCREASE CURVE RADII

The first proposal considered is to realign the line to provide greater curves and speed. The Consultant identified the key sections where the speed constraints where very high, preventing the train from reaching 50 km/h (R200 mini) to 70 km/h (R300 mini)

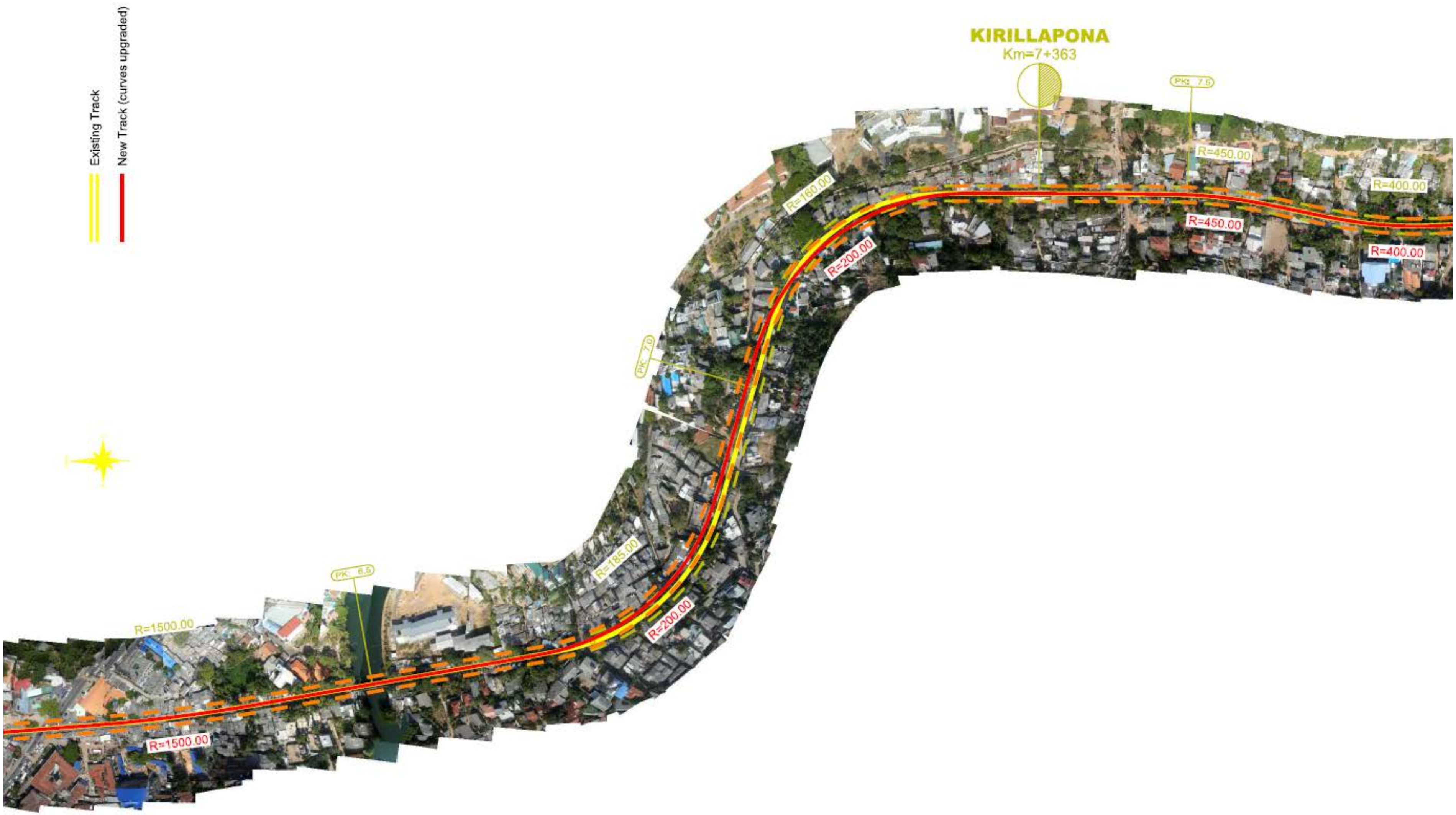
On the basis of aerial pictures provided for the study, the Consultant tested some options of realignment at critical sections of the existing alignment. Low radius curves near stations have not been considered as the train speed is de facto reduced when approaching / leaving the station.

The following table list the critical section, the proposed realignment and the travel time saved.

Sections	Test of realignment	Feasibility	Travel time saved
Near Kirrilapona, KP 6000 to 8000 2 curves with R160 and R185	Test of realignment at R200 mini	Moderate impacts on neighboring structures	10’
Near Maharagama, KP 14500 to 16000 5 consecutive curves at R165, R150, R200, R110 and R120	Test of realignment with 3 curves at R300, R300 and R500	High impacts on neighboring structures	30’
Near Pannipitiya, KP 16500 to 18500 4 consecutive curves at R120, R115, R125 and R120	Test of realignment at R200 minimum	High impacts on neighboring structures	**80’**
Near Kottawa, KP 17000 to 19500 5 consecutive curves at R125, R180, R125, R115 and R145	Test of realignment at R200 minimum	High impacts on neighboring structures	20’
Near Homogama, KP 21750 to 23250 8 consecutive curves at R130, R110, R130, R150, R120, R125, R120 and R120	Test of realignment at R200 minimum	Moderate impacts on neighboring structures	**120’**

The following figures show the track realignment proposals.

Figure 5-1: Realignment options on section from KP 6000 to 8000



egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

Figure 5-2: Realignment options on section from KP 14500 to 16000

egis
Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

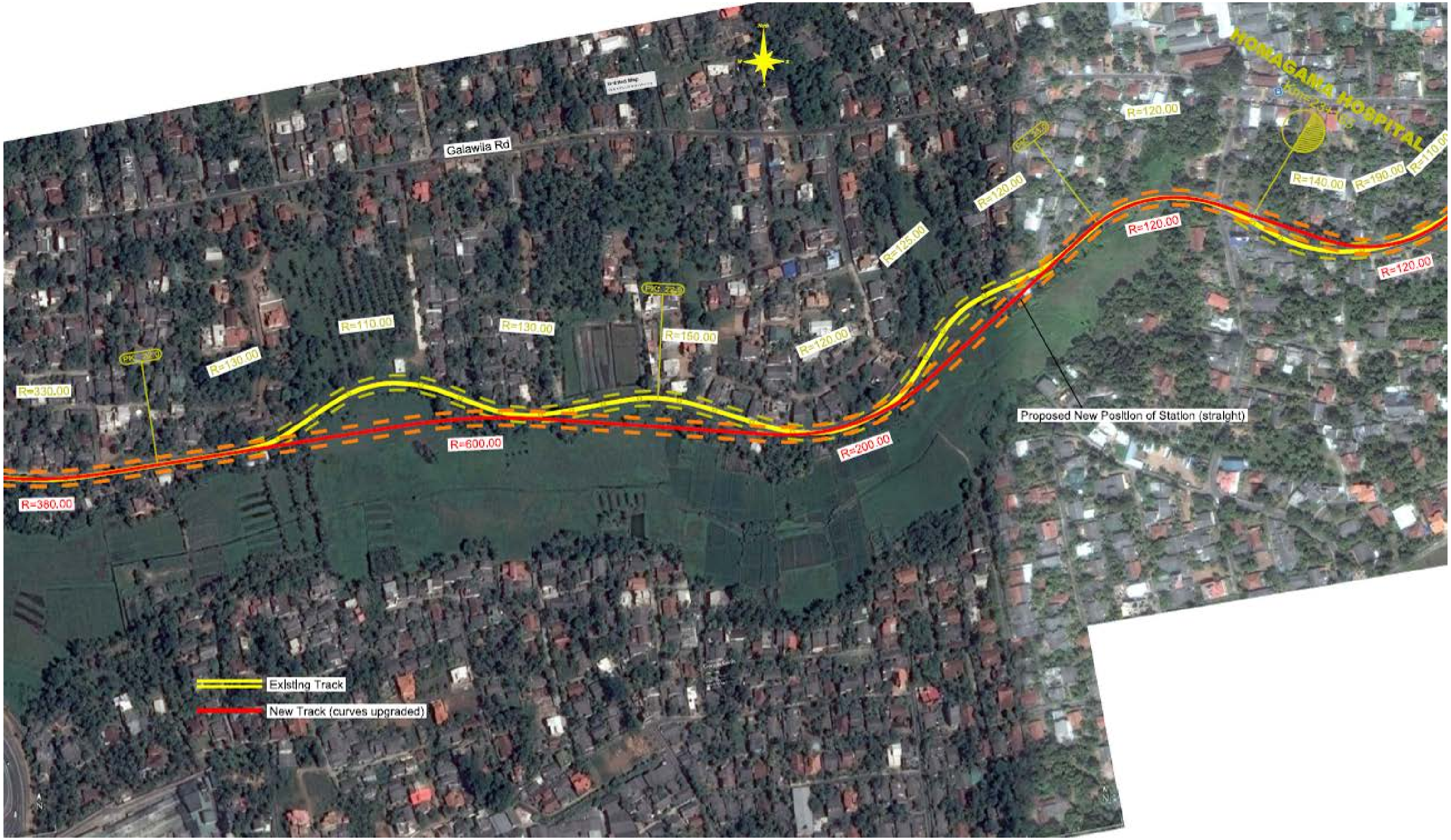
Figure 5-3: Realignment options on section from KP 16500 to 18500

egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

Figure 5-4: Realignment options on section from KP 18500 to 20000

egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

Figure 5-5: Realignment options on section from KP 22000 to 23500



egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

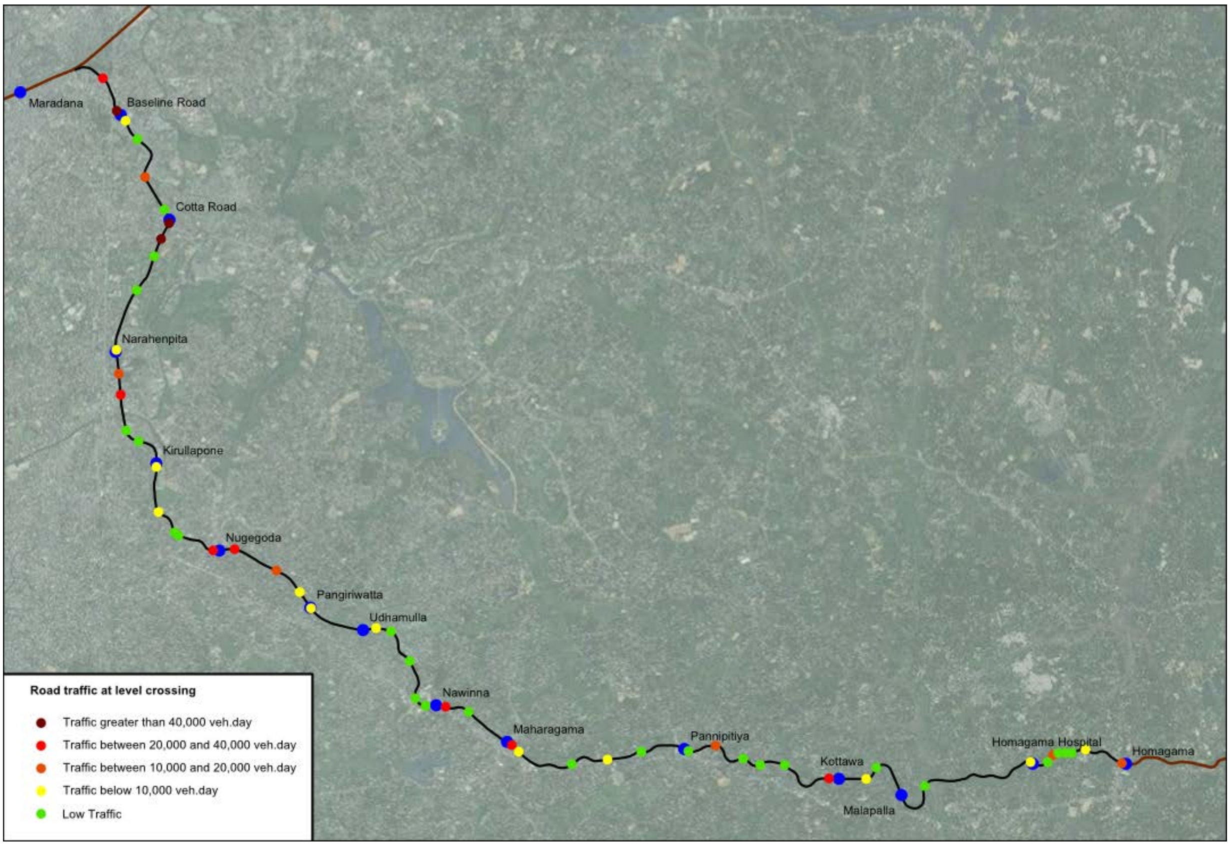
This realignment of the tracks would save 4 minutes and 20 seconds. Yet, it has a very high impact on the urbanization; it requires land acquisition and relocation in many sections. The cost of land acquisition and relocation and the time delay due to relocation and compensation is not compensated by the time saved. The consultant has abandoned this option as a viable option.

5.2 REMOVING OF LEVEL CROSSINGS

Another major operational constraint is the number of level crossings on the line. It affects both train operations and road traffic. With an expected headway towards 5 minutes in 2035, keeping level crossing would implies that the roads are closed half of the time, which can't happen on roads such as Baseline Road with a current daily traffic greater than 80,000 vehicles per day. Therefore, the Consultant has studied the 53 level crossing on KV lines to identify the ones where grade separation is essential and the ones that can be closed / diverted on adjacent flyovers.

The following figure shows the level crossings by traffic type. The level crossing with a low traffic will be closed / diverted and the other ones need to be upgraded into grade separation.

Figure 5-6: level crossings and road traffic



In total, 24 crossing may be closed / diverted and 29 need to be upgraded into grade separation.

The main option for grade separation is to create a road flyover. This requires a minimum distance of 70 m before and after the level crossing to allow the flyover to be 7m high as the railway line will be electrified. Yet, in a very densely urbanized and populated area, with a tight road network, it may be quite difficult and constrained to insert flyovers, especially when the level crossing is close to major junction such as in Kattiya Junction, between Old Kesbewa road and Mirihana road, the latest having currently 27,000 vehicles per day.

All pedestrian only crossing are closed and the railroad is fenced to prevent any crossing. All road flyovers include pedestrian access which means pedestrians can cross the railway line at least every kilometre.

5.3 GRADE SEPARATION OPTIONS

As the removing of level crossing may prove to be quite difficult, three options can be studied for grade separations:

- Railway at grade level with road flyovers;
- Elevated railway for full grade separation;
- Underground railway for full grade separation.

Yet, the construction costs for underground railway are very high and may not be justified regarding the urbanization context. Therefore, this option has not been studied by the Consultant.

5.3.1 Option 1 – Railway at grade

This option requires:

- The widening of the existing railway right of way to insert the second tracks;
- 29 flyovers to remove level crossings;
- The realignment of the line in Colombo Golf Club green as, with an increased frequency, the pedestrian – rail conflict will be too high to be acceptable.

5.3.1.1 Widening of the railway right of way

The current right of way is 9m wide. To insert a second track, 5 additional meters are required. This means the acquisition of 180,000 m².

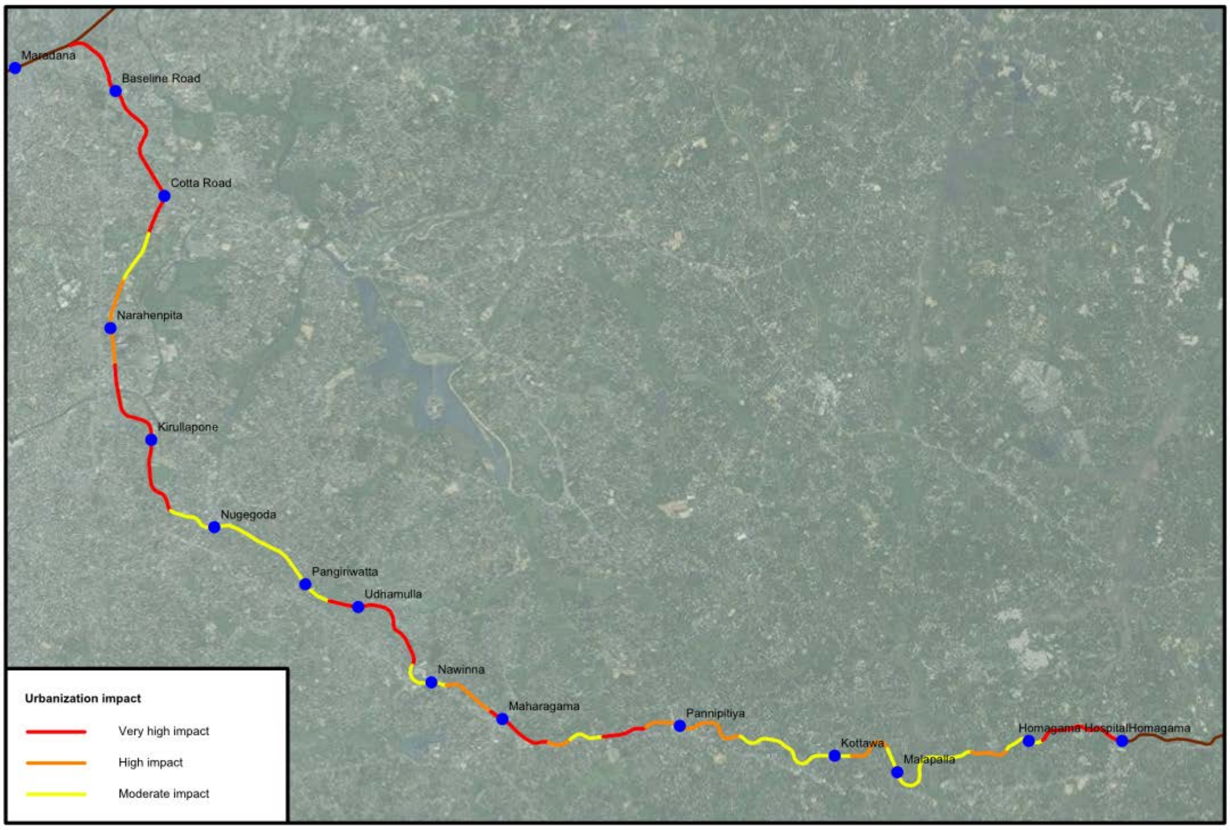
Yet, this is affecting a densely urbanized area and the needed right of way is impacting existing building. This means resettlement and compensation will be required.

UN-Habitat[2] is currently surveying a buffer of 20 m centred on KV line tracks to estimate the affected population, commerce and institutions. As the results are yet to come, the Consultant could not use them for this pre-feasibility study, but they will be highly useful for further stages of the study.

In the absence of detailed data, a provision for relocation and compensation has been taken into account in the cost estimates.

The impact is very high on the Maradana – Nugegoda section, high on Nugegda – Pannipitiya section and moderate on Pannipitiya – Homagama section, as shown on the following figure.

Figure 5-7: Impact on urbanization



5.3.1.2 Removing of level crossings

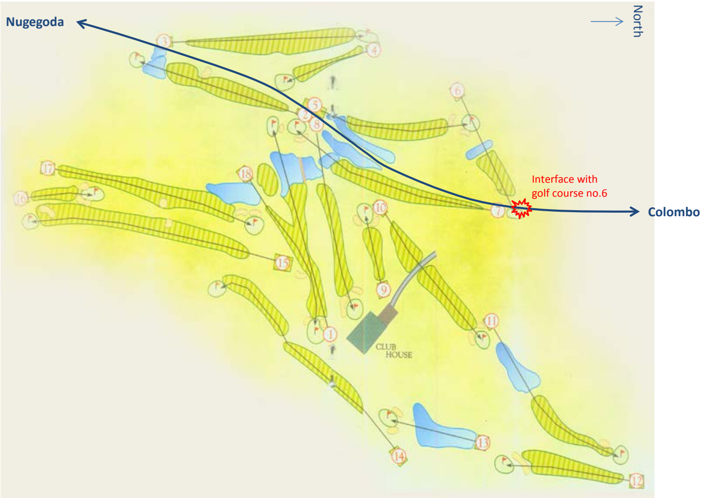
29 level crossings would be affected and need to be replaced by a flyover.

5.3.1.3 Re-routing next to Royal Colombo Golf Club Green

[2] UN–Habitat is the United Nations agency for human settlements and sustainable urban development.

Due to the major increase of service on the line (in average one train every two minutes and a half), the section within the Royal Colombo Golf Club section needs to be reviewed to reduce existing conflict of usage between the railway and the golf.

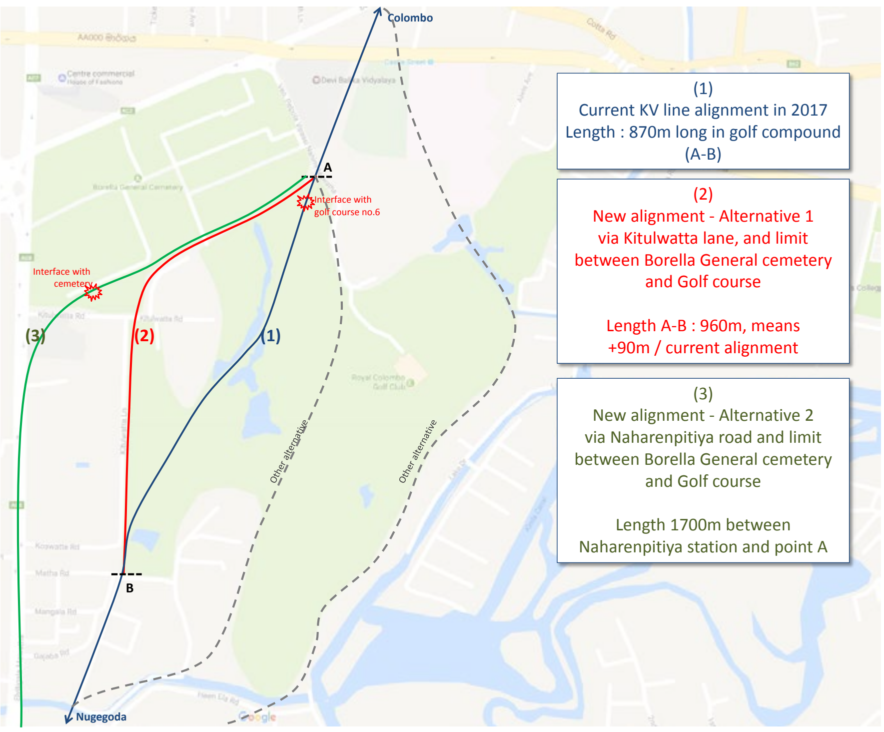
Figure 5-8: Location of the railway line inside the Royal Colombo Golf Club



Several options can be developed:

- Re-routing the railway line outside of the Golf, with several alignment options (see below);
- Elevating the railway within the Golf Green;
- Creating underpasses for golf players.

Figure 5-9: Realignment options inside the Royal Colombo Golf Club



In terms of operations, the re-routing options would imply an additional time of 10 seconds for alternative 2 and 1 minute and 40 seconds for alternative 3.

5.3.2 Option 2 – Elevated railway

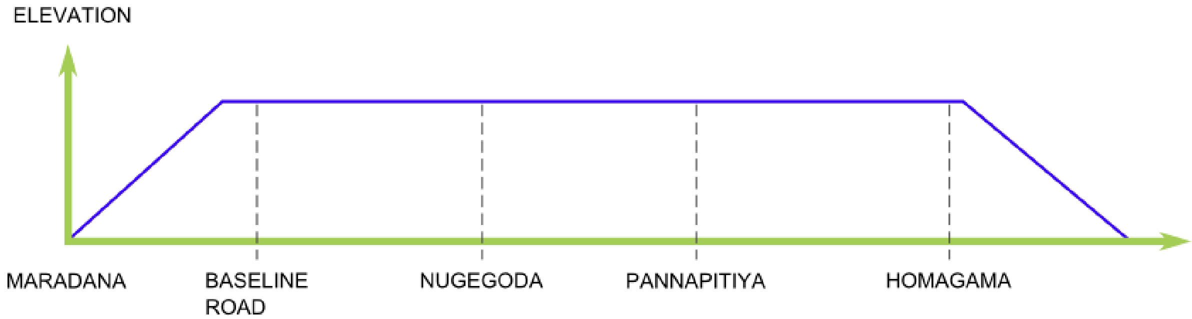
Two options have been studied for railway elevation: fully elevated from Maradana to Homagama or partially elevated, with an elevated section from Maradana to Nugegoda or Pannipitiya and at grade railway after with removal of level crossings.

The proposed viaduct height will be estimated during the design phase, depending on the operational and insertion constraints. When crossing roads, there should be a minimum clearance of 5m to allow all kind of traffic.

The following paragraphs summarize the different elevation options.

5.3.2.1 Option 2a – fully elevated railway

In such case, the line is placed onto a 23.8-km long viaduct with double tracks. Stations and rail line are elevated. It enables punctual or significant modification of the alignment, reducing in such manner the winding configuration of the line, helping improve the applied maximum speeds (better running time and average commercial speed and, as a result, a reduced fleet size).

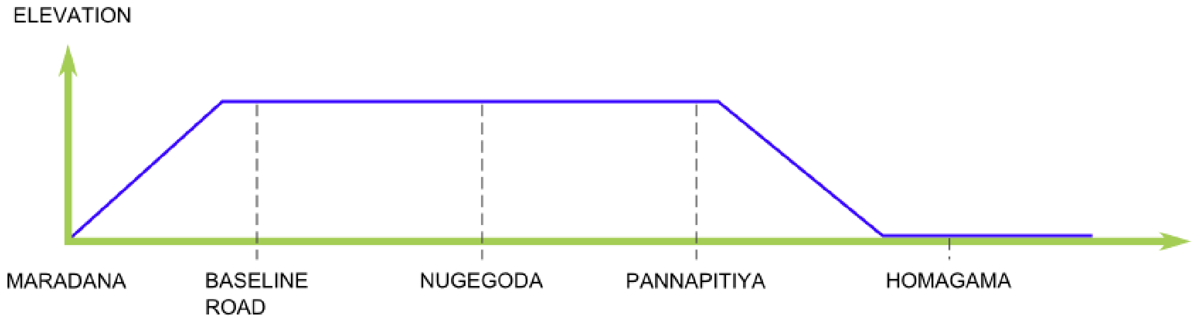


The viaduct will come over existing buildings. It has been considered that acquisition and ressetlment was required for all buiding affected by the viaduct. The total land to acquire is 46,000 m². Provision for relocation and compensation has been taken into account in the cost estimates..

5.3.2.2 Option 2b – partially elevated railway until Pannipitiya

The viaduct length is reduced to 16.8 km to cover the densely urbanized area. After Pannipitiya and Pannipitiya – Malabe Road, the railroad is kept at grade but upgraded with double tracks. 6 flyovers are created to replace removed level crossing.

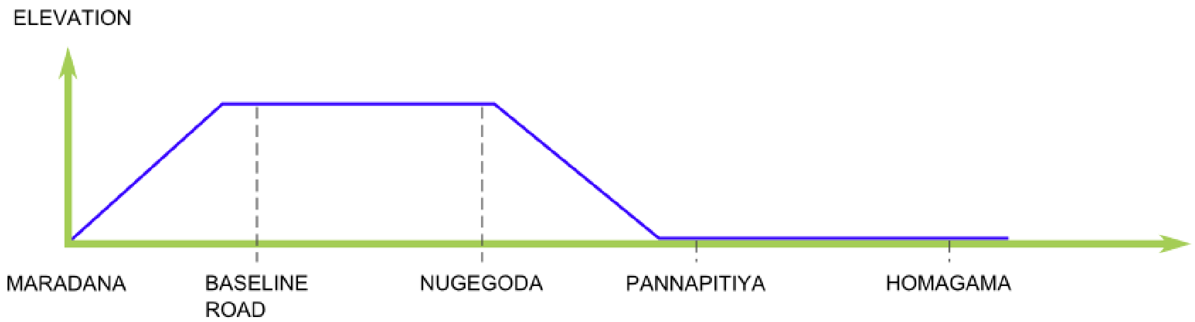
The viaduct will come over existing building and the at-grade railway will require a wider right of way. It has been considered that land acquisition and ressetlment was required for all buiding affected by the viaduct and full land acquisition for the at-grade railway. The total land to acquire is 108,000 m². Provision for relocation and compensation has been taken into account in the cost estimates.



5.3.2.3 Option 2c – partially elevated railway until Nugegoda

The viaduct length is reduced to 8.6 km to cover the highly densely urbanized area. After Nugegoda and Mirihana Road, the railroad is kept at grade but upgraded with double tracks. 15 flyovers are created to replace removed level crossing.

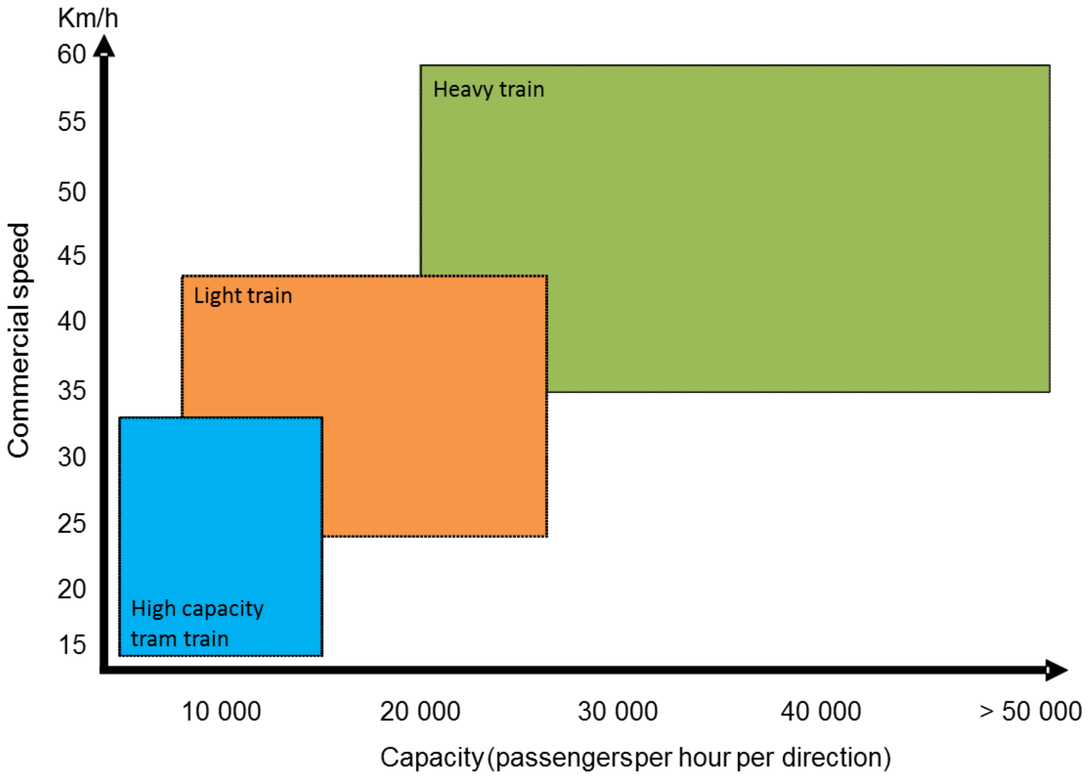
The viaduct will come over existing building and the at-grade railway will require a wider right of way. It has been considered that acquisition and ressetlment was required for all buiding affected by the viaduct and full land acquisition for the at-grade railway. The total land to acquire is 145,000 m². Provision for relocation and compensation has been taken into account in the cost estimates.



5.4 TECHNOLOGY OPTIONS

The line is currently developed as a heavy rail line, which has some operational impact such as low dynamic performance (low acceleration due to the heavy rail rolling stock inertia) and reduced performance with sharp curves as heavy rail rolling stock cannot handle sharp curve at high speed. As the KV Line has a short inter-station distance and many sharp curves, the Consultant estimated the opportunity to change the technology for a lighter one that may be more appropriate.

The capacity handled by the different technologies differs greatly and the proposed technologies shall accommodate the forecast traffic. The following figure shows the capacity range provided by the different rail technologies.



The traffic forecasts expect a maximum needed capacity of 26 000 PPHPD in 2035. Therefore, the high capacity tram-train technology is not suitable as not enough capacitive.

The light rail can accommodate the traffic with high frequencies and high capacity rolling stock. This means that there is little room for any traffic increase after 2035. Only the heavy rail technology can easily accommodate the expected traffic providing a sustainable solution.

Two technology options have been studied:

- Heavy rail;
- Light rail.

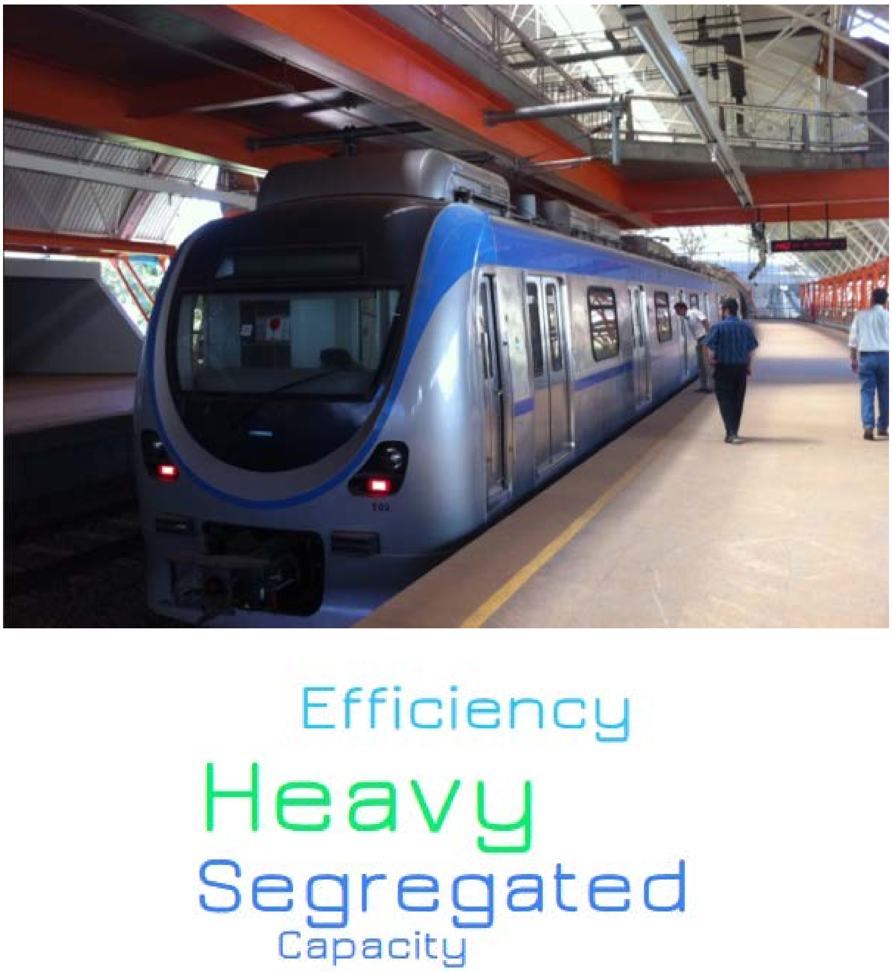
The following paragraphs describe the two options and their impact on train operation.

5.4.1 Option 1 – Heavy rail

5.4.1.1 Technical characteristics

Heavy rail is the continuum of the existing system. It offers the advantage of ensuring full compatibility and interoperability with all railway operations, especially if freight services have to be considered on the KV line. Rolling stock can be shared with the other suburban railway lines and can offer capacities ranging from 30 000 to 60 000 persons per hour and per direction (PPHPD).

Figure 5-10: Heavy train concept



The following table summarizes the main technical features for heavy rail.

Table 5-1: heavy rail line characteristics

Maximum speed	160 km/h
Max capacity of system	60 000 PPHPD
Shortest headway	2 minutes
Track gauge	Broad gauge, possibility for narrow and standard roads
Transport system width for double tracks	14m considering pedestrian safety gauge
Alignment type	Fully grade separated is recommended. However, it is possible to keep some sections at-grade
Power supply	25 kV AC Reinforced catenary, use of feeder
Minimal horizontal curve radius	100m
Maximal vertical gradient	3.5%

Table 5-2: heavy rail rolling stock characteristics

Dimensions	Length: 160 m Width: 3.2 m Floor level: 900 mm
Maximum capacity provided by system	3 000 passengers per train per direction
Axle load	20-22t / axle
Composition-type	Coupling of single unit possible
Signaling – driving mode	Manually driven, block signaling at any speed
Dynamic performance	- Service acceleration: 0.65-0.85 m/s² - Service braking: 1.0 m/s²

5.4.1.2 Typical cross sections on open route (at-grade and elevated, straight and in curve)

Figure 5-11: Typical cross section at-grade and straight, for Heavy Train

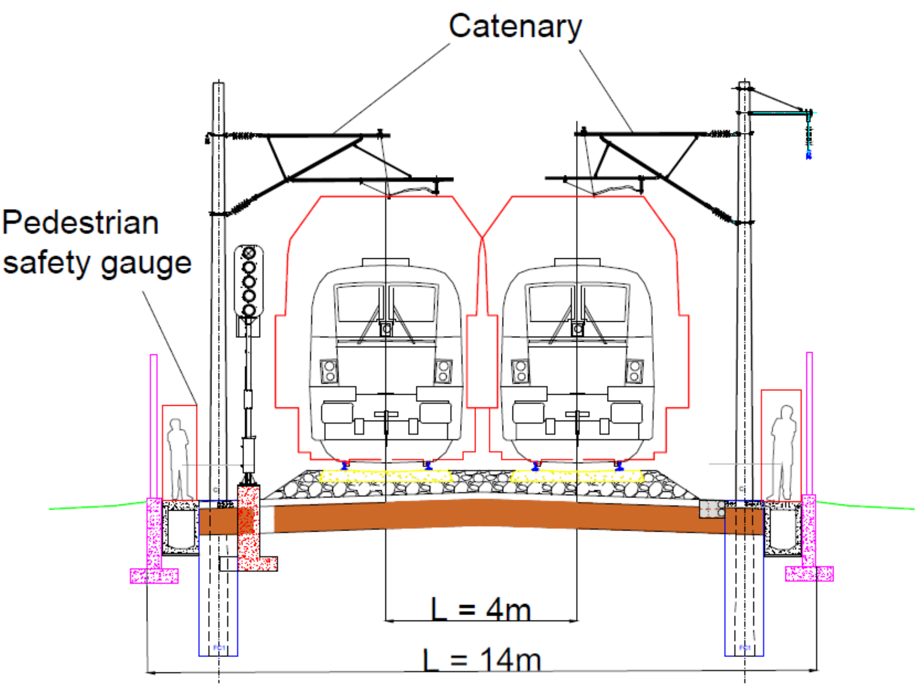


Figure 5-12: Typical cross section at-grade and in curve, for Heavy Train

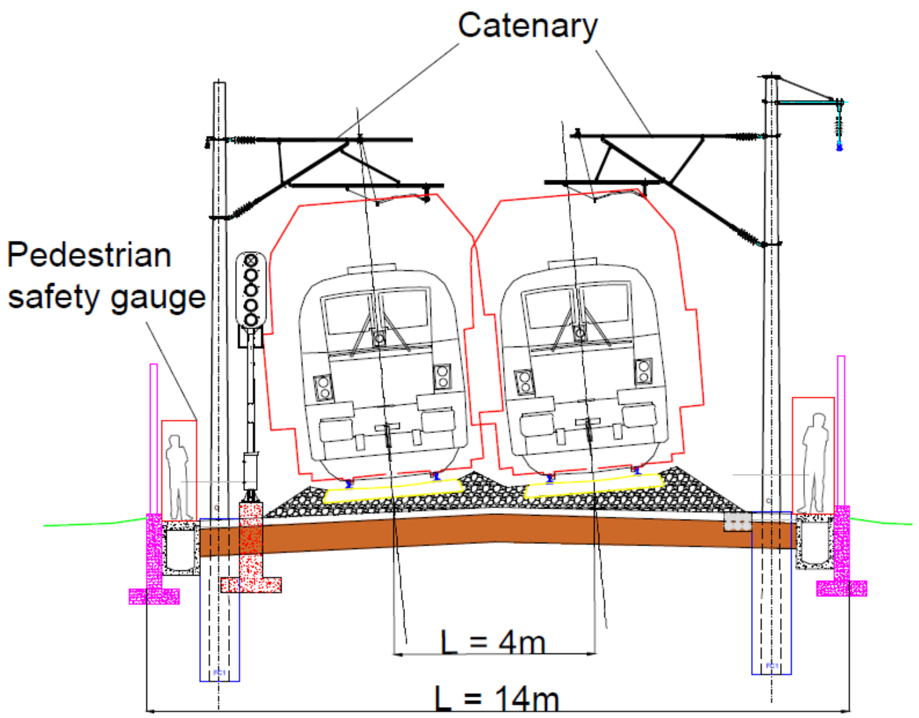


Figure 5-13: Typical cross section elevated and straight, for Heavy Train

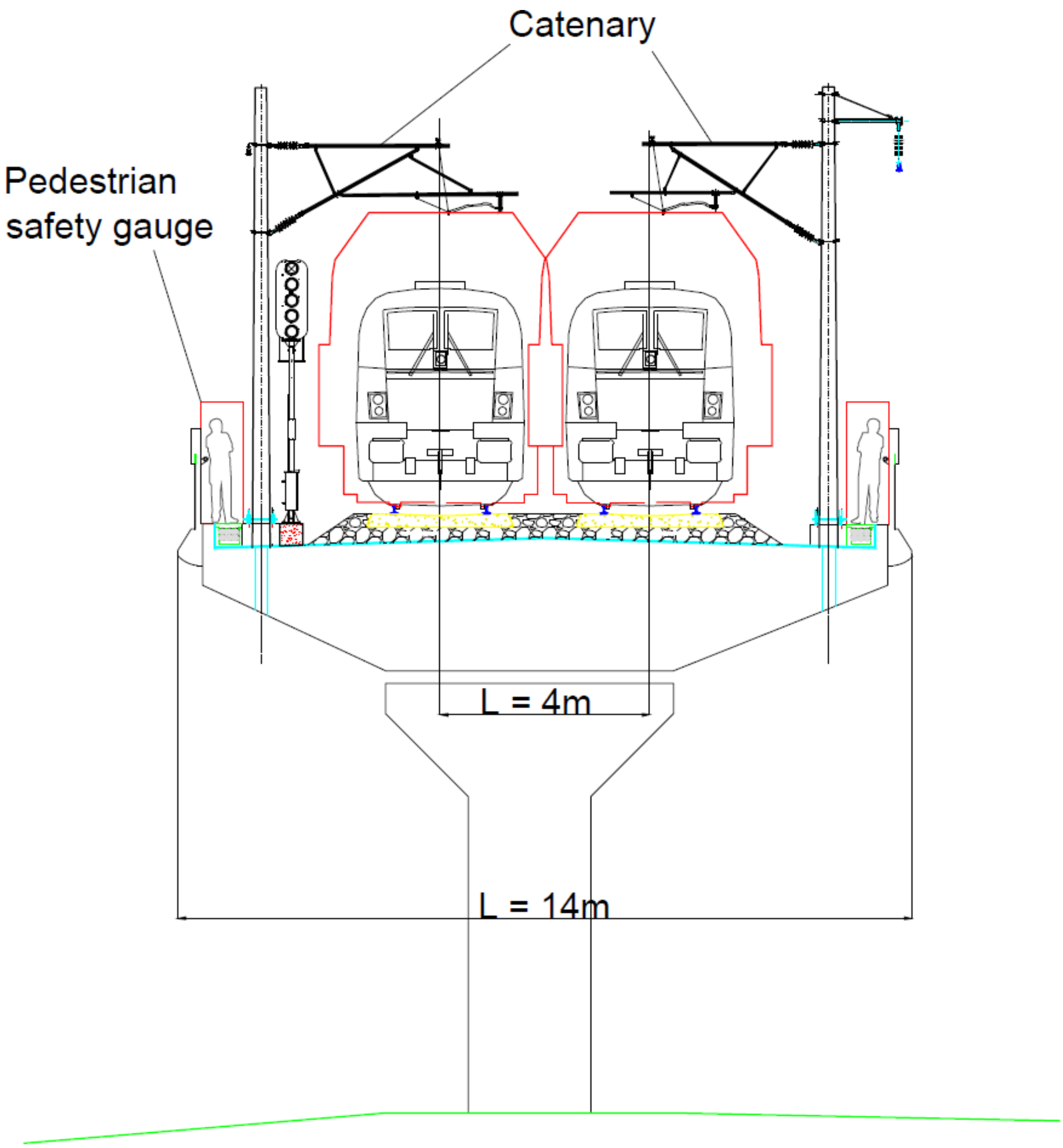
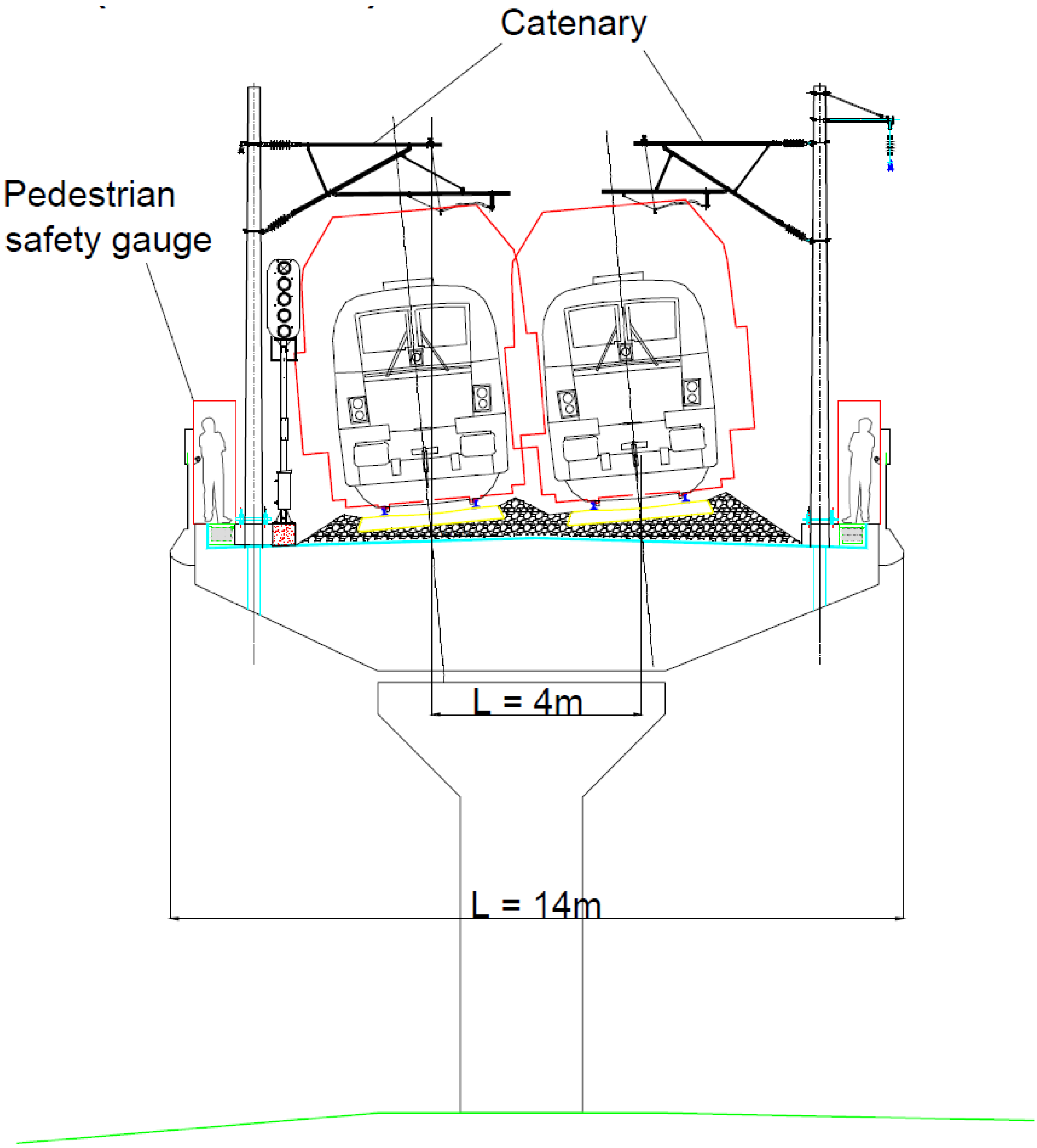


Figure 5-14: Typical cross section elevated and straight, for Heavy Train



5.4.1.3 Operational performance – with current situation

The run time calculation is done for a typical heavy train with the technical features given above. It is performed with Egis own software (Sim-One), integrating both detailed elements of infrastructure (curves and gradients) and train dynamic performances.

It is important to note that narrow curves have a direct impact on potential maximum commercial speed. As a consequence, numerous "speed wells" are identified all along the path, due to the repetition of small curves, with indicated speed steps

Radius (m)	Max speed (km/h)
120m	30
140m	30
160m	40
240m	60
300m	70
320m	70
480m	90
560m	90

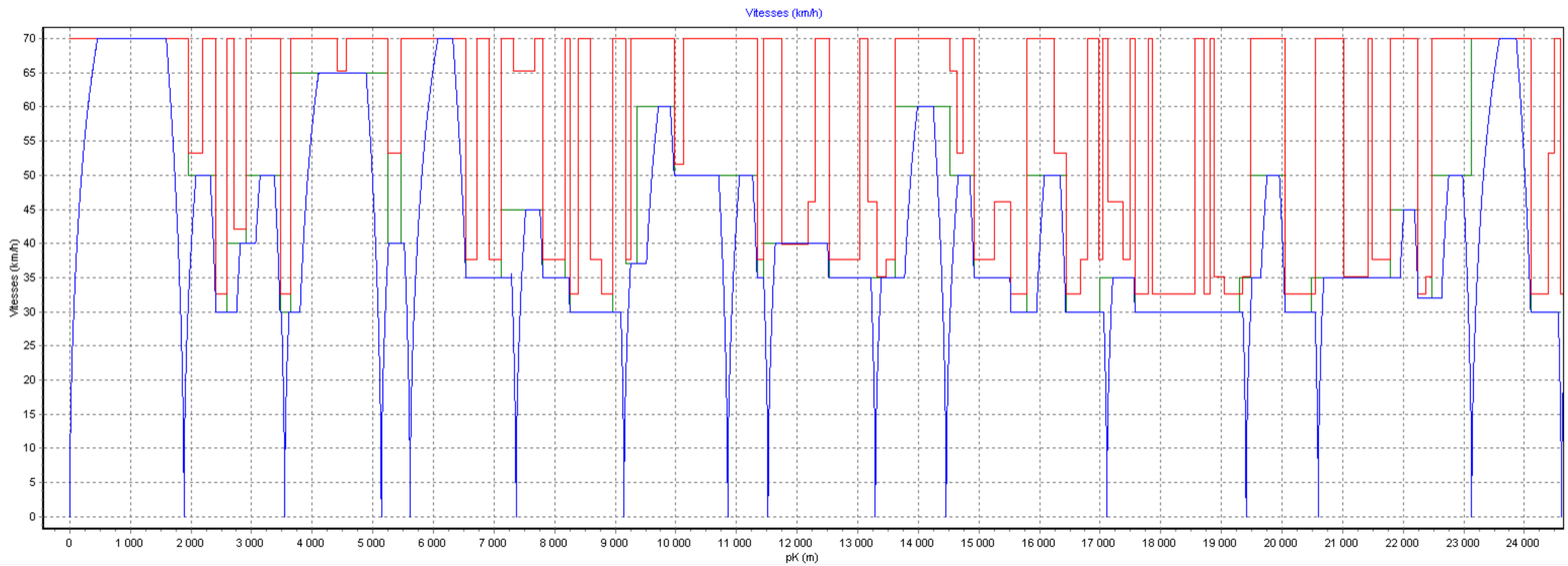
In 2016, for the interim report of "Colombo suburban railway project", a first run time approach has been made for the suburban train, compiling best performances of all 3 rolling stocks (acceleration and braking, maximum speed).

The following speed distance diagram shows the running of train taking into account the current alignment, with speed limits imposed by narrow curves, as well as permanent speed limits (input from Sri Lankan railways). This diagram represents the optimum possible speed profile, complemented by smooth-over of train.

5.4.1.4 *Speed-distance diagram*

The following simulation is pessimistic because considering a stop at Manning Town (technical sub-station):

Blue: Optimum speed profile / **Red**: speed limit of infrastructure + speed restrictions / **Green**: Proposed smooth-over of speed



egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

5.4.1.5 Journey Time table

<u>Journey Timetable: Maradana – Homagama : Heavy train stopping at all stations</u>

The estimated commercial speed is 29.0 kmph. Regulation time and margin have been taken into account to ensure a realistic timetable.

N°	Stations	Cumulative distance (m)	distance between stations (m)	Cummulative run time (sec)	run time between stations (sec)	Regulation time (sec)	*Optional additional margin (sec)*	Total time between station with margin	Speed (km/h)	Dwell time at stations (sec)	Arrival time	Departure time
1	Maradana	0		0								0:00:00
2	Baseline Road	1884	1884	131	131	6.6	*6.6*	2min24sec	47.0	30	0:02:18	0:02:48
3	Cotta Road	3545	1661	301	170	8.5	*8.5*	3min7sec	32.0	30	0:05:46	0:06:16
4	Manning Road	5140	1595	434	133	6.6	*6.6*	2min26sec	39.3	30	0:08:36	0:09:06
5	Naharenpita	5615	475	495	61	3.1	*3.1*	1min7sec	25.4	30	0:10:10	0:10:40
6	Kirillapone	7363	1748	658	163	8.1	*8.1*	2min59sec	35.1	30	0:13:31	0:14:01
7	Nugegoda	9145	1782	866	208	10.4	*10.4*	3min49sec	28.0	30	0:17:39	0:18:09
8	Pangiriwatta	10855	1710	1016	150	7.5	*7.5*	2min45sec	37.3	30	0:20:47	0:21:17
9	Udahamulla	11521	666	1092	76	3.8	*3.8*	1min24sec	28.7	30	0:22:37	0:23:07
10	Nawinna	13291	1770	1279	187	9.4	*9.4*	3min26sec	31.0	30	0:26:23	0:26:53
11	Maharagama	14460	1169	1395	116	5.8	*5.8*	2min8sec	33.0	30	0:28:55	0:29:25
12	Pannipitiya	17112	2652	1683	288	14.4	*14.4*	5min17sec	30.1	30	0:34:27	0:34:57
13	Kottawa	19408	2296	1966	283	14.2	*14.2*	5min11sec	26.5	30	0:39:54	0:40:24
14	Malapalla	20798	1390	2105	139	6.9	*6.9*	2min33sec	32.7	30	0:42:50	0:43:20
15	Homagoma Hospital	23130	2332	2370	265	13.3	*13.3*	4min52sec	28.8	30	0:47:59	0:48:29
16	Homagoma	24610	1480	2511	141	7.1	*7.1*	2min35sec	34.3	30	0:50:57	

Total time	0:50:57
Average commercial speed	29.0

egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road, Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

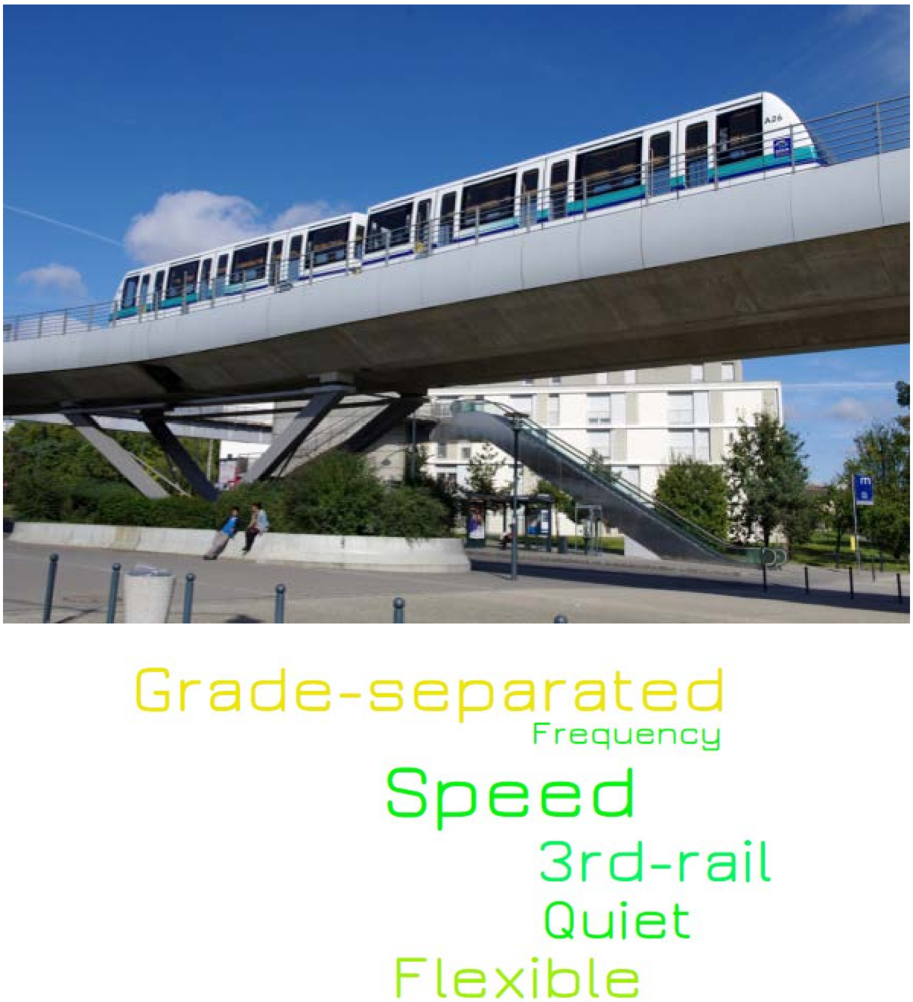
5.4.2 Option 2 – Light rail

5.4.2.1 Technical characteristics

Light rail is a grade-separated solution that can be run by a driver with block signaling or automated, and is fed by third rail. All along the track, the necessary right-of-way is higher for construction purpose and the full segregation is ensuring a high level of safety. Light rail is able to climb steeper grades and turn tighter curves than heavy rail, thus allowing flexible alignments, and has a lower running noise. With rapid acceleration/deceleration, its capacity can reach 25 000 to 30 000 PPHPD.

Considering the line goes up to Avissawella, it does not make sense to pursue the line as elevated up to the final destination. Thus, the system shall be hybridized for the purpose of compatibility with the existing railway line beyond Homagama to Avissawella.

Figure 5-15: Light train concept



Compatibility with the existing railway network will prove to be more difficult on the Maradana – Homagoma section as light rail requirements are different than heavy rails. It might restrain freight operations, impact the Kottawa – Horana extension and prevent use of the rolling stock of the other commuter rail lines.

The following table summarizes the main technical features for light rail.

Table 5-3: light rail line characteristics

Maximum speed	100 km/h
Max capacity of system	30 000 PPHPD
Shortest headway	2 minutes
Track gauge	Standard gauge only, no broad gauge
Transport system width for double tracks	12m considering pedestrian safety gauge
Alignment type	Fully grade separated
Power supply	25kV AC Reinforced catenary, use of feeder
Minimal horizontal curve radius	50m
Maximal vertical gradient	3% (recommended), exceptionally 5%

Table 5-4: light rail rolling stock characteristics

Dimensions	Length: 120m Width: 2.5-2.7m Floor level: 450mm
Maximum capacity provided by system	2 000 passengers per train per direction
Axle load	12.5-14t / axle
Composition-type	Coupling of single unit possible
Signalling – driving mode	Manually driven, block signalling at any speed Can be automated
Dynamic performance	- Service acceleration : 1.2 m/s² - Service braking : 1.2 m/s²

5.4.2.2 *Typical cross sections on open route (OCS central or lateral, straight and in curve)*

Figure 5-16: Typical cross section with lateral OCS and straight, for Light Train

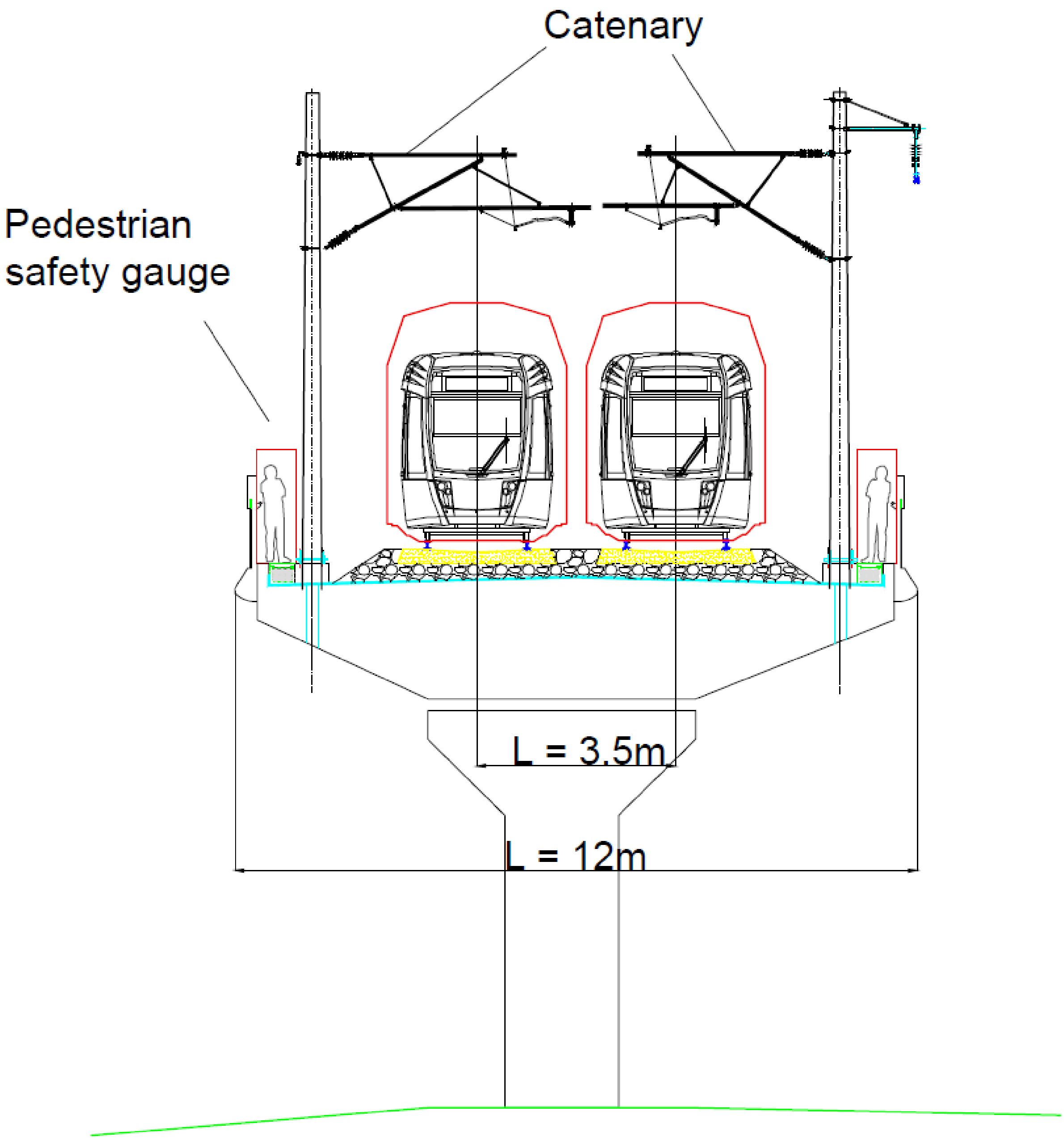
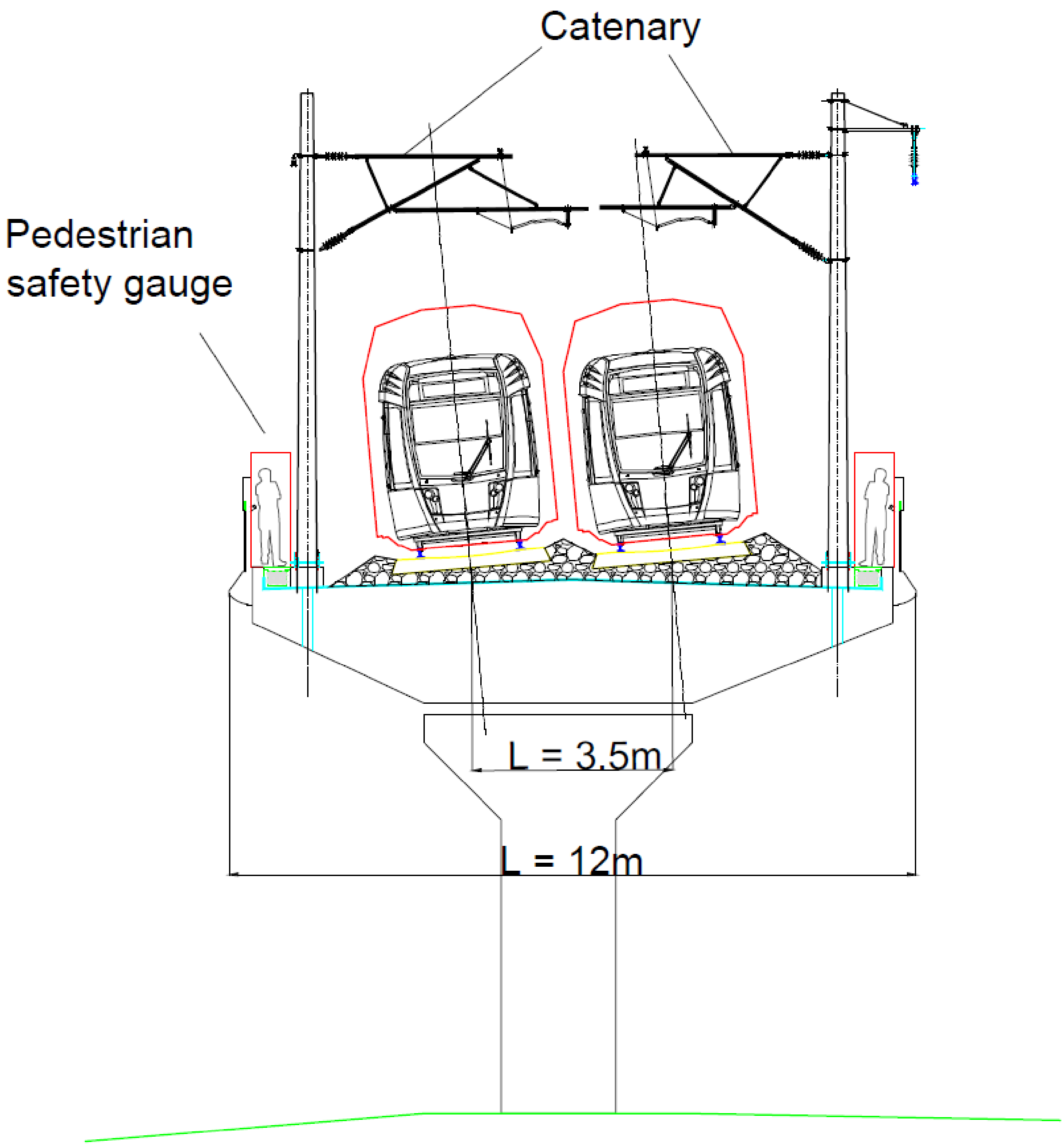


Figure 5-17: Typical cross section with lateral OCS and in curve, for Light Train



5.4.2.3 Operational performance – with current situation

The run time calculation is done for a typical Light train with the technical features given above. It is performed with Egis own software (Sim-One), integrating both detailed elements of infrastructure (curves and gradients) and train dynamic performances.

It is important to note that narrow curves have a direct impact on potential maximum commercial speed. As a consequence, numerous “speed wells” are identified all along the path, due to the repetition of small curves, with indicated speed steps

Radius (m)	Max speed (km/h)
120m	30
140m	30
160m	40
240m	60
300m	70
320m	70
480m	90
560m	90

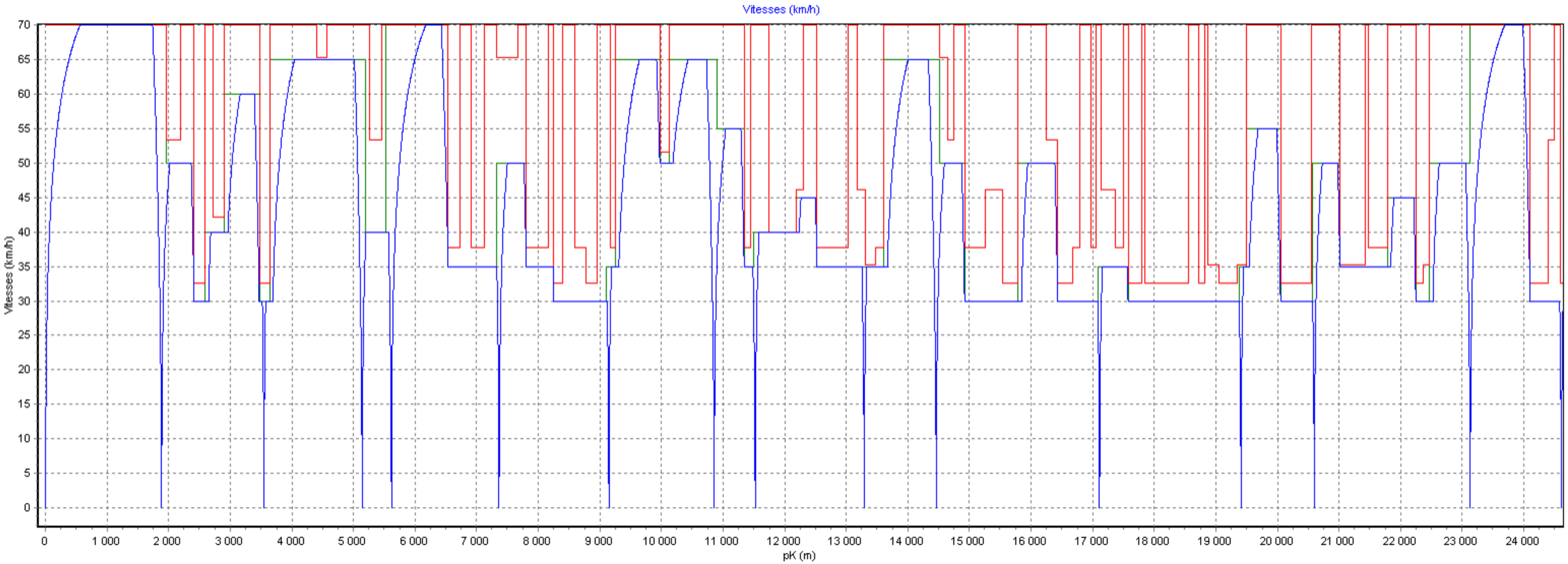
In 2016, for the interim report of “Colombo suburban railway project”, a first run time approach has been made for the suburban train, compiling best performances of all 3 rolling stocks (acceleration and braking, maximum speed).

The following speed distance diagram shows the running of train taking into account the current alignment, with speed limits imposed by narrow curves, as well as permanent speed limits (input from Sri Lankan railways). This diagram represents the optimum possible speed profile, complemented by smooth-over of train.

5.4.2.4 Speed-distance diagram

The following simulation is pessimistic because considering a stop at Manning Town (technical sub-station):

Blue: Optimum speed profile / **Red**: speed limit of infrastructure + speed restrictions / **Green**: Proposed smooth-over of speed



egis RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road, Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

5.4.2.5 Journey Time table

Journey Timetable: Maradana – Homagama : Light-train stopping at all stations

The estimated commercial speed is 31.5 kmph. Regulation time and margin have been taken into account to ensure a realistic timetable.

N°	Stations	Cumulative distance (m)	distance between stations (m)	Cummulative run time (sec)	run time between stations (sec)	Regulation time (sec)	*Optional additional margin (sec)*	Total time between station with margin	Speed (km/h)	Dwell time at stations (sec)	Arrival time	Departure time
1	Maradana	0		0								0:00:00
2	Baseline Road	1884	1884	116	116	5.8	*5.8*	2min8sec	53.2	30	0:02:02	0:02:32
3	Cotta Road	3545	1661	265	149	7.4	*7.4*	2min44sec	36.5	30	0:05:08	0:05:38
4	Manning Road	5140	1595	378	113	5.6	*5.6*	2min4sec	46.2	30	0:07:37	0:08:07
5	Naharenpita	5615	475	429	51	2.6	*2.6*	0min56sec	30.4	30	0:09:00	0:09:30
6	Kirillapone	7363	1748	579	150	7.5	*7.5*	2min45sec	38.1	30	0:12:08	0:12:38
7	Nugegoda	9145	1782	774	195	9.8	*9.8*	3min35sec	29.9	30	0:16:03	0:16:33
8	Pangiriwatta	10855	1710	897	123	6.1	*6.1*	2min15sec	45.5	30	0:18:42	0:19:12
9	Udahamulla	11521	666	959	62	3.1	*3.1*	1min8sec	35.2	30	0:20:17	0:20:47
10	Nawinna	13291	1770	1134	175	8.8	*8.8*	3min13sec	33.1	30	0:23:51	0:24:21
11	Maharagama	14460	1169	1231	97	4.9	*4.9*	1min47sec	39.4	30	0:26:03	0:26:33
12	Pannipitiya	17112	2652	1512	281	14.0	*14.0*	5min9sec	30.9	30	0:31:28	0:31:58
13	Kottawa	19408	2296	1787	275	13.7	*13.7*	5min2sec	27.3	30	0:36:46	0:37:16
14	Malapalla	20798	1390	1910	123	6.1	*6.1*	2min15sec	37.0	30	0:39:25	0:39:55
15	Homagoma Hospital	23130	2332	2149	239	12.0	*12.0*	4min23sec	31.9	30	0:44:06	0:44:36
16	Homagoma	24610	1480	2277	128	6.4	*6.4*	2min21sec	37.8	30	0:46:51	

Total time	0:46:51
Average commercial speed	31.5

egis RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road, Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

5.4.3 Impact on traffic forecast

Based on the characteristics of the different technology options, we estimated the expected impact on the forecast traffic. This sensitivity analysis takes into account:

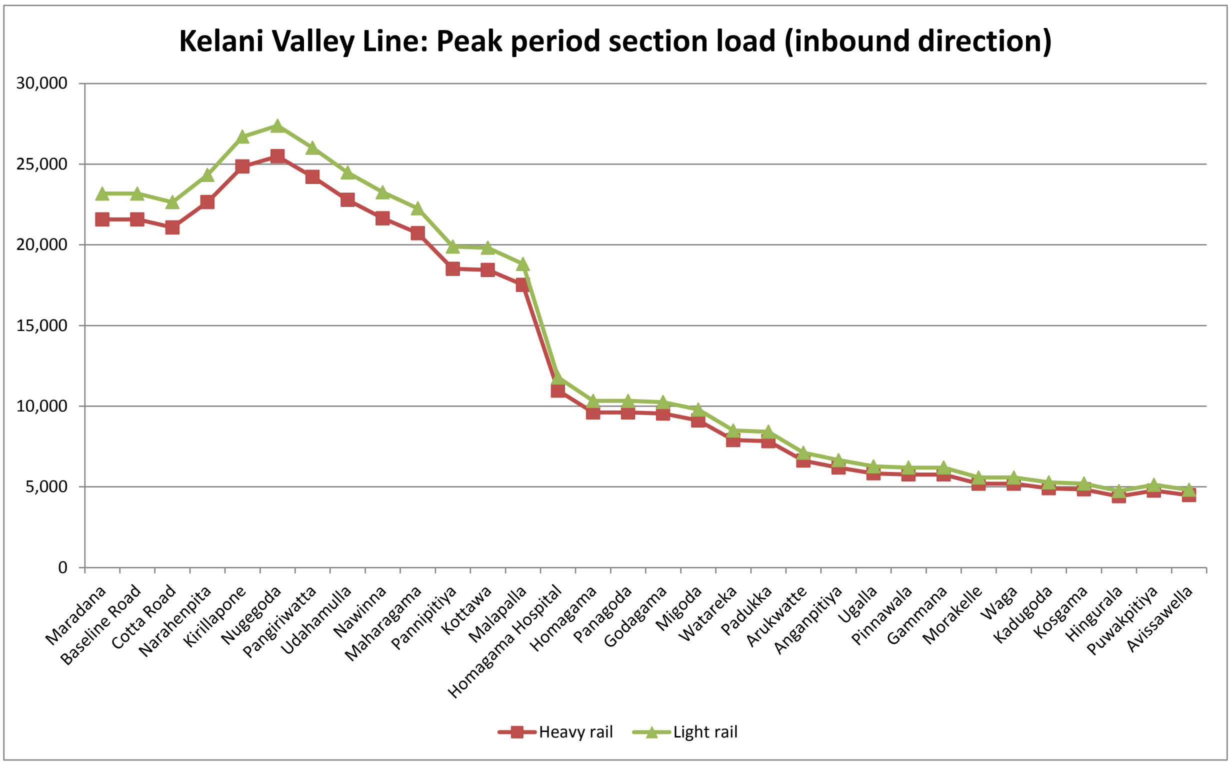
- The difference of travel time, depending on the technology,
- The difference of frequency, depending on the technology

The impact on traffic is estimated using demand elasticity. These coefficients were estimated for the feasibility study of the priority corridor Panadura-Veyangoda (coefficients based on an SP survey):

- Elasticity of rail demand to rail travel time: -0.305
- Elasticity of rail demand to rail frequency: 0.610

The following chart shows the results of the analysis and the estimated traffic loads per section for the two technology options.

Figure 5-18: Traffic sensitivity analysis



If we consider the heavy rail as the base situation, the light rail can attract 7% more traffic.

The maximum traffic load for the peak hour in the peak direction on the Cotta Road – Nugegoda section reaches 27,000 passengers with the light rail.

6 SCENARIOS ASSESSMENT

6.1 SCENARIOS

The previous options have been combined to propose 8 different scenarios as follows:

- Scenario A: Fully elevated heavy rail;
- Scenario B: Partly elevated heavy rail to Pannipitiya;
- Scenario C: Partly elevated heavy rail to Nugegoda;
- Scenario D: At grade heavy rail;
- Scenario E: Fully elevated light rail;
- Scenario F: Partly elevated light rail to Pannipitiya;
- Scenario G: Partly elevated light rail to Nugegoda;
- Scenario H: At grade light rail.

6.2 MULICRITERIA ANALYSIS

6.2.1 Methodology

These scenarios will be compared through a multi-criteria analysis structured around three main criteria:

- Users;
- Railway actors: Ministry of Transportation and Sri Lankan Railways;
- General public.

The following table describe for each criterion the sub-criteria that will be used to evaluate the scenarios.

Table 6-1: sub-criteria for the Users criterion

Comparison criteria	Assessment
Reliability	The user is very sensitive to the reliability of the transport mode, more than the speed. It is strongly depending on the **level of segregation of the transport system**
Travel time / Commercial speed	The travel time is an important criterion for the user. Being the maximum speeds of 100kmph never reached on the KV line, the comparison will concern the commercial speeds, which will be strongly related to the **average interstation** and the **dynamic performances of the rolling stock**. The comparison will use the results from travel time simulations with ‘tram train’, ‘light rail’ and ‘heavy rail’ rolling stock.
Proposed level of service and delay risk due to operational constraints	If the proposed headway is close to the minimum headways, any disturbance can impact the whole operation of the line and induce **delays**.
Seat and coach capacity	Comfort is an important side of public transport. The train capacity gives an estimate of the possibility for a passenger to find a seat.
Accessibility to stations	At grade stations are more accessible for users than elevated ones.

egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road, Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

Table 6-2: sub-criteria for the Railway actors criterion

Comparison criteria	Assessment
Compatibility with the existing system	This is a **key criterion** for the selection of relevant transport systems, especially to ensure other train operations than the sole suburban ones, including freight trains and, in the long run, long distance passenger trains.
Insertion and geometry	The **typical cross section** differs in terms of width for the scenarios (vertical alignment / technology), which has an impact on the dense human environment of the project. Each rail system enables different permitted maximum gradients and curve radius, which have an influence in case of track elevation and impacts in case of realignment
Safety	**Road rail conflict and pedestrian hazard** are safety risks that need to be minimized.
Transport capacity	This is a **decisive criterion** for the section of relevant transport systems
Level of rolling stock investment	It depends on the rolling stock type but also on the **rolling stock size** to fulfil the expected headway
Duration and impacts during construction	The nature and level of the **impacts during construction** phase may affect the acceptability of the project
Land acquisition	**Railway right-of way** to be acquired depends on the alignment option.
Relocation	**Urbanized area affected** by the railway right of way depends on the alignment option.
Investment costs / Life cycle costs	Strongly related to **vertical alignment** (km of elevated tracks) and **technologies**. Overall kilometric cost ratios from similar projects will be used at that stage. Life cycle cost differs depending on the selected technologies.
Experience in maintenance and operation of trains and systems	The introduction of **new technology** implies the acquiring of the knowledge of operation and maintenance of the new system.

Table 6-3: sub-criteria for the General Public criterion

Comparison criteria	Assessment
Visual impacts	The visual impacts differ among the vertical alignment options depending on **track and station elevations** and the type of **infrastructure surface** (ballast, concrete, asphalt, green).
Commercial impacts	The capacity of the transport system to become a nodal point for the district functioning, **boost urban projects and commercial activities** in the neighborhoods can be assessed.
Noise	A **low noise** generated by the transport system would be appreciated by neighborhood.
Road traffic	The removal of level crossing will improve the ro**ad network and performance**. Also with a higher mode shift to rail, road traffic congestion will be reduced.

6.2.2 Scenario comparison

The criteria and sub-criteria have been evaluated for each scenario. The following tables show the scenario evaluations. The colour indicates the efficiency of the scenario for each sub-criterion and is proposed as follows:

(dark green)	Very good performance
(light green)	Good performance
(light orange)	Low performance
(red)	Very low performance

egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

6.2.2.1 For the Users

Table 6-4: Scenario comparison from the user point of view

Scenarios / Comparison criteria	A	B	C	D	E	F	G	H
Reliability	Fully segregated	Segregated but risk of intrusions when alignment at-grade	Segregated but risk of intrusions when alignment at-grade	Segregated but risk of intrusions when alignment at-grade	Fully segregated	Segregated but risk of intrusions when alignment at-grade	Segregated but risk of intrusions when alignment at-grade	Segregated but risk of intrusions when alignment at-grade
Travel time / Commercial speed	Travel Time 51min 29.0 kmph	Travel Time 51min 29.0 kmph	Travel Time 51min 29.0 kmph	Travel Time 51min 29.0 kmph	Travel Time 47min 31.5 kmph	Travel Time 47min 31.5 kmph	Travel Time 47min 31.5 kmph	Travel Time 47min 31.5 kmph
Proposed headway and delay risks	5 min	5 min	5 min	5 min	3 min Close to minimum headway	3 min Close to minimum headway	3 min Close to minimum headway	3 min Close to minimum headway
Maximum train capacity	3 000	3 000	3 000	3 000	2 000	2 000	2 000	2 000
Accessibility to stations	Only elevated stations	Elevated and at grade stations	Elevated and at grade stations	Only at grade stations	Only elevated stations	Elevated and at grade stations	Elevated and at grade stations	Only at grade stations

The heavy rail scenarios present similar attractiveness from the user point of view whereas the light rail one is slightly below.

6.2.2.2 For the Rail Actors

Table 6-5: Scenario comparison from the rail actors' point of view

Scenarios Comparison criteria	A	B	C	D	E	F	G	H
Compatibility with the existing system / interoperability	Fully compatible	Fully compatible	Fully compatible	Fully compatible	Low compatibility. Heavy investment needed for the Homagoma – Avissawella section No compatibility for freight circulation and Kottawa – Horana extension	Low compatibility. Heavy investment needed for the Homagoma – Avissawella section No compatibility for freight circulation and Kottawa – Horana extension	Low compatibility. Heavy investment needed for the Homagoma – Avissawella section No compatibility for freight circulation and Kottawa – Horana extension	Low compatibility. Heavy investment needed for the Homagoma – Avissawella section No compatibility for freight circulation and Kottawa – Horana extension
Insertion / Geometry	14m-width of cross section	14m-width of cross section	14m-width of cross section	14m-width of cross section	12m-width of cross section	12m-width of cross section	12m-width of cross section	12m-width of cross section
Safety	Fully segregated with pedestrian and road traffic. No trespassing possible	Partially segregated. Trespassing possible at grade	Partially segregated. Trespassing possible at grade	Partially segregated. Trespassing possible at grade	Fully segregated with pedestrian and road traffic. No trespassing possible	Partially segregated. Trespassing possible at grade	Partially segregated. Trespassing possible at grade	Partially segregated. Trespassing possible at grade
Transport capacity	Up to 60 000 PPHPD	Up to 60 000 PPHPD	Up to 60 000 PPHPD	Up to 60 000 PPHPD	Up to 30 000 PPHPD	Up to 30 000 PPHPD	Up to 30 000 PPHPD	Up to 30 000 PPHPD
Rolling stock investment	Inter-operability with the other suburban lines. Rolling stock can be transferred from one line to the other	Inter-operability with the other suburban lines. Rolling stock can be transferred from one line to the other	Inter-operability with the other suburban lines. Rolling stock can be transferred from one line to the other	Inter-operability with the other suburban lines. Rolling stock can be transferred from one line to the other	Need for rolling stock dedicated to the line. The reduced capacity compared to heavy rail induced a need of 50% more trains	Need for rolling stock dedicated to the line. The reduced capacity compared to heavy rail induced a need of 50% more trains	Need for rolling stock dedicated to the line. The reduced capacity compared to heavy rail induced a need of 50% more trains	Need for rolling stock dedicated to the line. The reduced capacity compared to heavy rail induced a need of 50% more trains

Scenarios / Comparison criteria	A	B	C	D	E	F	G	H
Duration and impacts during construction	23.8-km long viaduct No road	16.8-km long viaduct 6 roads	8.6-km of viaduct 15 roads	No viaduct 29 roads	23.8-km long viaduct No road	16.8-km long viaduct 6 roads	8.6-km of viaduct 15 roads	No viaduct 29 roads
Land Acquisition	0	63,000 m²	137,000 m²	214,000 m²	0	49,000 m²	107,000 m²	167,000 m²
Relocation	0	2,800 m²	17,400 m²	47,600 m²	0	1,400 m²	11,200 m²	33,800 m²
Investment costs	Rail Infra 736.4M$ Vehicle 262M$ Land acquisition 91.04M$ Road Infra 0M$ Total 1089.44M$	Rail Infra 622.4M$ Vehicle 262M$ Land acquisition 172.03M$ Road Infra 102M$ Total 1158.43M$	Rail Infra 539M$ Vehicle 262M$ Land acquisition 219.87M$ Road Infra 255M$ Total 1275.87M$	Rail Infra 450.8M$ Vehicle 262M$ Land acquisition 264.07M$ Road Infra 493M$ Total 1469.87M$	Rail Infra 617.4M$ Vehicle 313M$ Land acquisition 75.13M$ Road Infra 0M$ Total 1005.53M$	Rail Infra 524.4M$ Vehicle 313M$ Land acquisition 102.56M$ Road Infra 102M$ Total 1041.96M$	Rail Infra 465.6M$ Vehicle 313M$ Land acquisition 131.68M$ Road Infra 255M$ Total 1165.28M$	Rail Infra 403.2M$ Vehicle 313M$ Land acquisition 158.46M$ Road Infra 493M$ Total 1367.66M$
Experience in maintenance and operation of trains and systems	Good experience	Good experience	Good experience	Good experience	No experience	No experience	No experience	No experience

From the rail actors' point of view full grade separation with full railway elevation provides better operation conditions, safety and reduces the needs for land acquisition and relocation. The heavy rail solution provides better interoperability of the network, existing maintenance and operation knowledge and opportunity for rolling stock sharing with the other suburban lines. Therefore, the fully elevated heavy rail solution is the most appropriated one, on the rail actors' point of view.

6.2.2.3 For the General Public

Table 6-6: Scenario comparison from the General Public's point of view

Scenarios / Comparison criteria	A	B	C	D	E	F	G	H
Visual impacts	23.8-km long viaduct	16.8-km long viaduct	8.6-km long viaduct	No Viaduct	23.8-km long viaduct	16.8-km long viaduct	8.6-km long viaduct	No Viaduct
Commercial impacts	Most capacitive More elevated stations for commercial activities	Most capacitive	Most capacitive Less elevated stations for commercial activities	Most capacitive No elevated stations for commercial activities	Capacitive More elevated stations for commercial ativities	Capacitive	Capacitive Less elevated stations for commercial activities	Capacitive No elevated stations for commercial activities
Noise	Heavy technology	Heavy technology	Heavy technology	Heavy technology	Light technology	Light technology	Light technology	Light technology
Traffic	No rail road conflict due to full elevation of the railroad	Some level crossing may remain on very low traffic roads, with a very low impact in local traffic	Some level crossing may remain on very low traffic roads, with a very low impact in local traffic	Some level crossing may remain on very low traffic roads, with a very low impact in local traffic	No rail road conflict due to full elevation of the railroad	Some level crossing may remain on very low traffic roads, with a very low impact in local traffic	Some level crossing may remain on very low traffic roads, with a very low impact in local traffic	Some level crossing may remain on very low traffic roads, with a very low impact in local traffic

All scenarios present similar attractiveness from the user point of view.

6.3 RESULTS OF THE MULTICRITERIA ANALYSIS

All sub-criteria have been rated from 1 to 4, according to the colour ranking, 1 meaning very low performance and 4 very good. The criterion rating is the average of the sub-criteria. Some weighting has been introduced for the rail actors to give more weight to the interoperability of the system, its capacity, the costs and the safety.

The following table shows the results for the 3 scenarios.

Table 6-7: Scenario comparison

Scenarios / Comparison criteria	A	B	C	D	E	F	G	H
Users	3.63	3.63	3.50	3.50	3.13	3.13	3.00	3.00
Rail actors	3.72	3.44	3.11	2.72	3.00	2.83	2.61	2.00
General Public	3.00	2.75	3.00	3.00	3.00	2.75	3.00	3.00
Total	**3.45**	**3.27**	**3.20**	**3.07**	**3.04**	**2.90**	**2.87**	**2.67**

The heavy rail solutions are the best rated ones. The fully elevated is the one having the highest score that we would recommend.

The key decision-making advantages of this solution are:

- Full **compatibility** with the other lines of the suburban network and the national railway network;
- Reduced **fixed costs for rolling stock** at purchasing and at operation on depot/workshop sites; compatibility of the rolling stock with the whole commuter rail network;
- Harmonized **maintenance** rules;
- Higher **safety**,
- Reduced costs for **land acquisition and relocation**.

egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: rnd@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

7 RECOMMENDATIONS

7.1 COST ESTIMATES FOR THE PREFERRED ALTERNATIVE

The following table details the cost estimate for the preferred scenario – heavy rail fully elevated.

Table 7-1: Cost estimates for the preferred alternative

Line Maradana - Homogama	Quantity	Unit price (M$)	Total Cost (M$)
Infrastructure 2 tracks elevated	23.8 km	24	571
Infrastructure 2 tracks at-grade	0 km	12	0
Railway equipment 2 tracks	23.8 km	4	95
Stations elevated	14 unit	5	70
Stations at-grade	0 unit	2	0
Sub-total infrastructure			**736**
Rolling stock	29 unit	9	261
Depot-Workshop	1 unit	1	1
Sub-total rolling stock			**325**
Land Acquisition	45.8 1,000m²	1.3	60
Resettlement – provision		32	32
Sub-total land acquisition			**91**
Road Infrastructure	**0 unit**	**20**	**0**
TOTAL			**1089**

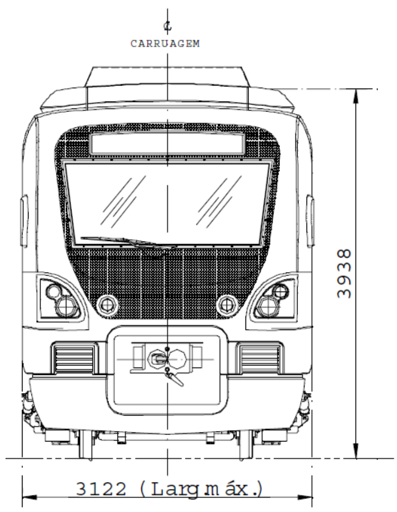
The rolling stock size has estimated based on the 5 minute headway, both directions, scenario. With a travel time of 51 minutes, it is estimated that 24 units are needed for peak hour. The fleet has been increased by 20% to take into account any down units or delays that would require the operation of addition units. In total it has been estimated that 29 units were needed. This volume can be optimized, especially in case of mutualisation of the rolling stock with the rest of the suburban network.

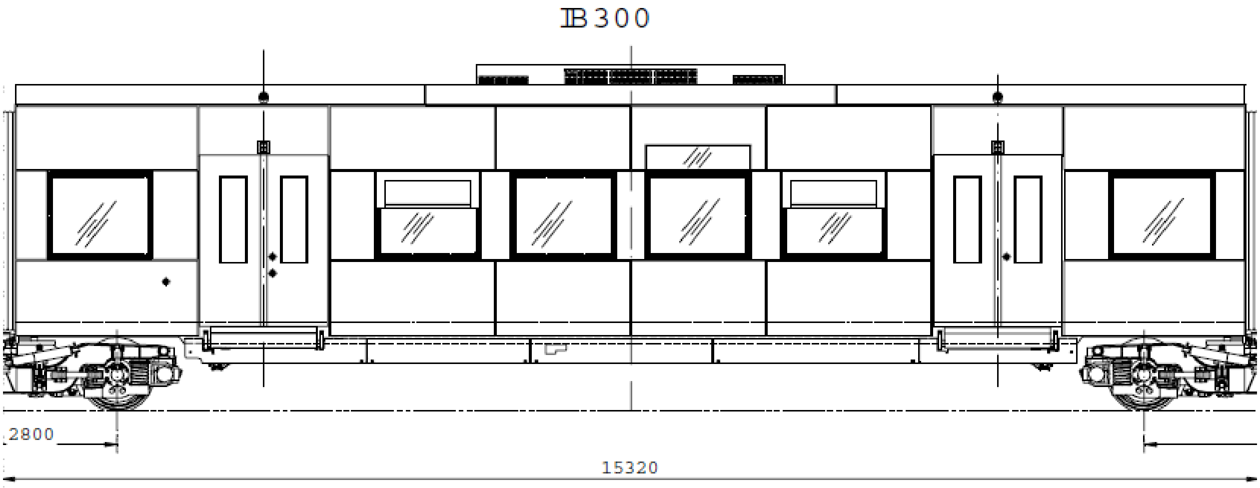
7.2 DISCUSSION ON ROLLING STOCK

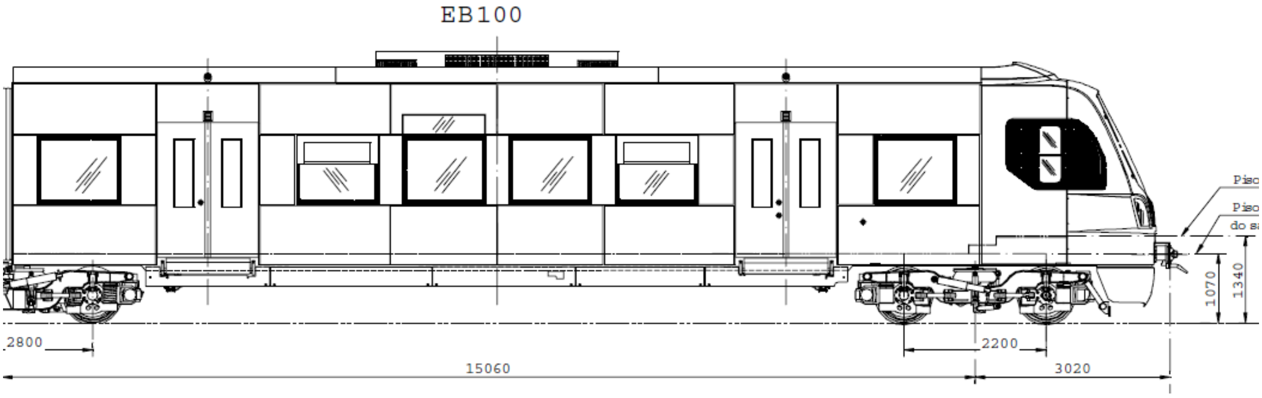
7.2.1 Typical characteristics

The Consultant recommendations for the rolling stock characteristics are:

- 3.1m width
- 15m car body length
- 150-160m long (10 coaches)
- 21 t / axle
- 460t







For the ‘Heavy Train’ series, the use of ‘Jacobs’ bogie is recommended for both reasons of limitation of the weight of the trainset and tight curves.

Figure 7-1: ‘Jacobs’ bogie

Yet, to ensure compatibility, reduction of fixed costs depot/workshop sites maintenance harmonization, it is also recommended to purchase trainsets of the same series or a close one as for other lines of suburban network.

7.2.2 Plan for rolling stock purchase

The purchase of rolling stock is to be staged in compliancy with the growth of traffic over the years.

In 2020, the expected ridership is a maximum of 19,000 PPHPD. This would require a headway of 7 minutes and thus, a rolling stock fleet of 20 trainsets. By 2035, the increase of passengers required an increase of the headway and the buying of 9 additional trainsets.

7.3 STATIONS

7.3.1 Station locations

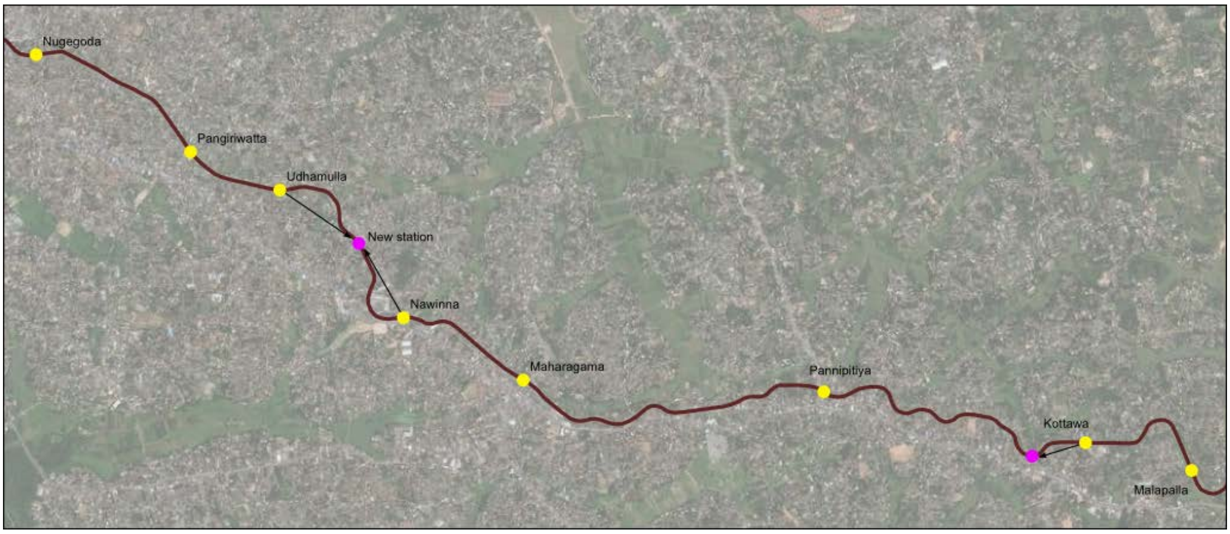
As highlighted in chapter 3-1, some distance between stations can be very short, impacting the commercial speed and also the population catchment of the line as two stations may share the same population.

When designing the viaduct the exact location of the stations will have to be carefully studied in order to:

- Optimize the station interdistance to improve travel speed and optimize the overall catchment of the line;
- Optimize station location to improve connections with the road network, especially the bus network and to improve pedestrian and cycle accessibility.

For example, the locations of the stations between Nugegoda and Makumbura are the ones with the most uneven interdistances. It can be proposed to merge Udhamulla and Nawinna and move Kottawa to the West, closer to Kottawa bus terminal.

Figure 7-2: Proposed station location between Nugegoda and Makumbura



7.3.2 Elevated station integration

The following figures show the conceptual designs for elevated platforms.

Figure 7-3: Sketch for elevated stations

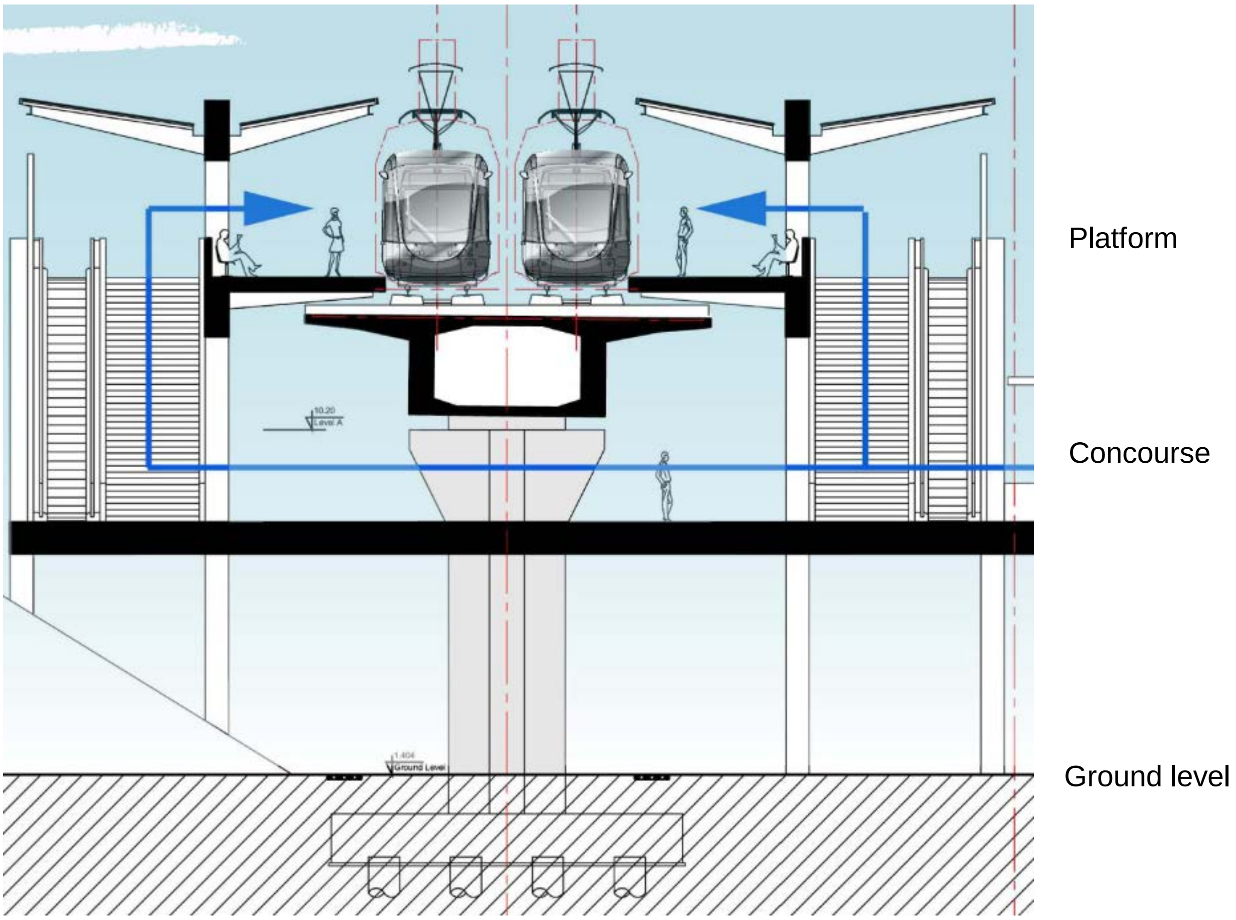


Figure 7-4: Examples of elevated stations

egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

7.4 OPERATIONAL COSTS

The trains have a maximum capacity of 3 000 passengers per direction. Yet, it is proposed to target 75% of this capacity to avoid overcrowding of the coaches. Thus a 5 minutes headway during peak hour can accommodate the demand with comfortable conditions and is in line with the operational constraints of heavy rail.

The following table presents a possible repartition of headways during typical weekdays, week-end and public holidays:

Figure 7-5: Repartition of headways during the day

	Weekdays	Satudays	Sundays	Public Holidays
05h-06h	15	15	20	20
06h-07h	7.5	15	20	20
07h-08h	5	10	15	15
08h-09h	5	10	15	15
09h-10h	7.5	10	15	15
10h-11h	10	10	15	15
11h-12h	10	10	15	15
12h-13h	10	10	15	15
13h-14h	10	10	15	15
14h-15h	10	10	15	15
15h-16h	7.5	10	15	15
16h-17h	5	10	15	15
17h-18h	5	10	15	15
18h-19h	5	10	15	15
19h-20h	10	15	20	20
20h-21h	15	15	20	20
21h-22h	15	15	20	20
22h-23h	15	15	20	20
23h-24h	15	15	20	20
Total daily trains	**280**	**200**	**138**	**138**

It leads to an estimation of the yearly kilometres travelled at 2 200 000 train-km. Based on the current operational costs at Sri Lankan railways, the operational cost unit is estimated at 920 Sri Lankan Rupies per kilometre. It leads to the yearly operational cost of **1 980 000 000 SL Rupies**.

7.5 COST BENEFIT ANALYSIS

7.5.1 Costs and benefits

The cost-benefit analysis was undertaken assuming the following benefit from the project:

- Time saving for existing passengers thanks to reduced travel time;
- Time savings and vehicles costs savings for passengers shifting from road to rail;
- Time savings and energy costs saving for road users thanks to the elimination of level crossings;
- Fatalities with reduced accidents with the elimination of level crossings;
- Energy costs saving by switching fuel trains by electricity trains.

Value of time has been estimated from Comtrans study and is estimated to 73.05 LKR per passenger per hour for rail users and to 292.18 LKR per passenger per hour for users shifting from road to rail and other road users. The passenger travel time value is estimated to grow like the GNP per capita, with an elasticity of 1.

Table 7-2: Cost and benefits of the project (in 2016 M$)

Capital Expenditure (CAPEX)	-	1,442.79
Initial investment	-	1,289.87
Infrastructure 2 tracks elevated	-	741.55
Railway equipment 2 tracks	-	103.77
Stations elevated	-	73.15
Rolling stock	-	230.32
Depot-Workshop	-	1.00
Land acquisition	-	91.61
Resettlement and compensation	-	48.47
Maintenance & renewal costs	-	152.92
Rail	-	16.43
Sleepers	-	14.69
Fastening	-	4.90
Ballast	-	21.08
Viaduct	-	46.11
Rolling stock	-	49.72
Operation Expenditure (OPEX)	-	125.98
Sri Lankan Railways Operation Costs	-	131.00
Sri Lankan Railways Energy Costs savings (from fuel to electricity)		10.80
Sri Lankan Railways Energy Costs (new electricity trains)	-	5.79
Socioeconomics benefits		2,111.31
Rail users		145.74
New rail users shifting from PV		1,745.57
New rail users shifting from bus		19.21
Road users		170.76
Externalities		30.03
TERMINAL VALUE		20.8
TOTAL NPV		**563.3**
EIRR		**12.08%**

82% of the benefit is for road users shifting to rail. The remaining road users also benefit from the project with reduced travel time and fuel consumption due to the elimination of level crossings.

7.5.2 Economic Internal Rate of Return

The cost benefit analysis shows the project has a positive Net Present Value of USD 563.3 million. The following table shows the CBA details.

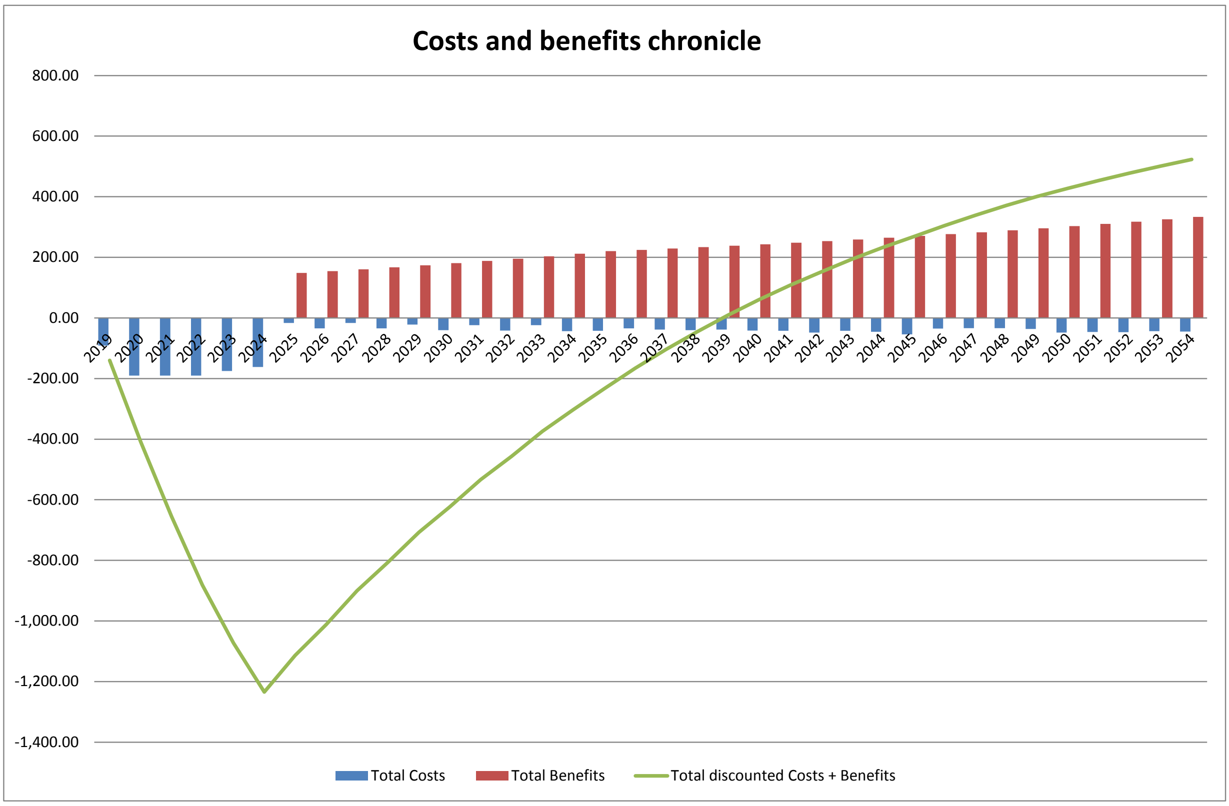
Table 7-3: Cost benefit analysis for KV line (in 2016 M$)

BENEFITS		2,111.3
Rail users		145.7
New rail users shifting from PV		1,745.6
New rail users shifting from bus		19.2
Road users		170.8
Externalities		30.0
COSTS	-	278.9
Sri Lankan Railways operation Costs	-	126.0
Maintenance and renewal costs	-	152.9
INVESTMENT	-	1,289.9
TERMINAL VALUE		20.8
TOTAL NPV		**563.3**
EIRR		**12.08%**

The Economic Internal Rate of Return (EIRR) is evaluated at 12.08%, indicating the project is generating economic benefits.

The following graph presents the economic analysis for 30 years of operation period. The balance is getting positive in 2039, 14 years after the project starting year.

Figure 7-6: Cost and benefits chronicle (in $ million)

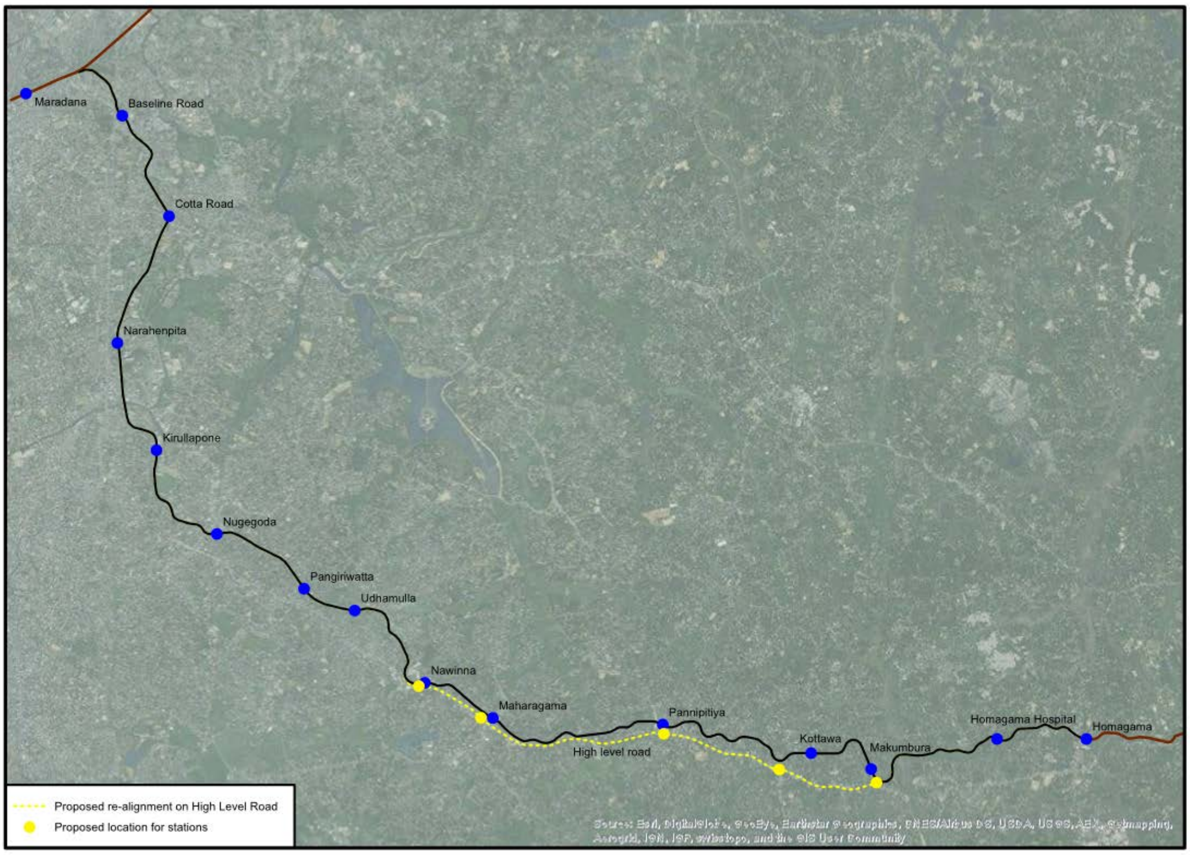


7.6 ALIGNMENT OPTIMIZATION

7.6.1 Proposed alignment optimization

The current draft report focuses on the existing railway right of way. Yet, an optimization may be done by re-aligning the KV Line between Nawinna and Makumbura section to be aligned on High Level Road. The proposed optimisation is displayed on the following figure.

Figure 7-7: Proposed optimization layout



This optimization may have several benefits:

- Shorter distance, with a total length of 23 km instead of 23.8 km;
- Less windy line as High Level Road layout has longer curves and straighter alignment. This would imply a better commercial speed and thus a reduced travel time;
- Better connection with the bus network;
- Reduced impact such as noise and visual impact as the viaduct infrastructure would be inserted above the existing road.

However, this option may prove to be more difficult to be implemented:

- The piers have to be inserted in the middle of the road. Therefore, it requires a minimum of three meters in the middle of the line to insert the piers. As road capacity reduction is not an option, it first need to be asserted that the roads are wide enough to accept such piers;

- The viaduct would need to be higher at the station location as the station would need to be fully elevated with an intermediate level between the road and the platforms to buy the tickets;
- Construction will have a high impact on the road traffic as pier foundations will required the closing of the adjacent traffic lanes;
- The new alignment will bypass the newly constructed Makumbura station. Yet it will still be connected to the Makumbura intermodal centre;
- Need for liaison and interaction with more stakeholders that may induce delays in the implementation.

The following paragraphs analyse in more details this option.

7.6.2 Improved travel time

The configuration of High Level road allows greater commercial speed thanks to the greater curve radii. The following table shows the estimated travel time. 6 minutes can be saved thanks to the new alignment.

Table 7-4: Journey time with proposed optimized alignment

N°	Stations	P m (m)	Inter-station distance (m)	Cummulative optimum run time (sec)	Marche type intergare (sec)	Regulation time (sec)	*Optional margin (sec)*	Commercial run	Interstation speed (km/h)	Dwell time (sec)	Arrival time	Departure time
1	Maradana	0		0								0:00:00
2	Baseline Road	1884	1884	131	131	6.6	*6.6*	2min24sec	47.0	30	0:02:18	0:02:48
3	Cotta Road	3545	1661	301	170	8.5	*8.5*	3min7sec	32.0	30	0:05:46	0:06:16
4	Manning Road	5140	1595	434	133	6.7	*6.7*	2min26sec	39.2	30	0:08:36	0:09:06
5	Naharenpita	5615	475	495	61	3.1	*3.1*	1min7sec	25.4	30	0:10:10	0:10:40
6	Kirillapone	7363	1748	658	163	8.2	*8.2*	2min59sec	35.1	30	0:13:31	0:14:01
7	Nugegoda	9145	1782	866	208	10.4	*10.4*	3min49sec	28.0	30	0:17:39	0:18:09
8	Pangiriwatta	10855	1710	1016	150	7.5	*7.5*	2min45sec	37.3	30	0:20:47	0:21:17
9	Udahamulla	11521	666	1092	76	3.8	*3.8*	1min24sec	28.7	30	0:22:37	0:23:07
10	Nawinna	13247	1726	1274	182	9.1	*9.1*	3min20sec	31.0	30	0:26:18	0:26:48
11	Maharagama	14278	1031	1364	90	4.5	*4.5*	1min39sec	37.5	30	0:28:22	0:28:52
12	Pannipitiya	17064	2786	1528	164	8.2	*8.2*	3min0sec	55.6	30	0:31:45	0:32:15
13	Kottawa	18829	1765	1654	126	6.3	*6.3*	2min19sec	45.8	30	0:34:27	0:34:57
14	Malapalla	20302	1473	1772	118	5.9	*5.9*	2min10sec	40.9	30	0:37:01	0:37:31
15	Homagoma Hospital	22433	2131	2014	242	12.1	*12.1*	4min26sec	28.8	30	0:41:45	0:42:15
16	Homagoma	23913	1480	2155	141	7.1	*7.1*	2min35sec	34.3	30	0:44:43	

Total time	0:44:43
Average commercial speed	32.1

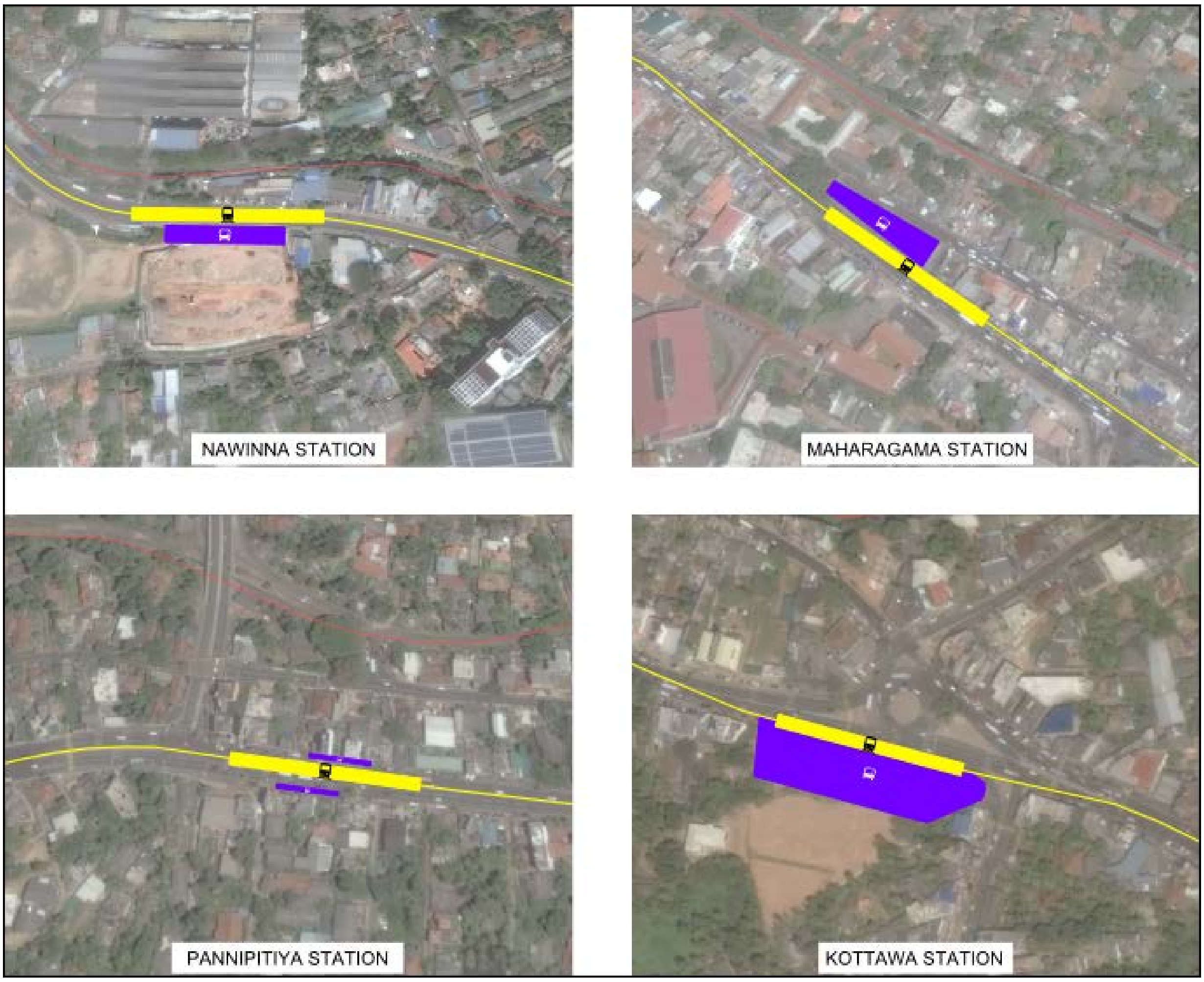
This time saved in travel time also implies a reduction of the rolling stock fleet as there will be a need for less trains to fulfil the peak hour headway requirement. Indeed, the fleet size could be reduced to 24 instead of 29.

7.6.3 Improved connection with the bus network

On the five stations that would be moved (Nawinna, Maharagama, Pannipitiya, Kottawa and Makumbura), the connection with the bus terminals and bus stages will be improved for four of them. Only Makumbura won't see any improvement as it is already an efficient multimodal centre.

The following figure shows the opportunities for efficient connections between the railway stations and the bus stages / terminals.

Figure 7-8: Proposed bus connection at stations



7.6.4 Alignment constraints

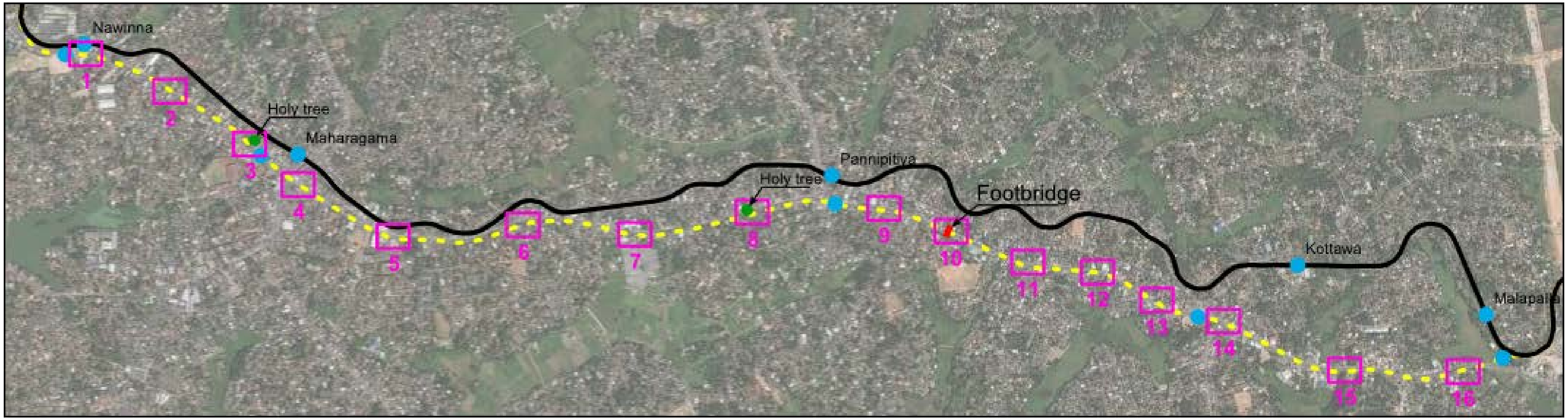
Inserting the viaduct on High Level Road requires inserting the piers in the middle of the road. The Consultant made a preliminary assessment of the road width to estimate the difficulty of inserting the piers.

Indeed, a 3m wide strip is needed in the middle of the road. The minimum road with required is then:

- 20m when the road has two lanes per direction;
- 13m when the road has only lone lane per direction.

The following figures show the available width on some selected sections of the road as well as the identification of specific constraints such as footbridge and holy trees.

Figure 7-9: Location of the sections



egis
RDC Resources Development Consultants (Pvt) Ltd. (RDC)
55 – 2/1 Galle Road,
Colombo 3, SRI LANKA.
T: +94-11-2435746, 2320159, 2436724
F: +94-11-2382723
E: md@rdc-lk.com, rohini@rdc-lk.com, operations@rdc-lk.com
A Member of Association of Consulting Engineers Sri Lanka affiliated to FIDIC
A Member of the United States Green Building Council

Figure 7-10: Zoom 1 to 8

Figure 7-11: Zooms 9 to 16

This analysis highlights several sections that are quite constrained, especially between Pannipitiya and Kottawa where the width of the road oscillates between 16m and 19m. Inserting the elevated railway might prove to be difficult or require land acquisition to extend the road width.

There is also an existing footbridge which will have to be removed.

7.6.5 Estimated cost of the optimization

The following table shows the estimated cost for the optimization scenario.

Table 7-5: Cost for the optimization scenario

Line Maradana - Homogama	Quantity	Unit price (M$)	Total Cost (M$)
Infrastructure 2 tracks elevated	23 km	24	552
Infrastructure 2 tracks at grade	0 km	12	0
Railway equipment 2 tracks	23 km	4	92
Stations at grade	14 unit	5	70
Stations elevated	0 unit	2	0
Sub-total infrastructure			**714**
Rolling stock	24 unit	9	216
Depot-Workshop	1 unit	1	1
Sub-total rolling stock			**217**
Land acquisition	38.6 1,000 m²	1.3	50
Resettlement and compensation	800 households	0.035	28
Sub-total Land Acquisition			**78**
Additional road pavement (3m wide strip)	26.4 1,000 m²	0.278	7
Sub-total Road Infrastructure			**7**
TOTAL			**1017**

The cost doesn't take into account any land acquisition / resettlement for the widening of High Level road as the Consultant couldn't have enough detail information on this subject.

The total cost is lower than the main scenario of 7%. Yet, this may prove to be less significant if any land acquisition / resettlement is needed.

7.7 HOMAGOMA – PADUKKA SECTION

After Homogama, the Kelani Valley line continues to the East on a single track and reaches Padukka after 10.8 km and 5 intermediate stations.

Figure 7-12: Homogama – Padukka section

The inter-stations average length is 1.8 km.

Stations To…	Interstation length (km)
Panagoda	1.8
Godagama	1.7
Meegoda	1.6
Watareka	1.6
Liyanwala	2.4
Padukka	1.7

The horizontal alignment is as winding as on Maradana – Homogama section, with similar minimum radius around 100-120m. For the purpose of increasing the speed, it appears feasible to realign without major impact from Meegoda station.

There are 18 level crossings on the section and 9 other pedestian crossings.

There is one road flyover on Homogama – Panagoda section, and 1 railway bridge on Megoda – Watareka and 1 railway bridge on Liyanwala - Padukka section.

The topography of the line is almost flat.

Stations	Altitude (m)
Homogama	38
Panagoda	37
Godagama	30
Meegoda	23

Watareka	30
Liyanwala	24
Padukka	20

The urbanization density is lower than on Maradana – Homogama section, and comparable to Ragama – Veyangoda section on Main line. The operation of track doubling is feasible with some limited impacts at:

- Panagoda stations: in curve and structures close to the track,
- Curve at Godagama,
- Godagama station: in curve,
- Sections on which a road is located parallel to the track: retaining walls may be needed

7.8 RECOMMENDATIONS FOR SHORT TERM INVESTMENTS

In the short term, a land on an area of 20m-width centered on the existing track shall be freezed.

Below the recommended short-term investments:

- Addition of trains off-peak in order to enhance the modal shift,
- Intermodal facilities in several stations,
- Improvement of the passenger information at stations.
- Protection of the railway line against intrusions,
- Improvements of the stabling facilities at Homogama station,
- Adding siding track, platform extensions to 120m and platform enlargements at stations on Homogama – Padduka section.