DEVELOPMENT OF A QUEUING SIMULATION MODEL FOR TRAIN PASSENGERS

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Master of Engineering Degree

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Thesis/Dissertation submitted in partial fulfilment of the requirements for the degree
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DECLARATION

This report contains no material which has been accepted for the award of any other degree or diploma in any University or equivalent institution in Sri Lanka or abroad, and that to the best of my knowledge and belief, contains no material previously published or written by any other person, except where due reference is made in the text of this report.

I carried out the work described in this report under the supervision of Dr. Himan Punchihewa.

Signature : Date :

Name of Student :

Registration No :

Signature : Date :

Name of Supervisor :

Abstract

Sri Lanka Railway (SLR) is currently having a schedule with uneven time intervals between trains. It reduces the popularity of the railway system and as a result new passengers hesitate to join the system. Hence, this current system is generally used by regular travellers only. In order to seek ways to improve the train schedules simulation based approaches have not been used in Sri Lanka. Therefore, the aim of the research was to develop a simulation model to minimise queuing time of passengers while maintaining an even interval between trains.

A passenger survey and a railway survey were carried out to find current issues related to the timetable and the service. Considering the feedback of passengers, a simulation model was created using the Anylogic simulation software for the current train scheduling and the proposed train scheduling systems.

The simulation model shows that passenger queuing time is able to be changed using the parameters of the model. Results also indicate that queuing can be potentially reduced using even time intervals between trains. However there could be a necessity to change the number of compartments to cater for the number of commuters in the proposed system. In addition the proposed system needs to be piloted in order to understand and overcome the practical limitations. This could potentially help to improve the popularity of the railway system in Sri Lanka. The operation model was developed between two stations due to limitation of the software. Thus, it is proposed to develop the model to cover the entire train fleet and the network to obtain more accurate and repetitive results.

Keywords: train schedule, Anylogic, modelling, queuing time

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1 Introduction

The Railway industry constitutes an important and vital role in mode of transportation for both freight and passenger. The railway industry is a capital intensive industry with large investment in equipment and employees. The operation of a railway requires very complex decision making process and well educated crew due to the need to schedule over the complex railway network which has thousands of kilometre distances[1]. The competitive edge of the railways over other available modes of transportation depends on the quality of service it provides. Amongst the most important parameters that affect this service quality are the efficiency and the effectiveness with which railway operations are conducted. This provides the motivation for an in-depth study of traffic control process, an integral part of the railway's day-to-day operations and also there will be a significant financial return even when a small improvement is done for its efficiency[1], [2].

Train scheduling is one of the most challenging and difficult tasks in railway planning and which have attracted the attention of researchers for decades [2]. Since the physical railroad network is shared by a large number of trains, it is necessary to synchronize the use of the available resources. Moreover, the simultaneous scheduling of freight and passenger trains has an important impact on the quality and level of services provided to the public. Train scheduling has been conducted based on individual judgments for more than a century [3]. This causes ineffective use of trains and infrastructure and sometimes terrible accidents. It is worth mentioning that in some countries this approach is still being practiced [3].

History of modern train spans the range of last two hundred years of modern human civilization [3]. Today, in most countries, trains are used in variety of ways-from small city trains, subway electric trains, distance trains, freight trains to high speed bullet trains that can reach speed of 300-500km/h [3].

Synchronization of transport method together with other modes of transportation would be able to save the time as well as the costs [3]. Therefore, scheduling is most important task in every modes of transport and it is important to minimise delays, costs, and itefficiently organises the use of resources and maximises efficiency. It helps the organisations exploit their full potential. Furthermore, it helps to win the organisational goals [3].

There are two main types of domestic transportation methods in Sri Lanka such as highway and rail road. Most of area in the island is covered by highway and very little amountof island covered by railway. Recently Sri Lanka has been carrying out many developments in highway but railroad looks likequite old and no development has been done to the process in scheduling. Poor condition of railways and deteriorated services are the results of this. The lack of maintenance funds has led to the poor condition of tracks, bridges, and railway stations. In addition, the number of locomotives is insufficient while those available are obsolete, and signalling including communication systems are outdated. This causes significant delays in train schedules, as well as dangerous derailments [4].

Sri Lanka Railway (former Ceylon Government Railway (CGR)) was introduced in 1864 to transport coffee from the hill country to the Colombo Port. Today, it operates approximately with 1508 kilometres of track and 333 stations [5]. A total number of 324 trains are in operation during the peak and off peak hours and the railway now moves 300,000 passengers daily. Under the prevailing situation, the railway transports over 86 million passengers and one million tons of goods every year. Further they operate three train lines from the base, in high traffic area such as coastal line and, main line and Kalani Weli line [5], [6]. Corresponding investment is necessary for transportation. However, investment must be carefully made into several key areas such as:speed, scheduling, routing, access and information of transport sector. These are identified areas of proven customer preference in mode selection. The ability of the SLR to provide those operational features will result in the attraction of a satisfactory proportion of satisfied customers and thereby halt the present experience of the continuing migration of unsatisfied customers. Most of the passengers are not satisfied with the services rendered by the present public railway transportation system and they are compelled to travel by road transport systems, which result in congestion during peak hours [5], [6].

When consider schedules of SLR there are three main types, such as week day schedule, week end schedule, government holiday schedule and other holiday schedule. This planning was one according to the passenger demand of each day. Generally any transport method need good plan and time and which reduces the passenger queuing time and increase the popularity of public transport [6].

2 Aim and Objectives

2.1. Aim

The aim of the research was to develop a simulation model to minimise queuing time of passengers while maintaining an even interval between trains.

2.2. Objectives

- To identify the peak passenger line for trains
- To evaluate the current train schedule
- To develop a model to simulate passenger movement
- To compare the model against the current schedule

3 Methodology

It was started with gathering some information form literature regarding the public transport sector, railway, railway scheduling and synchronise public transportation and minimization of passenger queuing time. Carried out a passenger survey on railway to identify the passenger demand line and peak demand for week days, passenger satisfaction, and types of passengers, passenger queuing time and other issues facedduring thejourney. Railway survey was conducted to identify the train speeds, acceleration, disturbances and signal positioning, capacity of a train compartment, flat form length, distance between bypassing switches. In addition to that, it was able to capturethe current train schedule for weekdays though the internet to observe the current behaviour of rail transport sector.Advanced search had been carried out for the literature of train scheduling to identify the novel methods, barriers and problems faced during scheduling of trains. In addition that, foundout some literature for passenger demand and satisfaction of railway.

It was started to develop a model for help to train scheduling based on present details and which model was able to give an output as passenger count with respect to the time and as per the given information. Model output data was collected with the time for current railway schedule and for the proposed method. By analyzing those data, it was able to identify the passenger queuing time during the peak hours of the week days. Fond out the advantages and limitations of two method of schedule and discuss them.

Finally, it was started to verify the developed model using current train schedule and collect the passenger data by a photographic method with the 5 minute frequency. By using those data model was verified for single line railway.

4 Literature review

Rail road transportation was developed since 18th century specially transports coal and other goods form the mine to commercial areas. After it became fast and safe travel media, started passenger transportation throughout the Europe and the increase of the population and the development of their lifestyle countries had added more and more locomotive and complex railroads. The railway industry faced problems in scheduling so that many researches were carried out in train scheduling. Scheduling and planning was important to make the train timetable. Railway traffic scheduling is often considered a difficult problem primarily due to its complexity regarding size and the significant interdependencies between the trains [4].

4.1. Train scheduling

Generally scheduling of railway transit systems is a highly complex process, which is often divided into several steps such as demand analysis, line planning, train scheduling, rolling stock planning, and crew scheduling. The goals in rail scheduling like amount of rolling stock required, average passenger changing time, average speed of trains and the number of cross-wise can be met by carefully modelling. While finding the literature found three scheduling considerations such as Tactical, Operational and Re-scheduling, which have the basic problem and limitations in railway but the kernel of the problem, are the conflicts that arise when two or more trains want to occupy the same part of the network simultaneously. In practice, tactical and operational scheduling are often carried out using a combination of computational tools and human expertise, while for re-scheduling, human expertise and rules of thumb often is the dominating procedure[4].

There are two main timetable variants such as periodic timetable and non-periodic timetable. Periodic timetable that repeatsfor given time period andnon-periodic time table that allowsfollowing the passenger demand. The train departure frequencies are depending on the passenger demand. Generally the both timetable repeat every weekdays and the three are different time schedule for holidays and weekends [7], [8].

There are several software tools which used for timetable construction such as *FBS, HASTUS GIRO, BERTA, MICROBUS, VISUN OV 7.0, PTV AG* and solutions by *TLC* GmbH. But they are limited to only modify interactively an already existing timetable[8].

Models for periodic timetabling are commonly based on the periodic event scheduling problem (PESP) [7]. By which periodic timetabling instances may be formulated in a very compact way. Since then this model has been widely used. In the PESP, given a period time T and a set V of events, where an event models either the arrival or the departure of a directed traffic line at a certain station [7], [8].

In1974 Analytic model was developed for single railway track and in this model, trains operation at several different speeds are permitted [9]. Priority systems are included in the model to control trains behaviours when they meet and overtakes occur and delays time due to implementing these priority are formulated. In addition, it is assumed that the departing timers for trains are independent random variables that are uniformly distributed [9]. In 1980 proposed an algorithm that uses the range construction search technique to schedule and pass though relations of trains. That programme was able to determine how the timing of certain trains constraints time of others, Find possible time ad pass through relations, and evaluate the efficiency of train movement [10]. A Branch and Bound method is used to resolve the conflicts and lower bound to the remaining delay is generated by relaxing the remaining conflicts. Minimising the sum of the travel times was the objective and only small problems were tested. It has considered a similar dispatch algorithm which calculates the crosses, segment transit times and determines which train takes the sidings in order to minimise the total travel times [10].

4.2. Sri Lankan context for railway research

A total number of 300 trains are in operation during peak hours and 250 during off-peak hours. Due to different traffic demand patterns, there are three types of train schedules, one for weekdays, one for Saturdays and one for Sundays and public holidays. Some of the train runs are almost a day long, like run 1, while others are rather short, like runs 2 and 3. The three types of schedules change from time to time as the traffic demand changes. The train operator scheduling problem is to generate a duty schedule for train operators to man all the train runs in a given train schedule [11].

Computer based train scheduling wad developed in 2003 and that minimises operational conflicts due to service constraints on a single line railway track. This developmentwastried to facilitate re-scheduling of trains to minimize operational delays.And also it clearly expressed to accommodate uniform headways for off peak hours. It has some constraints which directly influence to the headway such as locomotive availability, poor track conditions and stations without siding facilities. In addition to that research describes a computer simulation model. This simulation model was designed to optimize train schedules on single-track rail lines. The simulation model was able to plan and optimize a railway schedule within a short period of time [12]. It concludes that the passenger queuing time might be minimized due to train runs in the short period of time. According to the this publication the model can be used for any single-track line where some stations do not have siding-tracks and when different speed limits between stations are given. For each train, the maximum speed, the number of stops on the line and the stopping time at each station can be specified [11], [12], [13].

In year 2013, the methodology of travel demand forecasting was developed as Potential of Centrality Measures. In that study, the centrality of railway stations in terms railway and road access were computed separately by using centrality measures. In addition to that analysis had been conducted to achieve the relationship with travel demand of station in Sri Lanka. It had been identified significant correlation between transit demand and centrality of railway stations. The centrality values have capabilities to explain over 79% of the variation in rail transit demand. It had been concluded that "Centrality Measures" method can serve as an alternative predictor of transit demand, in the absence of good, quality data on trip-making and employment trends [12]. Accordingly, this study concluded that centrality measures are useful to measure transit demand of railway station. Closeness and Between-ness were identified as appropriate centrality parameters that can use to measure street and transit network centrality of stations. Two parameters revealed a significant correlation with transit demand. By considering that, regression model was developed, to explain transit demand of station based on centrality values [12].

This research has contributed with a robust, dynamic planning tool that will offer apromise for transport planning applications in Sri Lankan context as; to identify the impact from network augmentation to transit demand of existing stations; to identify the impacts of proposed land use plans to transit demand of existing stations; and to select location for transit stations or to plan multimodal system [12], [14].

4.3. Passenger satisfaction

Most of the passengers are not satisfied with the services rendered by the present public railway transportation system.They are compelled to travel by roads which result in congestion during peak hours. Although the number of passengers using the railway is increasing, and the quantity of goods transported by the railway is becoming higher year by year, government railway seems to be running at a loss [12].

4.4. Summary of literature

It has been discussed through several types of researches regarding the train scheduling or commonly known as train planning. A lot of papers discussed here, has different concepts to each other or some papers had been developed the concepts which were created by the previous papers. Scheduling of railway is a highly complex process and has several parts to be completed such as demand analysis, line planning, and rolling stock scheduling and crew planning [2]. First linear programming train schedule had developed in 1972 and which was to determine overtaking, crossing position, departure times with upper velocity in single track railway system [4]. In 1974 analytic model had been developed and this model discussed several different speeds for each direction and it was discussed,overtakes and delays behind implementing that model [9]. In 1980 new algorithm has been developed and which was able to determine timing of one train, and how effect was felt to the other trains [9]. Again after 12 years, branch and bound (BBM) method to resolve the conflicts and lower bound to remaining delays generated by conflicts. In 1987 different approach had been developed by BBM dispatching rule and it has discussed track running times and delay penalties for trains. In 1995 analytical based model has been developed to quantify the mount of delays and according to that they have identified three main areas of delays such as station, track and rolling stock. In 1995 scheduling based traffic management system was developed and which helped to conflicts resolution in rescheduling the railway. In 2004 mixed integer linear programming (MILP) has been adopted with capacity constrains to railway scheduling [10]. Intelligent decision support system has been developed in 2013 by using BBM and tabu search algorithm; this was created near optimal solution by algebra within short period of time.

According to the literature, researchers have been used different type of mathematical formulations to find the optimal solution for train scheduling. Operational research had been used in 1972 for one of the first well known researches. Then Mixed integer linear programming, Branch and Bound algorithm and Tabu search algorithm have been used for crew scheduling for trains. In late 90, computershave been playing a vital role in planning industry and the advantage of this is all mathematical formulation would be able to solve by high speed computer and researcher’s calculation time has been reduced and accurate output has been observed [15].

A very few researches were carried out in Sri Lanka regarding the railway scheduling. In 2003 a paper has been published with the title of ‘facilitate rescheduling of trains to minimize operational delays for single line track, and also this concept has combined with the computer simulation [11],[12],[13].

Different aspects have been carried out by different researchers who were interested in the railway**.** Several researches of themwere based on mathematical formulations such as OR, MILP, TSA and BBM. Sir Lanka context is not enough to develop good railway schedule, it needed to identify problems and difficulties during operation of train services. As mentioned in objectives SLR needs high popularity and passenger satisfaction [14]. It was important to make further findings for railway by a research and re-analysing the problems and find the solution for them. Due to the difficulty of finding an optimal solution to large problems the trend has been towards finding approximate solutions. One of the objectives in this paper is to present computer simulated model for train schedule in Sri Lanka Railway. Before planning it’s very important to check the demand throughout the day, time and particular date. The next step is line planning, according to the demand allocation of line is essential. The third step is development of train scheduling according to the above two parameters. After developingthe train schedule it need rolling stock and crew.

5 Case study for the coastal railway

Public transport plays as an important role in the transport and traffic strategy of Sri Lanka. Periodic subways of public reactions and regular measurement of passenger satisfaction would provide useful information for quality management in the public transport sector. Findings from surveys can help to determine the response of passenger and in-depth studied can provide insights to identify the many factors that will affect travel behaviour. The objective is to gauge the reactions of the customers in the public transport market. Analytical result using robust statistical method can provide ways and means to compare the performance between different operators or the performance of the same operator over time.

It needs to havea rough description of the costal railway network. The total length of the track is m 156.8 km form Colombo Fort to Matara. But in this case study was conducted only form Kalutara South to Colombo Fort, so there is total 20 stations, and all of them allows line changes. There are two main tracks one for Kalutara South to Colombo Fort and the other one for Colombo Fort to Kalutara South. The track contains mainly two main bridges at the Kalutara and Panadura, and also there are seven small bridges at Pinwatta, Rathmalana,Dehiwala, Wellawatta, Bambalapitiya,Slave Island and Clombo Fort. This railway track is going through the highly crowded area such as Moratuwa to Colombo Fort. Because of this reason the train speed might be limited and the passenger queuing time might be increased.

To find out the passenger queuing time it was needed to conduct a survey focusing on railway passengers. Informant ions regarding the rail passengers could be converting in to statistical data and those data for further investigation about the railway were obtained through a questionnaire and the questionnaires were administered with the total number of passengers on board between the origin of Kalutara South and destination of Colombo Fort covered by the study. The sample space for the questioner contained 100 rail passengers. It was really not sufficient to understand and represent the all passengers in railway, but in this study the passenger queuing time only was followed, because the sample space was sufficient to get the required information for this study.

In the railway sector, the aim of the performance contract is to encourage the operator to provide reliable and quality service at a fair price to the passengers. In addition, the quality of travel, information for the schedule and passenger accessibility has to be improved.

The interviewers ask passengers on the platform at their standing point of the survey what are their experience and how they world rate the facilities, e.g. waiting time at the ticket office, delays, travelling dates etc. subsequently , the surveyors goon board and travel within the trains. Questioners are then handed out to a sample of passengers on the basis of a pre-determined scheme based on the sitting arrangement in different types of trains. Passengers are requested to cooperate by filling in the questionnaire and the questionnaires are then collected later.

The questionnaire is divided into a number of blocks with questions to identify user characteristics. Their subjective valuations of different aspects of service e.g. delays, cancelations, passenger information provided at station etc. Finally, the passengers are invited to give their suggestions as to what aspects are required to improve and how best to improve customer satisfaction. (Appendices 2- Passenger Survey questionnaire)

5.1. Findings

Findings through the questionnaire important to understand the current behaviour of rail transport sector. There are two findings in this study such as rail passenger density of a week day and types of passengers who used rail way. In addition to that passenger comment has been used to confirm the satisfaction of the railway service. In addition to that the passenger queuing time has been calculated by the obtained data.

5.1.1. Passenger density

Generally transport forecasting and appraisal models are used to predict the demand to travel and, in many cases, to assess the impact of these forecasts on the level of service offered by the transport network. Such forecasting models are also used to estimate the impacts of changes in transport networks caused by investment in capacity or decisions about managing demand by means of pricing or other interventions. Rail models are based on the relationship between changes each year in the volume of passengers travelling by rail between samples of the stations. By analyzing the passenger survey information it was able to identified passenger demand curve as in Figure*5.1*. The survey confirm that the SLR need to have proper passenger demand estimation process because SLR still has not used novel computerized methods for issuing tickets.

Table 5-1Passenger demand in Kalutara South station

Time	Number of passengers
5:56	4
6:18	7
6:36	5
6:45	6
6:58	17
7:00	25
7:20	20
8:10	9
8:36	4
8:50	3

At peak times, SLR currently operates the maximum possible number of trains but generally there were not enough trains to meet the passenger demand (PD). But in this study, it has acquired important information from selected main stations to obtain passenger demand of current situation. Oneof them is to capture images of the passenger waiting area by given interval in order tocount passengers in selected area with the time. Ticket issuing rate is represented the passengers who are irregular train users. But the passenger survey data verified the percentage of irregular users by considering both data series, it is able to say the total passenger demand of the peak time. Passenger counting process has been done for the verification of above data. The collected data with time is contained in the *Table 5-1* and it is graphically represent in the *Figure 5-1*.

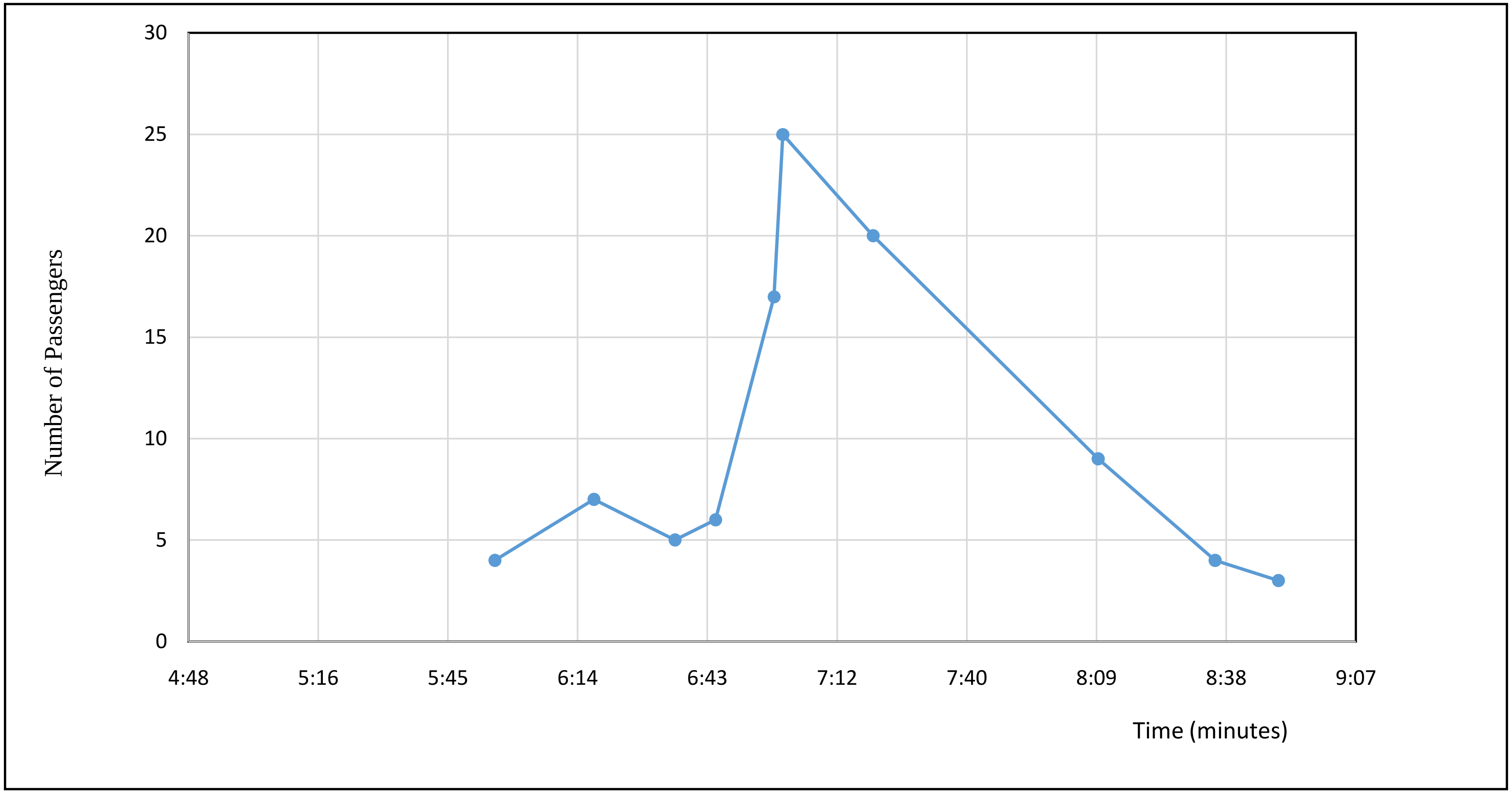


Figure 5-1Passenger demand variation in peak time of the day

5.1.2. Types of passengers

This survey was concluded that more than 97 % of passenger at a given time period were travelling as regular users. Figure 5.2 illustrate the pie chart to confirm the passenger type.

Table 5-2 Type of passengers

Purpose of travel	Number of passengers
Work	80
Study	17
Business	1
Other	2

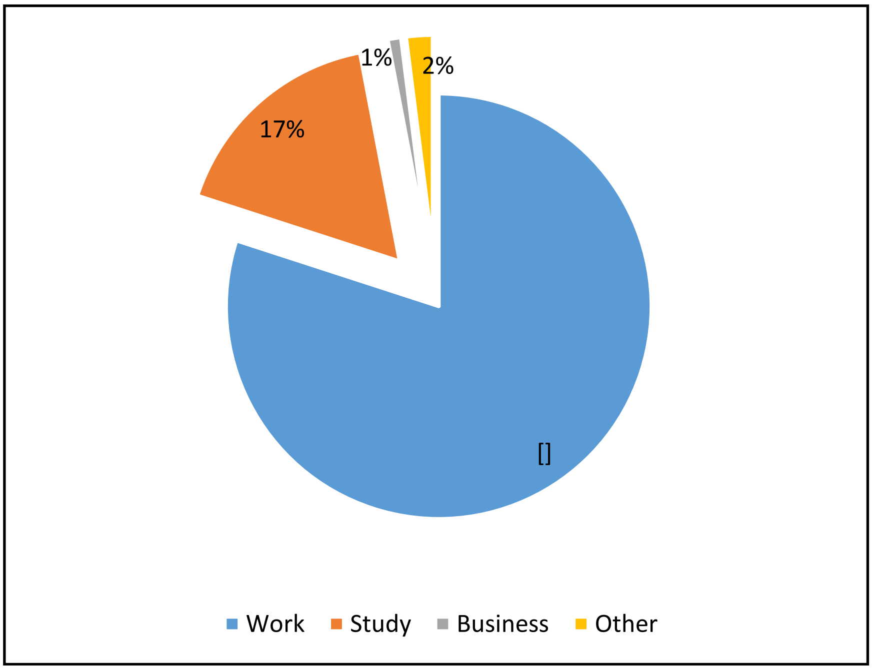


Figure 5-2Purpose of travel

5.2. Train capacity

In this study data were obtain by only form the DMU such as S09, S10 and S11.In the class S09 type train wagon has an average of ten coaches, each S 10 and S 11 are having a seating capacity for 90 passengers thus; The total number of passengers is about nine hundred (900) excluding the standing passengers. The standing passengers per coach were about 70 passengers. Consequently, about 700 standing passengers were on the train.

Table 5-3 Passenger demand variation in the day

Time	Number of Passengers			
	KSS	KNS	WDS	PAN
5:20:00 AM	10	3	8	15
5:25:00 AM	15	4	11	23
5:30:00 AM	20	5	15	30
5:35:00 AM	25	6	19	11
5:40:00 AM	10	10	20	15
5:45:00 AM	18	5	20	20
5:50:00 AM	21	8	25	35
5:55:00 AM	20	10	20	38
6:00:00 AM	19	14	24	42
6:05:00 AM	33	8	28	50
6:10:00 AM	52	13	39	78
6:15:00 AM	50	13	38	75
6:20:00 AM	20	20	40	75
6:25:00 AM	25	20	42	80
6:30:00 AM	40	24	40	85
6:35:00 AM	60	30	45	90
6:40:00 AM	80	35	60	120
6:45:00 AM	125	34	94	188
6:50:00 AM	140	35	105	210
6:55:00 AM	175	44	131	263
7:00:00 AM	190	48	143	285
7:05:00 AM	200	50	150	300
7:10:00 AM	195	20	146	293
7:15:00 AM	180	35	45	270
7:20:00 AM	150	38	54	200
7:25:00 AM	15	42	65	222
7:30:00 AM	15	4	60	220
7:35:00 AM	15	5	65	115
7:40:00 AM	20	5	15	151
7:45:00 AM	30	6	25	165
7:50:00 AM	30	7	28	45
7:55:00 AM	30	8	35	51
8:00:00 AM	30	10	34	48

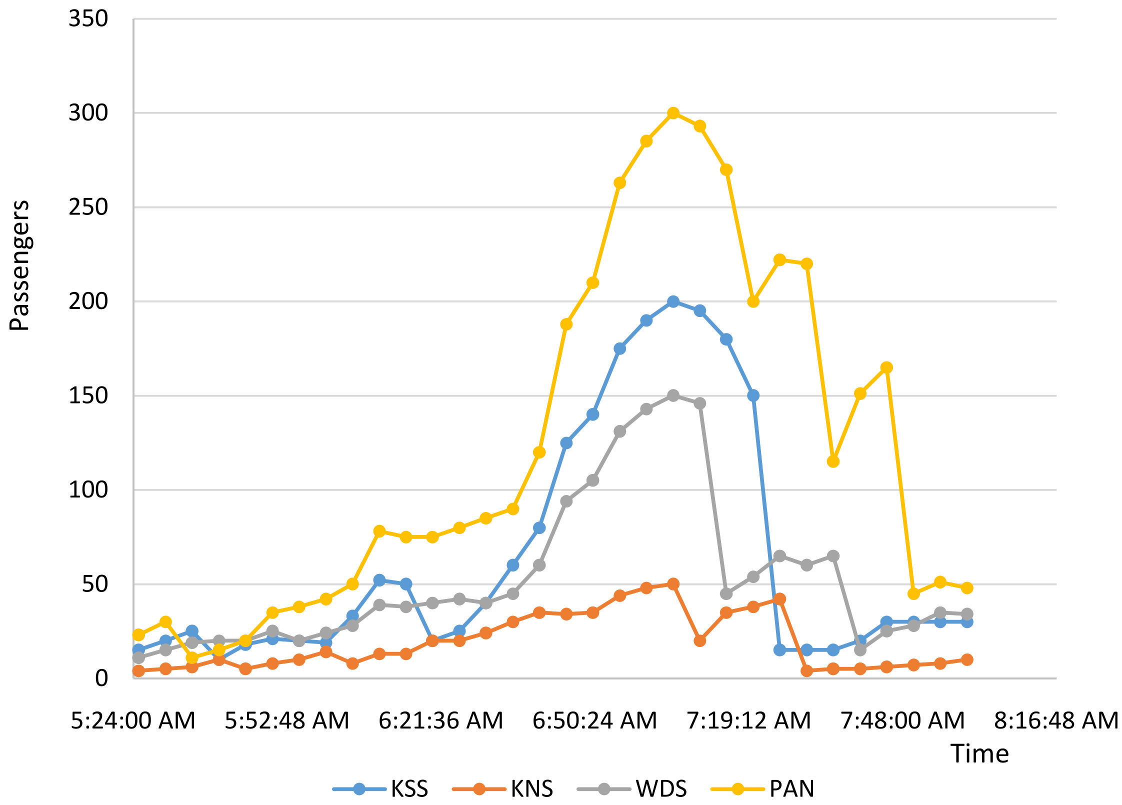


Figure 5-3 Passenger Demand curve with time

In the class S 09 type train wagon has an average of ten coaches, each having a seating capacity for 60 passengers thus; the total number of passengers is about six hundred (600) excluding the standing passengers. The standing passengers per coach were about 150 passengers. Consequently, about 1500 standing passengers were on the train.

As in the *Figure 5.1* the passenger demand data has been obtained *Figure 5.3*, and this verified the pattern for the passenger demand is same.

5.2.1. Weekly trip frequencies

Table 5-4 Trip frequencies of people

Number of trips	Frequency	Present
1-2 times	8	8
3-4 times	12	12
5-6 times	80	80

5.3. Limitations of Sri Lanka railway

There are several limitations found in Sri Lanka railway such as Sliding facilities, number of trains, Capacity of the trains, engine capacity, Platform length, Signal controllers, speed limits, number of crossing etc.

5.4. Current train schedule of each station

A public transport timetable is a document setting out information on service times, to assist passengers with planning a trip. Typically, the timetable will list the times when a service is scheduled to arrive and depart from specified locations. It may show all movements at a particular location or all movements on a particular route or for a particular stop. Traditionally this information was provided in printed form, for example as a leaflet or poster. It is now also often available in a variety of electronic formats. Current train schedule has been collected by referring SLR website. Sample schedule is displaying in the *Table 5-5* and the first two columns of the Table are related to the stations and its codes, from here onwards each station is described with its code.

Table 5-5 Current train Schedule Kalutara South to Colombo Fort

Station		**Train Number**									
		8302	**4021**	**8304**	**4077**	**8309**	**8311**	**8310**	**8317**	**8316**	**8320**
Kalutara S	KSS	3:52		4:22		5:02	5:36		5:56		6:15
Kalutara N	KNS	3:57		4:27		5:07	5:41		6:02		6:20
Wadduwa	WDS	4:09		4:39		5:19	5:53		6:13		6:32
Pinwatta	PIS	4:14		4:44		5:24	5:59		6:19		6:37
Panadura	PNS	4:19		4:49		5:29	6:05	6:10	6:25	6:30	6:42
Egoda Uyana	EUS	4:25		4:55		5:35		6:15		6:36	6:49
Koralawella	KWS	4:28		4:58		5:38		6:18		6:40	6:52
Moratuwa	MOR	4:32		5:02		5:42	6:17	6:23	6:37	6:45	6:56
Lunawa	LUN	4:36		5:06		5:46		6:26		6:50	7:01
Angulana	ANG	4:39		5:10		5:49		6:29	6:42	6:54	7:04
Rathmalana	RTH	4:42	5:10	5:12	5:50	5:52	6:26	6:33	6:46	6:58	7:07
Mt Lavinia	MTL	4:46		5:16		5:56		6:36	6:51	7:03	7:11
Dehiwala	DHS	4:50	5:13	5:20	5:53	6:01			6:56	7:08	7:15
Wellawatta	WWS	4:55	5:18	5:25	5:58	6:05		6:45	7:02	7:14	7:20
Bambalapitiya	BAM	4:59	5:26	5:29	6:07	6:09	6:40	6:49	7:07	7:19	7:24
Kollupitiya	KOL	5:03		5:33			6:44	6:53	7:11	7:24	7:29

5.4.1. Train movement data

The train movement data was collected using a GPS devises which records all Latitude and Longitude positions with 5Hz frequency. *Figure 5.4* shows the GPS tracking device the user interface of GPS tracking device.

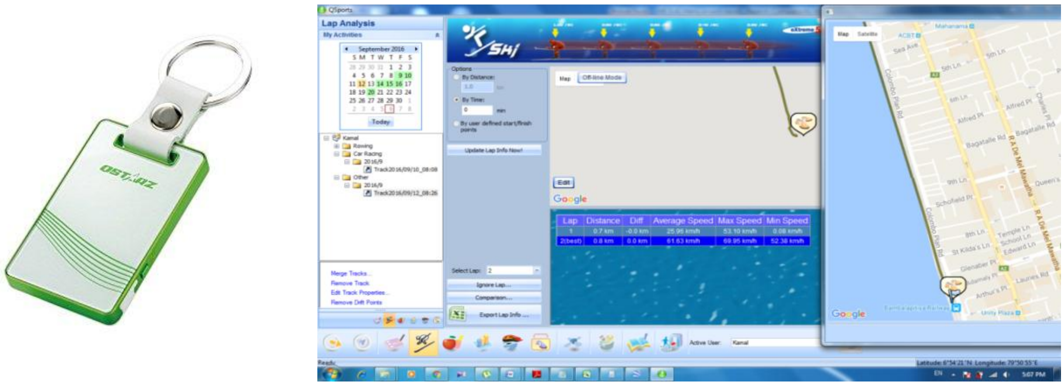


Figure 5-4 User interface of GPS device

Table 5-6 GPS Capturing Data

Lap	Distance (km)	Average Speed (km/h)	Max Speed (km/h)	Min Speed (km/h)	Lap	Distance (km)	Average Speed (km/h)	Max Speed (km/h)	Min Speed (km/h)
1	0	20	38	0	23	0.7	43	49	38
2	0.9	53	62	38	24	0.8	50	58	45
3	1.2	70	76	62	25	1.1	64	67	58
4	1.3	80	83	75	26	0.8	48	67	13
5	1.4	83	86	79	27	0.1	8	13	4
6	1.3	76	82	72	28	0.2	14	25	8
7	1	61	73	39	29	0.7	40	53	25
8	0.1	19	39	0	30	1	61	68	52
9	0.2	16	30	0	31	1.2	72	75	68
10	0.7	43	54	30	32	0.8	49	68	39
11	1.1	63	72	52	33	0.6	38	47	32
12	1	63	71	56	34	0.9	53	63	43
13	1.2	71	77	65	35	0.7	41	46	36
14	1.1	67	75	50	36	0.8	47	49	43
15	0.7	44	50	34	37	0.7	45	47	42
16	0.1	18	34	0	38	0.8	48	50	43
17	0.5	30	42	17	39	0.7	45	47	42
18	0.9	54	63	42	40	0.7	41	45	39
19	1.2	69	75	62	41	0.6	39	41	34
20	1.3	78	81	74	42	0.4	22	36	3
21	1.3	80	83	73	43	0.2	14	29	1
22	1.1	64	73	49	44	0.2	20	32	1

GPS capturing device provide Maximum, Minimum, Average speed and Distance which travelled by that particular Lap. The meaning of the lap is the recorder set particular time period for record the data, in this device lap timer is 60 seconds. *Table 5-6* contains imported data form capturing device. It has been captured 44 numbers of laps. According to capturing data the maximum actual speed was 86 km/h and average speed was 48 km/h. The maximum average speed was 56.6 km/h and minimum average speed was 38 km/h. these data has been used to calculate the average acceleration and deceleration. Average acceleration was taken by observing time during accelerate its cruises speed and deceleration was taken by considering time duration of stopping the train.

In this project minimization of travel time is also one of main objectives. The current time table clearly explained that it has some planned time to finish the journey. But during interview with rail passengers they had explained that only morning section trains are going under the plan and most of them are having delays. The main reason for that situation is heavy railway traffic during the peak time. Current plan is arranged with more than 10 trains within short period of time. As a result of that, if any train got late due to some disturbances whole time table will influence to the rest of the timetable.

In this study it was able to verify the maximum achievable running speed as86 kmh^{-1}. When achieving the 80 km/h in S class train,speedometer indicates by a red LED and alarm. In Table 8 shows the data which related to the maximum and minimum train and track. The railway track has been recently modified to 100 kmh^{-1} , but the current observation details show which speed is not still achieved by the train.

Considering the above data it is clear to say that more than 25 km is needed to accelerate and decelerate while travelling to KSS to COF for slow passenger train and also it has taken long time. This has direct effect to decrease the passenger popularity for SLR. This was clarified; other travelling disturbances must be minimized to improve the quality of the service. Every day every train is not able to arrive and depart in given time due to the disturbances, so that removal of disturbances should be further discussed under another research because this is very important area to be discussed.

5.5. Summaryof case study

It has successfully completed the rail passenger survey and it reflected some dissatisfaction of passengers, more than 95 % of passengers are regular passengers, there are significant delays during the journey, average time per kilometre is high etc. in addition to that rail passengers distribution of a day is also related only for regular passengers .when consider the railway time table it shows uneven schedule. Signal control distribution, station layout also to be considered.

Train moving data has been observed by the GPS capturing device and according to the data list it has proved the maximum speed is not reached by a train due to some disturbances and also according to that calculated acceleration and deceleration.

6 Computerised Model

As discussed in earlier chapters rail scheduling is not an easy task, it needed several time period to finalize the schedule. In addition to that, railway schedulers need high computational knowledge. Once they prepared a schedule, it is required to run through the railway system to check the errors such as conflict etc. Computerise simulated model will help to do this tasks.

6.1. Design Tree

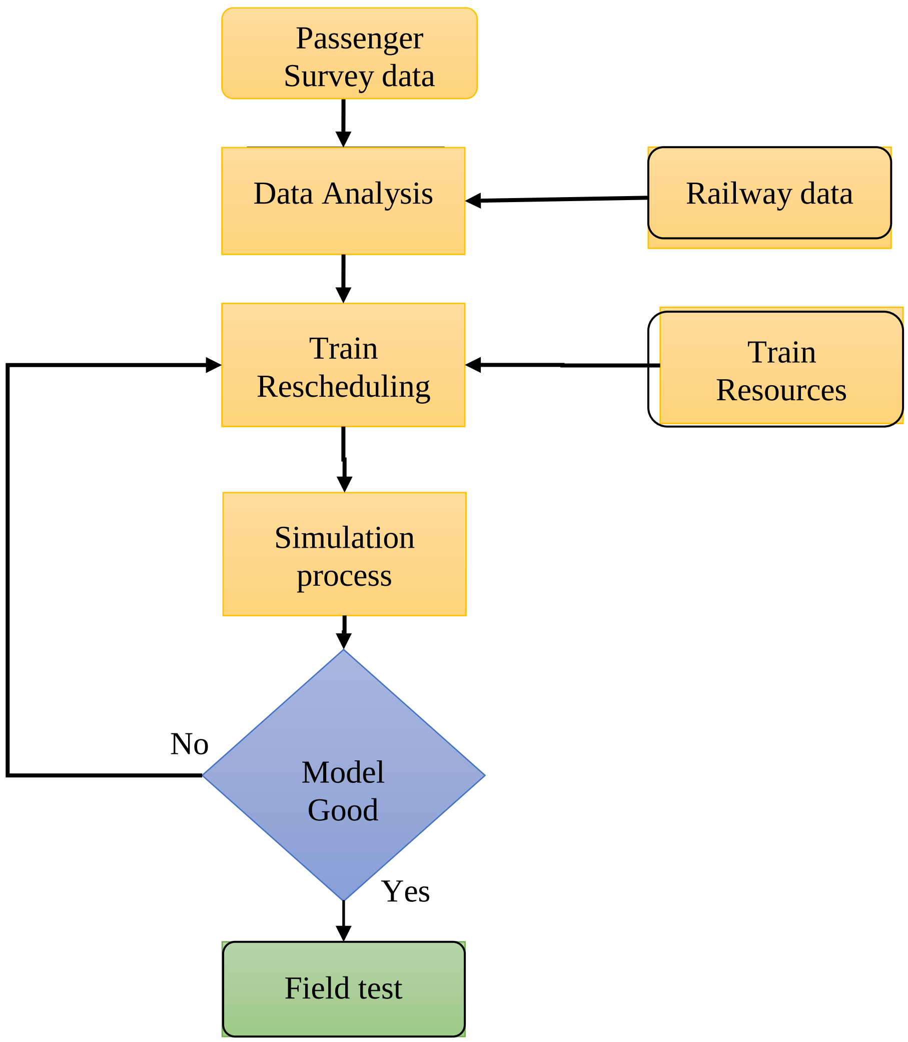


Figure 6-1 Design Tree

The model has been created by using several types of objects and symbols; they are running under JAVA platform. Identification of each part of the program will be helpful.

6.2. Objects in the program

6.2.1. Railway Track

One of themain objects in the railway is the railway track (See *Figure 6.2*), it is able to create by geographically or symbolically in the software. Distance between stations is proportional to length of the railway track. Once the object railway track creates in the drawing area, property manager related to the track will appear and it enabled to change its parameters.

6.2.2. Position on the track

After crating the the railway track it is needed to place in a special geograpic position on the track such as junction, stations, signal controllers and bridges. Anlylogic provides special object called position in the track (See *Figure 6.2*) and this object will help to improve controlability of the system while running.

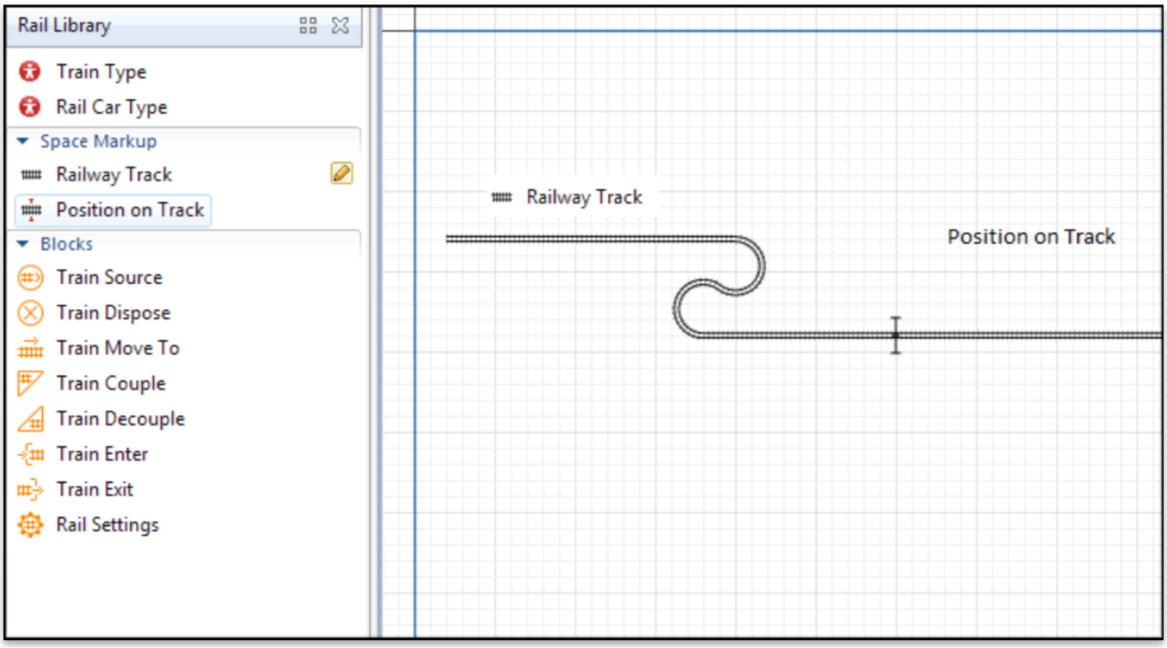


Figure 6-2 Railway Track and position on Track

6.2.3. Train source

Train sources are an object which generate a train in order to the schedule inthe given position of the track. The property manager of train sources can update several parameters of train such as train speed, number of locomotives, engine type, acceleration, deceleration, cruise speed, train arrival schedule etc. In this study train arrival schedule has been created mainly in two ways, first one is created according to the current railway schedule for each station and the other one is crated according to the newly proposed schedule.

6.2.4. Delay

These object delays entity for a given amount of time. The delay time is evaluated dynamically, may be stochastic and may depend on the entity as well as on any other conditions. Optionally, it may be calculated as the length of the animation path of the Delay divided by the "speed" of the entity. Multiple entities (up to the given Delay capacity) can be delayed simultaneously and independently.

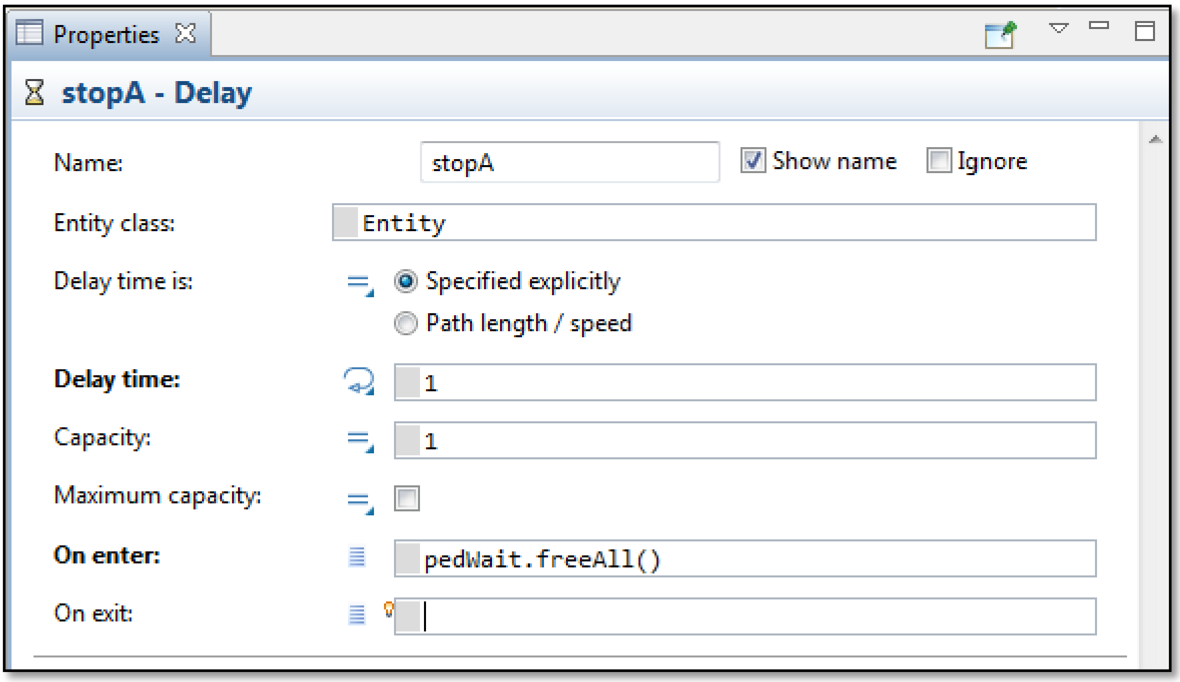


Figure 6-3 Properties of delay

According to the SLR time tables they have allowed 1 minute for passenger exchanging time. The property manager of delay is shown in *Figure 6.3*.

6.2.5. Pickup passengers

Removes entities from a given queue object and adds them to the contents of the incoming entity ("container"). The queue object may be either connected to the in Pickup port of Pickup or specified in the parameter queue (the latter has priority oven connected object). When an entity arrives at the in port, Pickup iterates through the contents of the queue and selects the entities according to the given mode, which can be: all entities, first N entities, entities for which the given condition is true. The whole operation takes zero time.

In this case predefined data were used for pickup passengers to the train compartment. Property window of the pickup property manager is shown in the *Figure 6.4*.

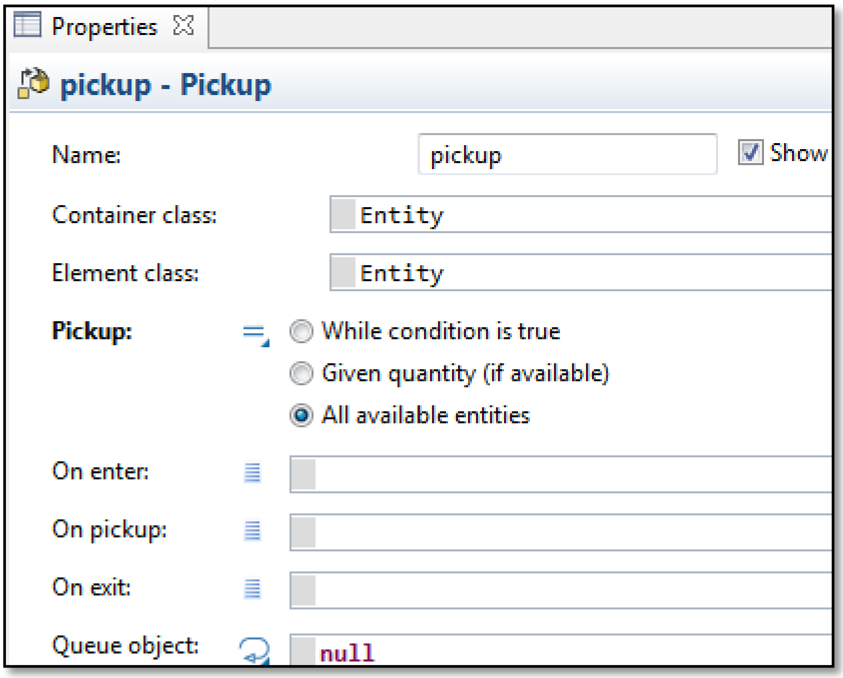


Figure 6-4 Pickup Properties

6.2.6. Train moving

The train can move forward (first car in front) or backward. The train can have a target position where it should get, or just move without a target. In the latter case the train agent will exit TrainMoveTo either when it leaves the rail yard via an open-ended track, or if it hits another train. We cannot manually stop the train while it is moving. The train can move without a pre-defined route, i.e. just follow the current states of switches, or can specify the route explicitly, or we can ask TrainMoveToto calculate the route automatically from the current location to target. We can optionally ask the train to accelerate to a given speed at the beginning of movement and to decelerate to stop at the target.

The property manager of Trainmoveto is shown in *Figure 6.5* and which had set direction as forward and route calculate automatically. Track is the polyline which created before and in here we can set the acceleration and deceleration also as start and finished options.

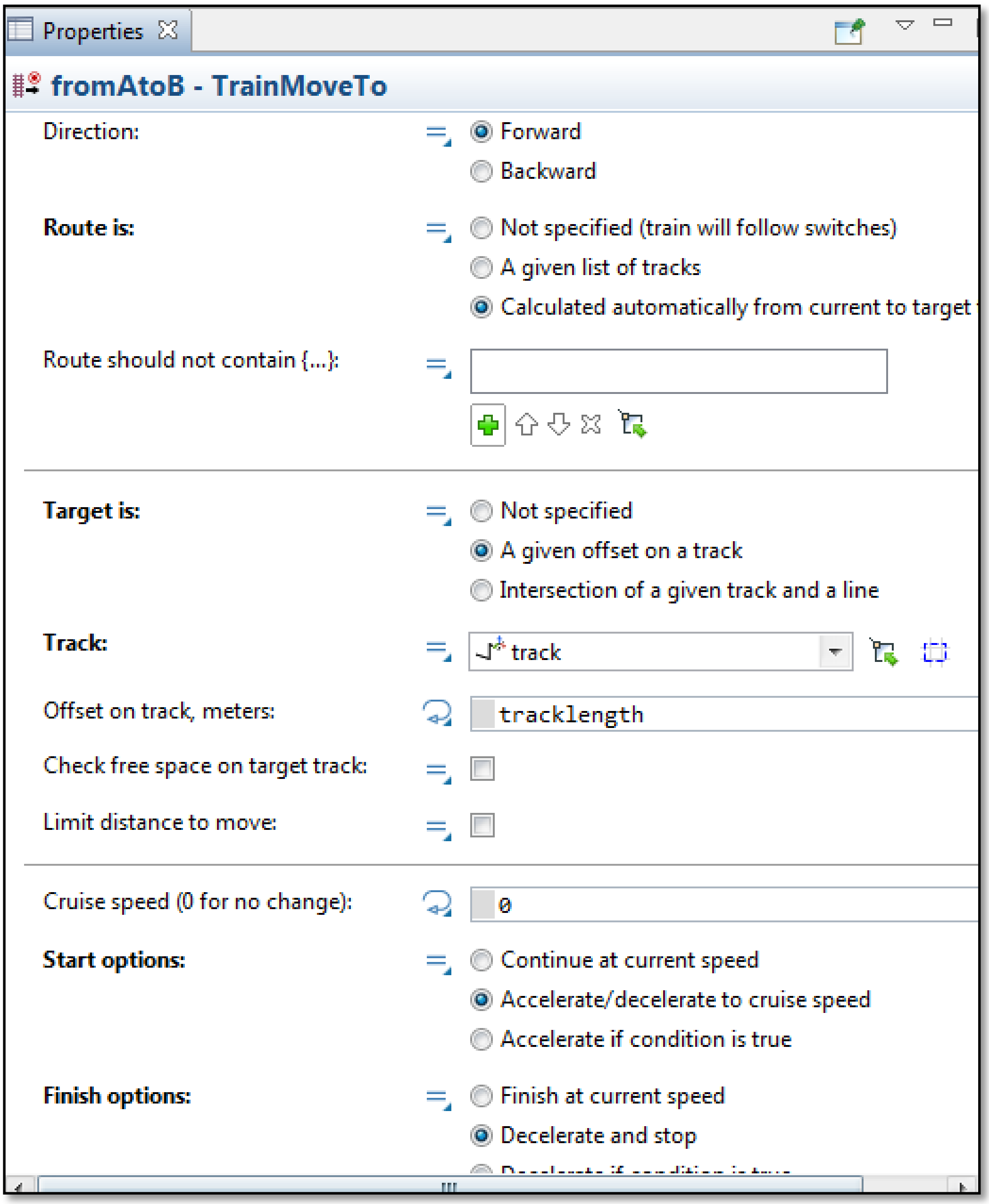


Figure 6-5 Properties window of TrainMoveTo

6.2.7. Passenger drop

Removes the entities contained in the incoming "container" entity and outputs them via out dropoff port. Similarly to the Pickup object that is used to add entities to the container, here entities are removed according to the given mode: all, a given number, or all satisfying the given condition. The whole operation takes zero time. In this study is not consider the capacity of a train because put droff off quantity as default valve. See *Figure 6.6* for the property manager of drofoff.

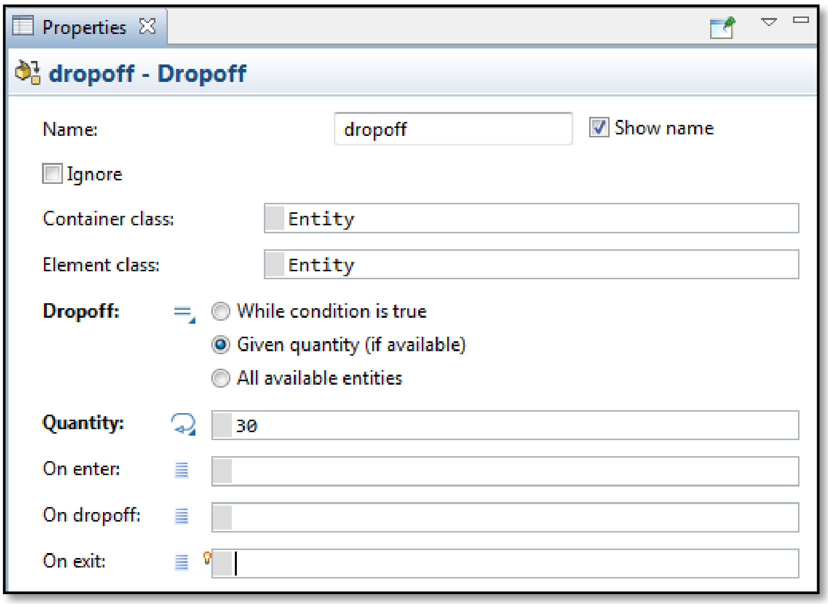


Figure 6-6 Properties window of dropoff

6.2.8. Train dispose

This is the termination point of train which removes a train from the model. There are two ways a train can be removed: it can move out of the rail yard via an open-ended track, in which case TrainDispose should follow the last TrainMoveTo block that was controlling the train, or it can "disappear" from any location in the rail yard, provided it is not moving. TrainDispose (and not Sink or Exit) must be used to remove any trains.

6.2.9. Pedestrian configuration object

This is the main object of the pedestrian library. This object must be put onto diagram in each Anylogic model using pedestrian library. Ped configuration object allows specifying general parameters related to all objects in ped library. *Figure 6.7* is the window of pedconfigauartin property manager. It is possible to change its parameters as required.

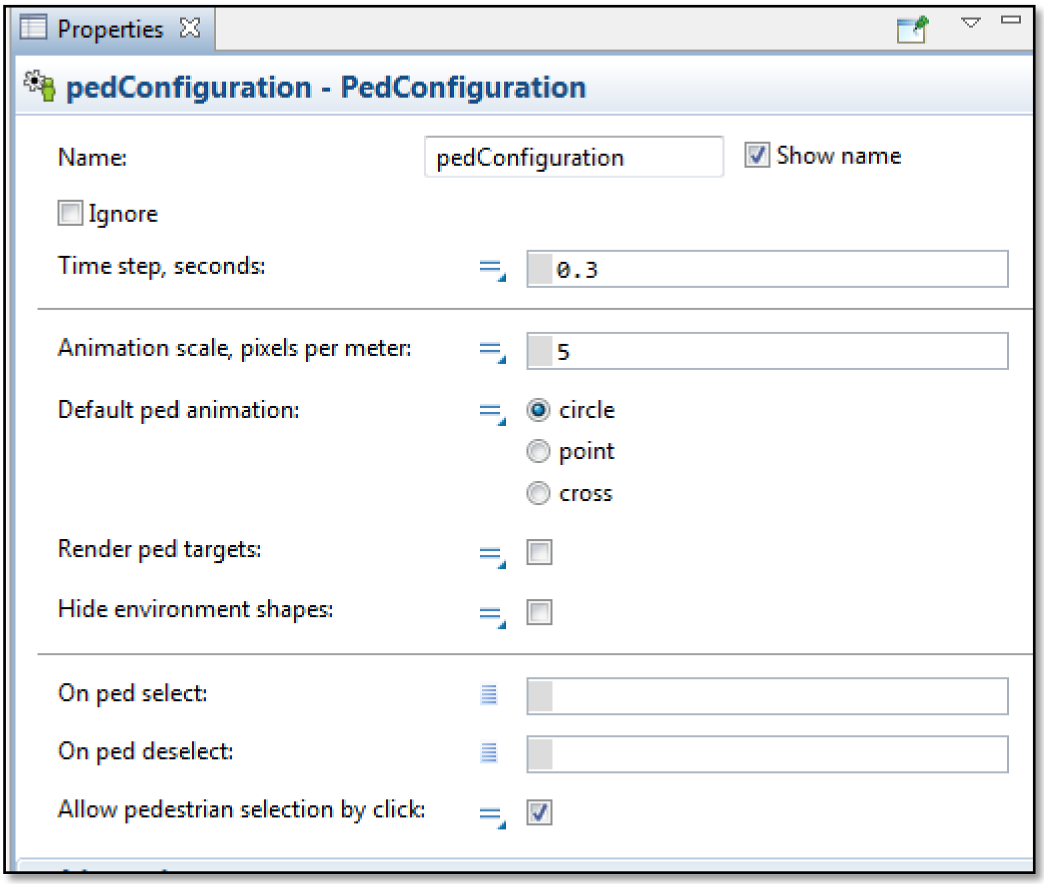


Figure 6-7 Ped Configuration Properties

6.2.10. Pedestrian waiting area

PedArea allows ground move effect. All pedestrians speed is evaluated relative to ground speed. Use this featured relative to ground speed. Use this features to simulate escalates and moving lines. In *Figure 6.8* shows the property manager of pedarea, this object allows to select a area to wait for passengers.

6.2.11. Pedestrian generation

Pedsource Generates pedestrians and which is usually used as a starting point of the pedestrian flow. Pedsource can produce pedestrians of a custom pedestrian type with arbitrary flow intensity. This block also can be used to generate groups of pedestrians. Allows defining multiple criteria for groups creation - group size, form, groups arrival rate, pedestrian interarrival delay, etc.

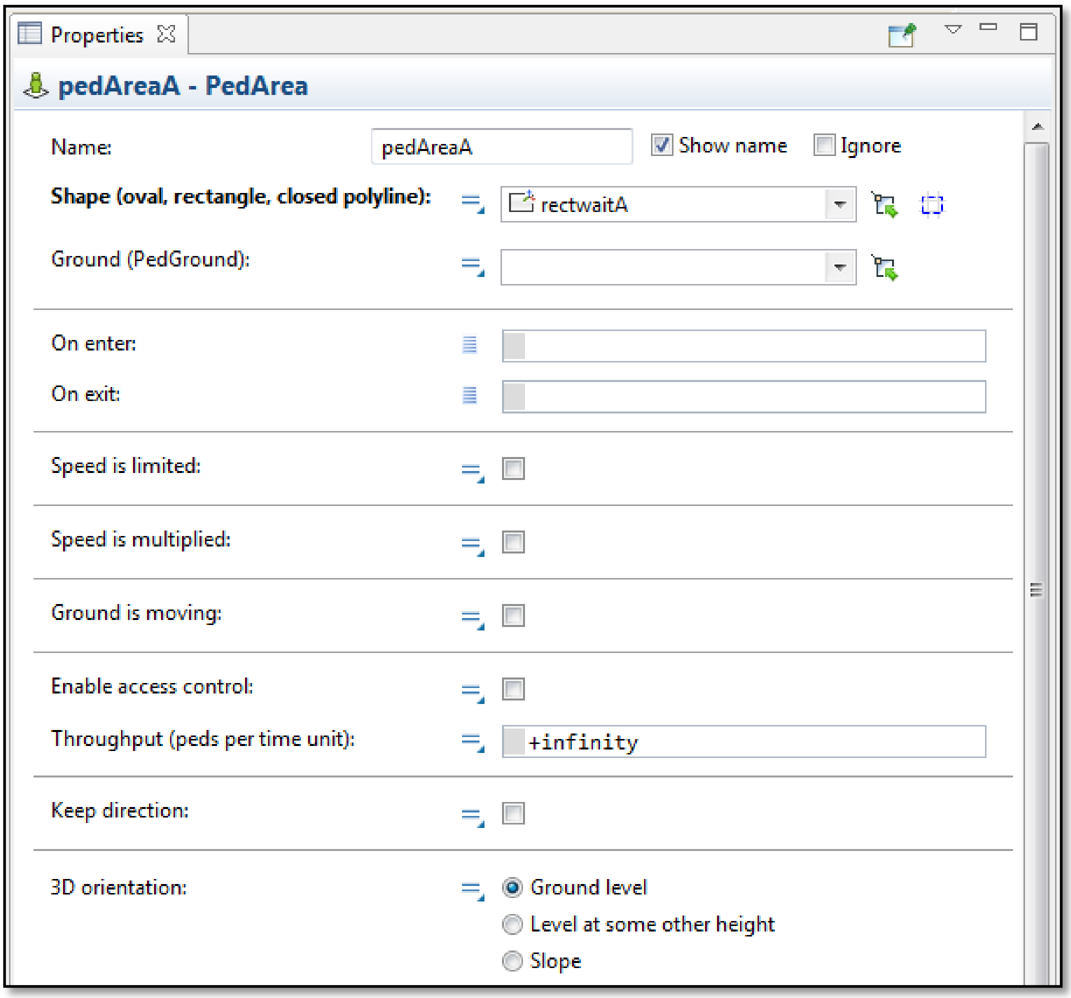


Figure 6-8 Property window of ped Area

There are a number of ways to define when and how many pedestrians (or groups of pedestrians) should be generated. You can use arrival rate (and change it dynamically by calling set_rate), interarrival time, rate defined by a schedule, schedule of exact arrival times and quantities, and you also can programmatically call the inject method of this object. For example, a Poisson steam of arrivals can be implemented by choosing arrivals with a certain rate, or by specifying the exponentially distributed interarrival time. You can also set the number of pedestrians in each arrival and limit the total number of arrivals.

In the *Figure 6.8* displays the property manager of pedsource and which can predefine pedestrian generation as Rate or schedule. In here we have set pediatricians arrival as schedule.

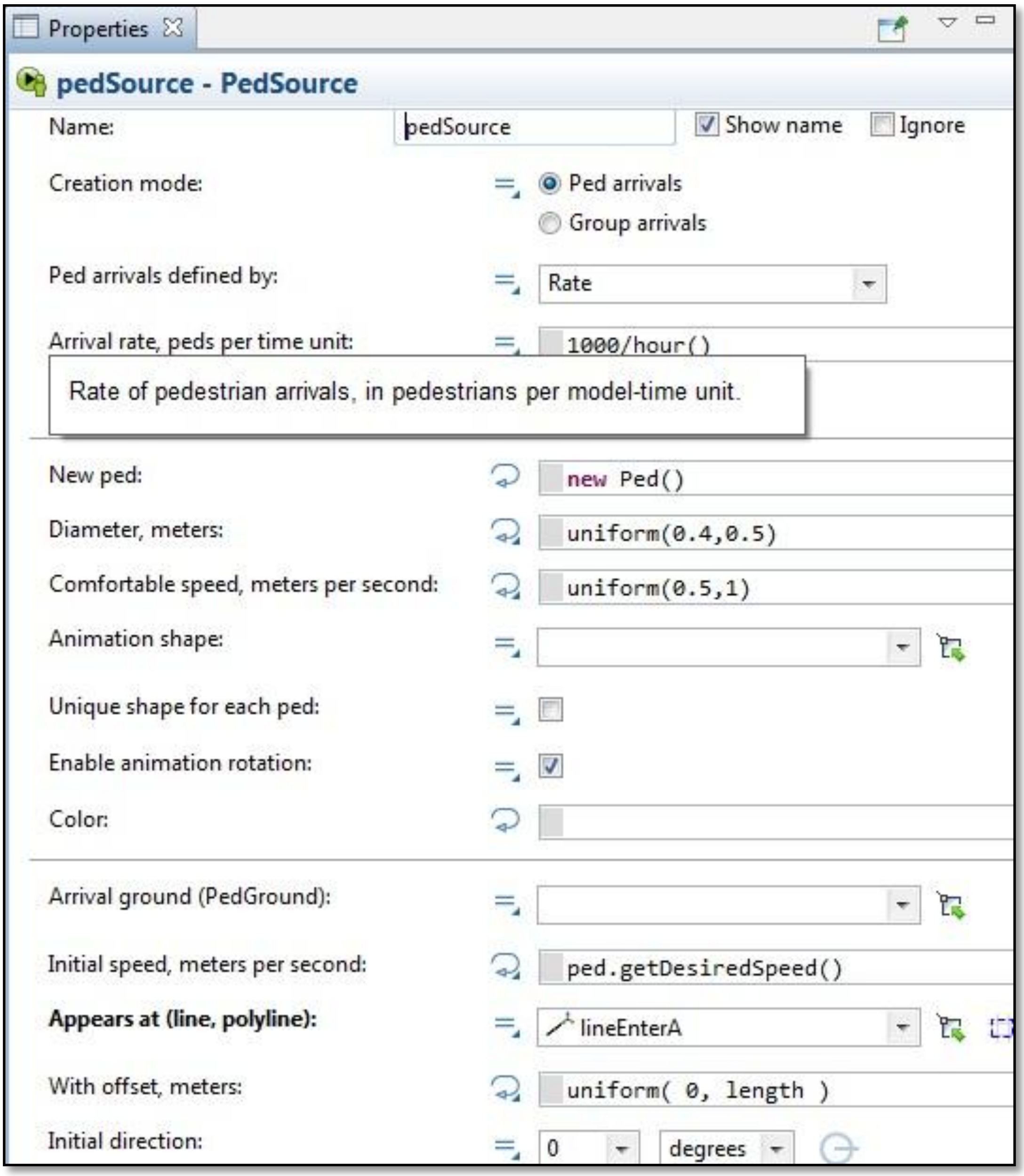


Figure 6-9 Property Window of pedsources

6.2.12. Ped select output

Routes the incoming pedestrians to one of several (up to five) processes depending on specified ratios or conditions. Each process has to be defined with its own flowchart connected to one of the block's output ports.

Routing according conditions works as follows: first, Condition 1 is checked. If it is true, ped leaves the object via the first output port. Otherwise, next condition is evaluated, checking, whether the ped should leave the object via the port out2, and so on. If no one from the defined conditions is true, ped leaves the object via the last port out5.

Routing according probabilities works in the following way: if, e.g. Probability 1 is 5, Probability 2 is 1 and Probability 3 is 4, pedestrians will use these three ports with average probabilities 0.5 , 0.1 0.4. *Figure 6.10* is the property manager of ped select output. As given weight of the passenger arrival rate set two inputs to both stations.

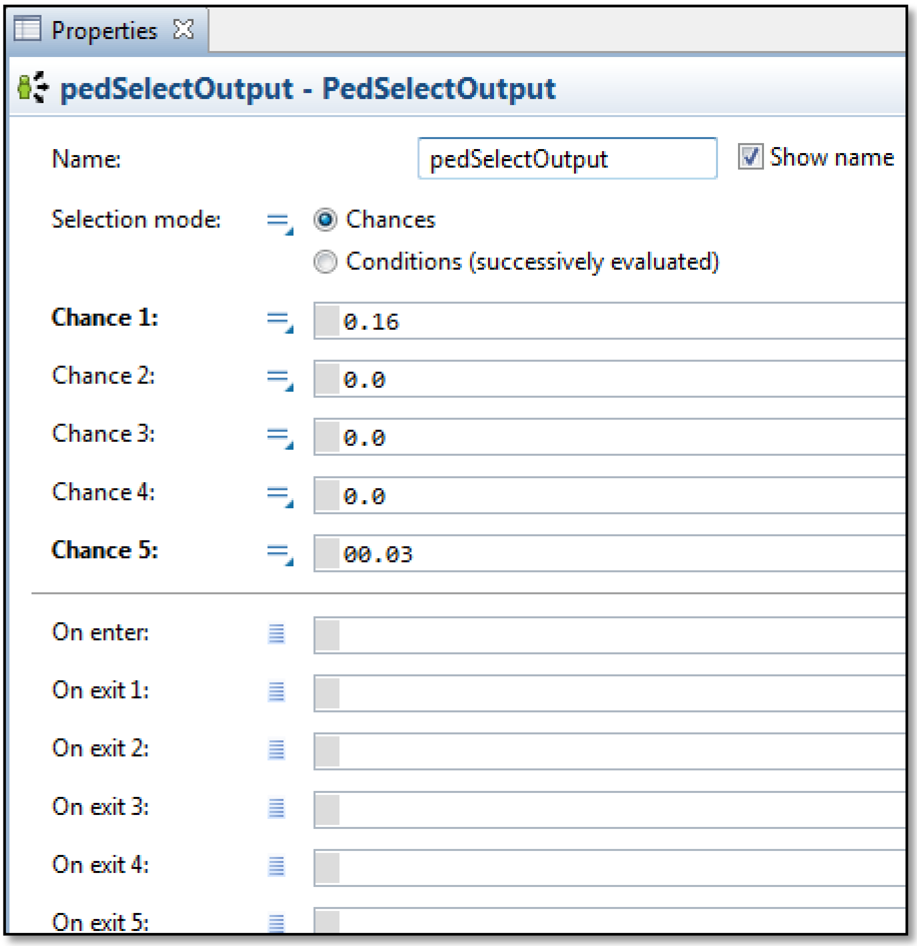


Figure 6-10 Properties windows of Selectoutput

6.2.13. Pedestrian waiting (Pedwait)

Causes pedestrians to go to the specified location and wait there for a specified period of time. Location can be defined by a target line, area or a point with given coordinates. If the location is area, you can specify exact waiting points inside it using attractors. Attractors are locations within the area, which will attract pedestrians during their stay. In Figure 6.11 selected area to wait in as previously defined pedAreaA.

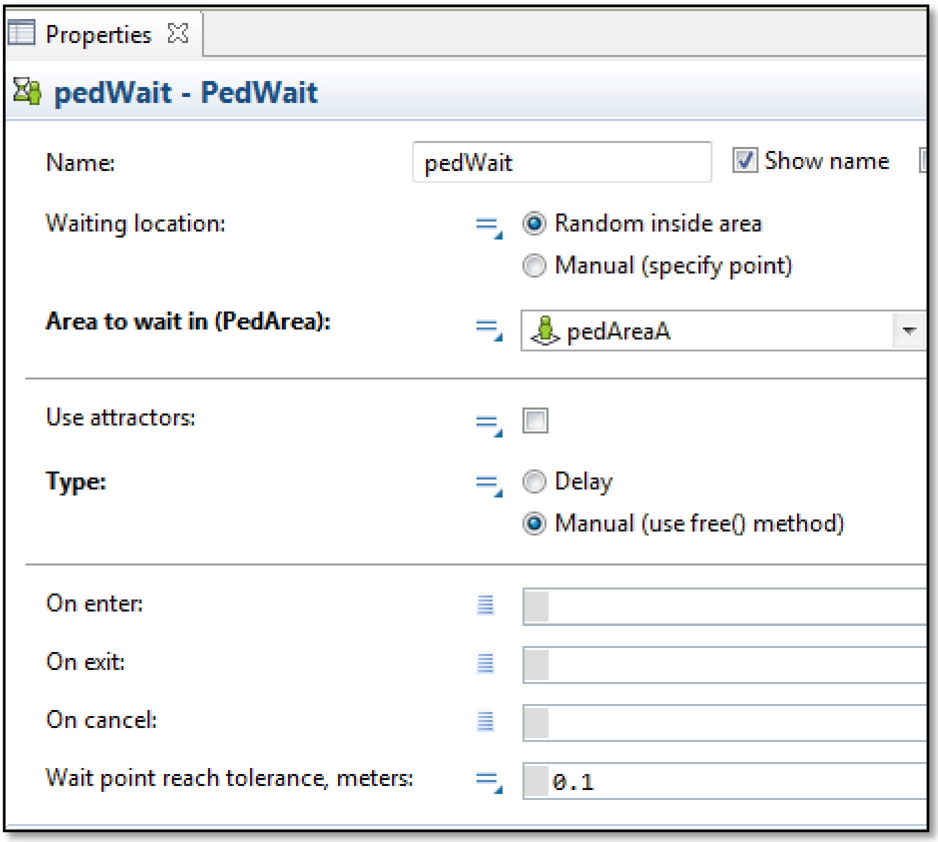


Figure 6-11 Property Window of Pedwait

6.2.14. Pedestrian go to (pedgoto)

This objects Causes pedestrians to go to the specified location. Location can be defined by a target line, area or a point with given coordinates. The pedestrian has to reach a given a given point, or any point of the specified line, or area. Pedestrians find path to the specified destination within current ground.

There are two path choice modes: Reach target and Follow route. In Reach target mode the path is automatically calculated by the library. Use this mode when you do not want draw a route by yourself. However, if your environment either has numerous walls and borders, or if they make up a maze, it will take plenty of time for the algorithm to calculate the shortest path. In these cases we recommend to define paths manually using the Follow route path choice mode. It has selected target line near station see *Figure 6.12* for the property widow of pedgoto object.

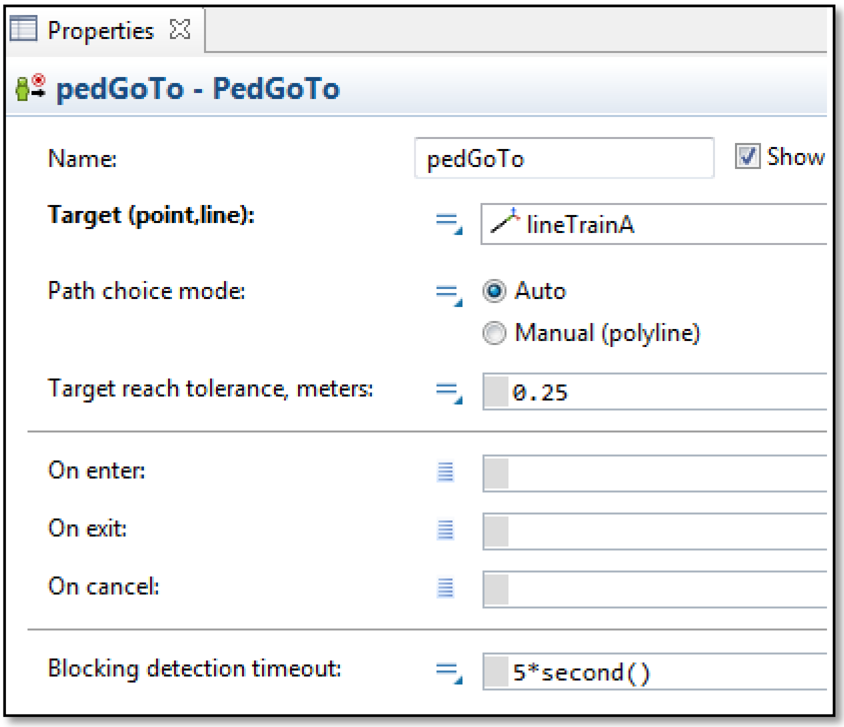


Figure 6-12 Property Window of ped goto

6.2.15. Pedestrian exit (Pedexit)

The model needed to Removes pedestrians from the simulated environment and sends them further via output port.

6.2.16. Queue

Queue (a buffer) of entities waiting to be accepted by the next object in the process flow, or a general-purpose storage for the entities. Optionally, you may associate a maximum waiting time with an entity. We can also remove entities programmatically from any position in the queue.

The queuing discipline may be FIFO or priority-based. The priority may be explicitly stored in the entity or calculated based on the entity properties and external conditions. A priority queue always accepts an incoming entity, evaluates its priority and places it at the corresponding position in the queue. If the queue is full, the new entity may then cause the last entity to be thrown out of the queue via out Pre-empted port, or may it immediately proceed there if its priority is lower or equal the priority of the last entity. In case a timeout is associated with the entity, it will exit via out Timeout port if the maximum waiting time is reached. The Queue object has several extension points, in particular you can execute the custom actions when the entity enters the queue, exits the queue via any of the three ports, and appears at the first position of the queue. Please note that when on Enter is executed, the entity is already placed in the queue. When on Exit, or on Exit Timeout, etc. are executed, the entity is already removed from the queue.

Capacity of the queue can be changed dynamically. The entities in the queue may be animated as standing one behind the other (animation type Path) or as staying at the specified positions. Property manager of queue is displayed as *Figure 6.13.*

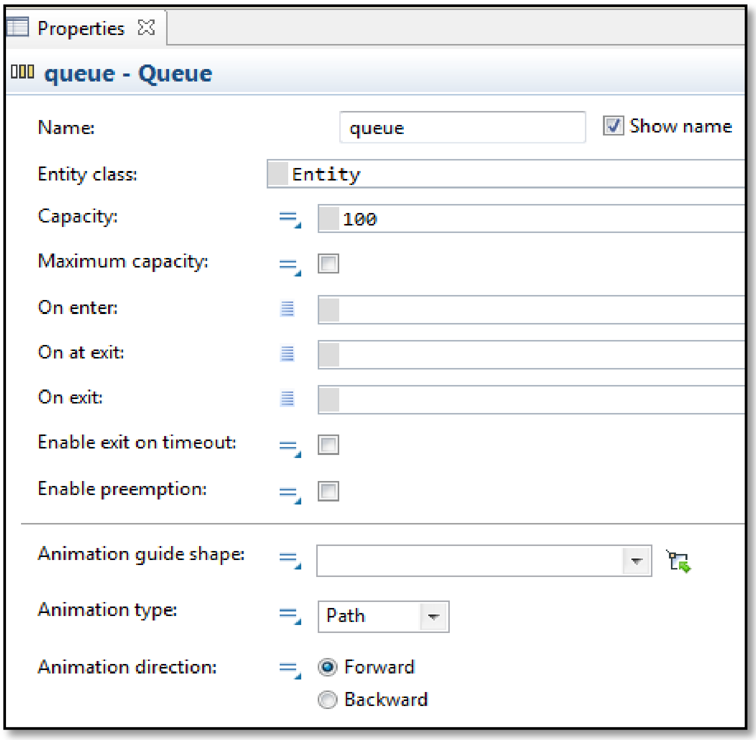


Figure 6-13 Property Window of Queue

6.2.17. Pedestrian enter

Accepts pedestrians generated somewhere at input port, assigns their physical parameters and injects pedestrians into the simulated environment at specified location.

This object also can be used to organize groups from sequence of pedestrians on input port. Allows defining multiple criteria for groups' creation - group size, form, groups arrival rate, pedestrians interarrival delay, etc.Also, this object can be used to change pedestrian parameters like speed, colour, diameter, etc. see *Figure 6.14.*

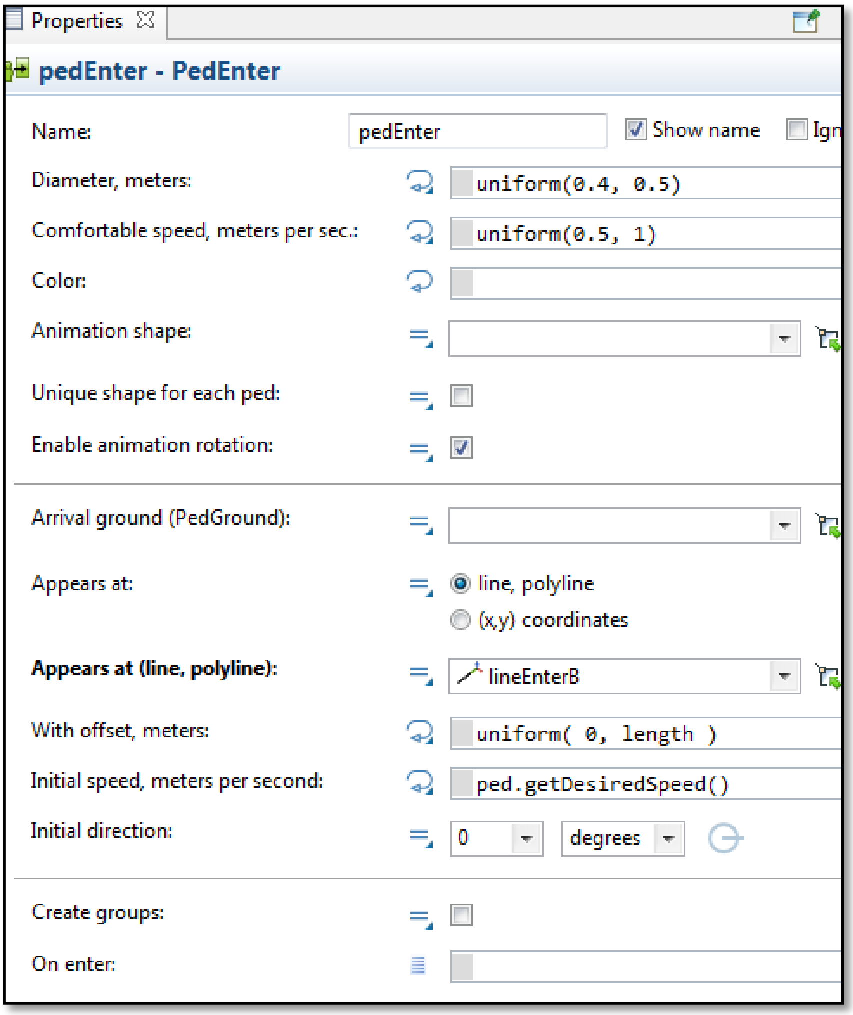


Figure 6-14 Properties windows of ped enter

6.2.18. Termination of pedestrian

Pedsink disposes incoming pedestrians and it is usually used as an end point of the pedestrian flow.

6.3. Simulation

The model can be tested on a computer and it can clearly see the simulation environment. Problems during the simulation can be observed and analyze them, the Anylogic parameters can change and see the result before go to actual environment. This study was done in actual section of railroad for Kalutara South to Colombo Fort. The rail corridor contains 20 Stations and nearly 50 trains are scheduled on the busiest days of the week. The two types of train are scheduled under one time table such as passenger and locomotive hauled passenger trains. Each train class has a different maximum achievable velocity. For the purposes of this paper it is assumed all sidings are sufficiently long to accommodate any train size. The Model the efficiency of the algorithm will allow the rapid updating of an optimum solution whenever an unexpected delay occurs.

Generally the priorities of rail passengers are office employees, very few amount of irregular passengers are using the railway. According to the current timetable it clearly shows irregular pattern of trains as well as very difficult to memorize the time table. Only people who know train schedule are offices employees. Due to that irregular pattern passengers do not like to use railway for their transportation requirements. Most of trains are scheduled for morning session, after 9:00 AM it is very difficult to catch a train. According to above information it has a clear requirement of a new train schedule. In this study I have tried to introduce train schedule in regular intervals.

There will be some problems and issues when a new time table is introduced; the main thing is high passenger demand of week-day morning. In this study, I suggest to increase the compartments of a train with the demand. It can be clearly understood by considering capacity of waiting area of the station. This model has an advantage to reschedule the train length with the passenger demand.

6.4. Summary

It is concluded that train movement and passenger behaviourwill be able to be modelled by using AnyLogic Software. It is able to add some algorithm discussed in literature. During the simulation of the model shows current status of each object and those data can be used to develop a train schedule with optimum solution. The objects could be selected according to the current situation of the system. Some of the objectswhich were used in the model are supporting objectives of the main program.

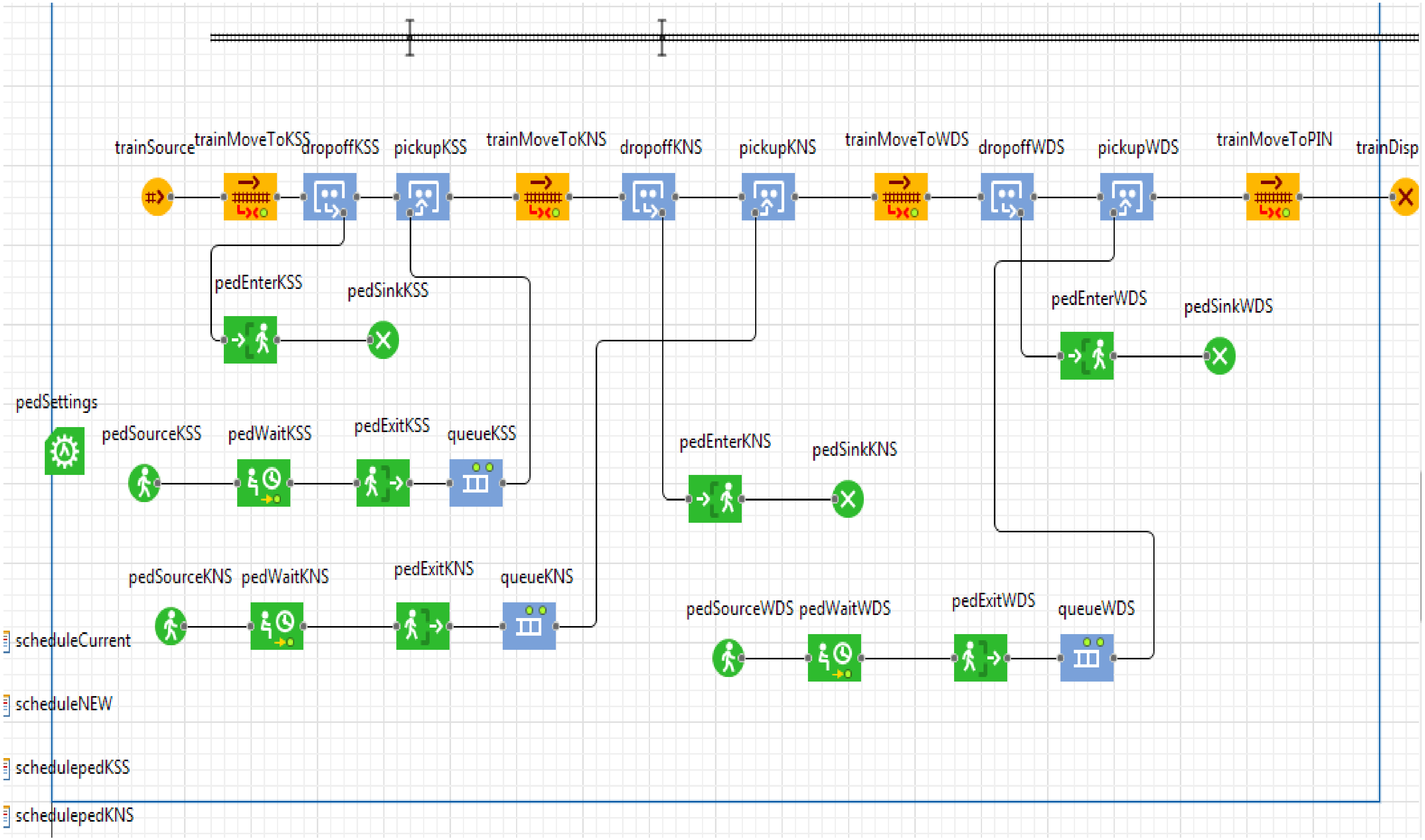


Figure 6-15 Model for two stations

7 Results and Discussion

7.1. Identified issues in current railway operations

Issueswhich identified during the literature review and the survey need to be properly analyzed to improve the transport servicein Sri Lankan. Current railway Time table was developed due to passenger demand and with respect to the railway resources so that several trains run during the peak time and very little trains are running at the normal time. It seems the capacity of the trains not enough to fulfil the demand at the peak time and also it has over capacity during the normal time. Survey was concluded that train speed is not enough, delays are not abnormal, most of train users are regular and office employees,time table is not able to remember and irregular, ticket issuing rate is not satisfied and high passenger queuing time.

Table 7-1The current Railway time table

Train No	**8302**	**4021**	**8304**	**4077**	**8309**	**8311**	**8310**	**8317**	**8316**
Station									
KSS	3:52	-	4:22	-	5:02	5:36	-	5:56	-
KNS	3:57	-	4:27	-	5:07	5:41	-	6:02	-
WDS	4:09	-	4:39	-	5:19	5:53	-	6:13	-
PIS	4:14	-	4:44	-	5:24	5:59	-	6:19	-
PNS	4:19	-	4:49	-	5:29	6:05	6:10	6:25	6:30
EUS	4:25	-	4:55	-	5:35	-	6:15	-	6:36
KWS	4:28	-	4:58	-	5:38		6:18	-	6:40
MOR	4:32	-	5:02	-	5:42	6:17	6:23	6:37	6:45
LUN	4:36	-	5:06	-	5:46	-	6:26	-	6:50
ANG	4:39	-	5:10	-	5:49	-	6:29	6:42	6:54
RTH	4:42	5:10	5:12	5:50	5:52	6:26	6:33	6:46	6:58
MTL	4:46	-	5:16		5:56	-	6:36	6:51	7:03
DHS	4:50	5:13	5:20	5:53	6:01	-	-	6:56	7:08
WWS	4:55	5:18	5:25	5:58	6:05	-	6:45	7:02	7:14
BAM	4:59	5:26	5:29	6:07	6:09	6:40	6:49	7:07	7:19
KOL	5:03	-	5:33	-		6:44	6:53	7:11	7:24
SIS	5:06	-	5:36	-	6:16	6:48	6:56	7:16	7:29
SEC	-	-		-	6:19	6:51	6:58	7:18	7:32
COF	5:10	5:35	5:40	6:17	6:22	6:54	7:02	7:22	7:35

7.1.1. Railway timetable

Sri Lanka railway train schedule is currently available in the internet and it provides train details, distance, date and time, price of the ticket in each class and classes available. *Table 7.1* current train time table form Kalutara South to Colombo Fort and the complete the time table is in Appendix 1.

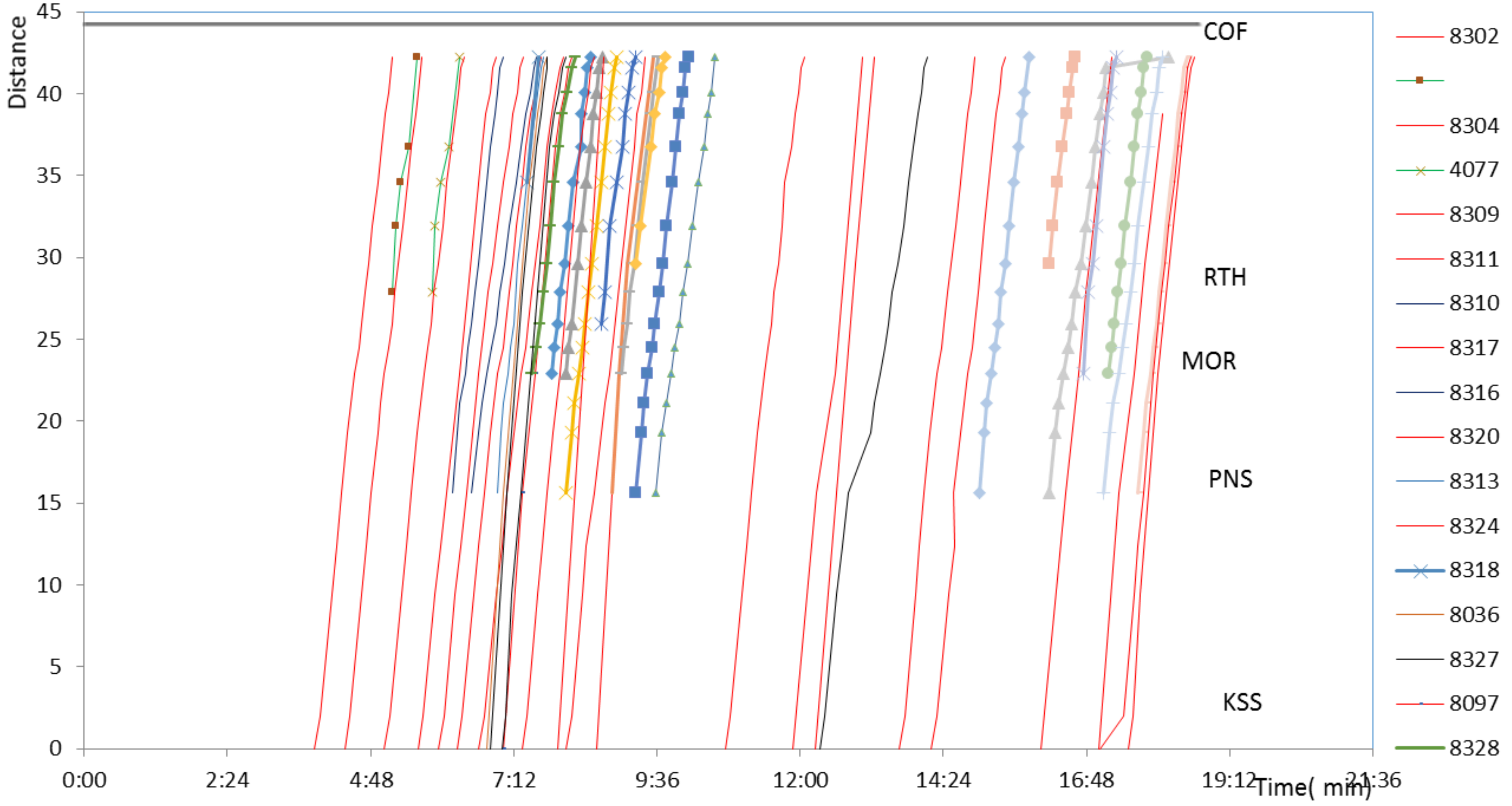


Figure 7-1 Graphic time table for Kalutara South to Colombo Fort

7.2. Identification of peak demand

Figure 7.1 graphically illustrate the current timetable for one way and according to that graph it is clear to say that irregularity of railway schedule and peak passenger demand Passenger demand has been identified by the survey as discussed in previous chapter. The peak demand time can be identifying*Figure 7.2*. In the morning 5:30 AM to 8:00 AM time is the busiest time of the Kalutara Southto Colombo Fort railway track. Passenger arrival rate has been identified by photo graph crate with the time. *Table 7.2* contains the data of passenger arrival rate for 5 minute intervals. Then the study was focused the peaked range to schedule with the computerized simulation.

In the morning hours of week days, more than 90 percent of passengers go for work or for studies that means they are regular users. Due to that morning of the day has highest peak in all starting stations. But in the case study, passenger survey verified that the passengers are travellingwith uncomfortable conditions, because of limited space in the trains such - as all the trains fully packed in the morning.

7.3. Computerised model creation

The one of the objectives of this study is to develop a computerized simulation model. Model is mainly used to simulate passenger movement and it is able to give the outcome such as passenger queuing time. Passenger queuing time is the one of the parameters which is able to measure the train schedule. The simulation software is able to simply creation of a model for train movement and passenger movement but it needed several parameters to control before run.

The important parameters in the train scheduling are train speed, passenger arrival rate, train capacity and length, acceleration, deceleration, track length, and the days. As explained in the previous chapter these parameters are able to change as per the requirement of the model. The software gives additional feature to simulate the model visually. Tacking out generate by the simulation, finally it has clarified the passenger queuing time as measuring parameter for this research.

Table 7-2 Passenger Count of week day for five stations (30 min)

Time	Number of Passengers			
	KSS	KNS	WDS	PAN
5:20:00 AM	10	3	8	15
5:25:00 AM	15	4	11	23
5:30:00 AM	20	5	15	30
5:35:00 AM	25	6	19	11
5:40:00 AM	10	10	20	15
5:45:00 AM	18	5	20	20
5:50:00 AM	21	8	25	35
5:55:00 AM	20	10	20	38
6:00:00 AM	19	14	24	42
6:05:00 AM	33	8	28	50
6:10:00 AM	52	13	39	78
6:15:00 AM	50	13	38	75
6:20:00 AM	20	20	40	75
6:25:00 AM	25	20	42	80
6:30:00 AM	40	24	40	85
6:35:00 AM	60	30	45	90
6:40:00 AM	80	35	60	120
6:45:00 AM	125	34	94	188
6:50:00 AM	140	35	105	210
6:55:00 AM	175	44	131	263
7:00:00 AM	190	48	143	285
7:05:00 AM	200	50	150	300
7:10:00 AM	195	20	146	293
7:15:00 AM	180	35	45	270
7:20:00 AM	150	38	54	200
7:25:00 AM	15	42	65	222
7:30:00 AM	15	4	60	220
7:35:00 AM	15	5	65	115
7:40:00 AM	20	5	15	151
7:45:00 AM	30	6	25	165
7:50:00 AM	30	7	28	45
7:55:00 AM	30	8	35	51
8:00:00 AM	30	10	34	48

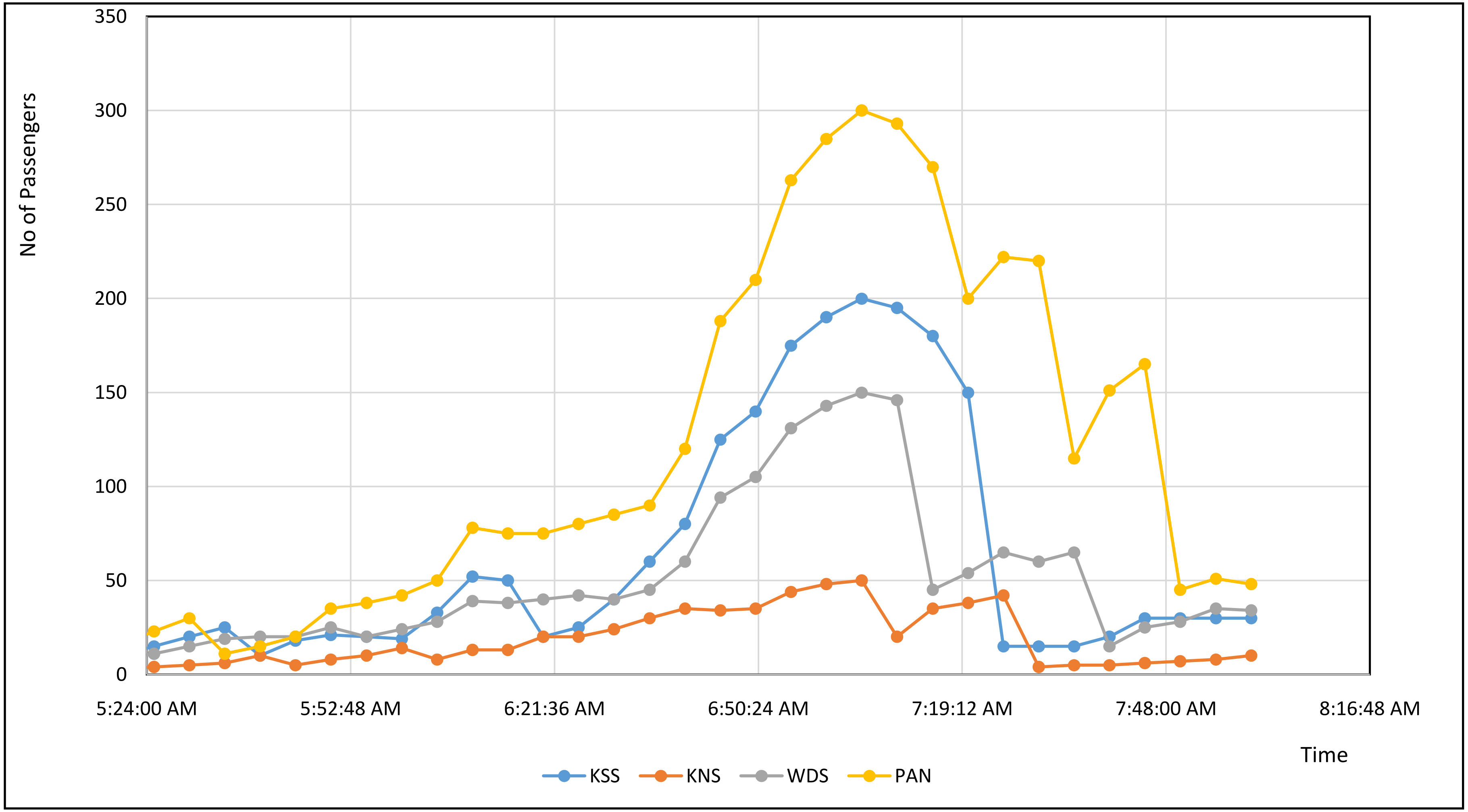
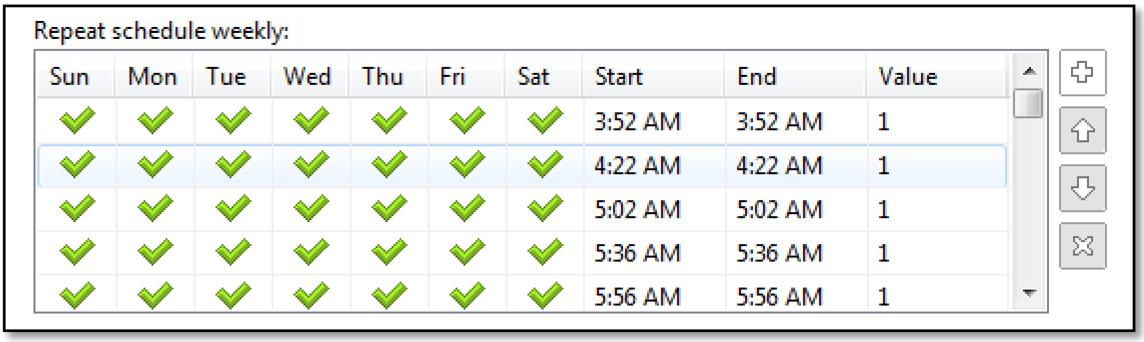


Figure 7-2 Passenger demand curve with time

7.3.1. Required input parameters

- **Train schedule**

Basically schedule is required to start train movements; schedule for the train couldcreate as per the time. In this case train schedule has been created to simulate the current rail way system and the proposed system. *Figure 7.3* illustrates the schedule for the current railway system. The digital train schedule of the model is able to create a train on the given position of the railway track such as , if the time reach the schedule gives an output value to the system and train source create a train as per the given instruction also it appears at the railway track. For the simulation the schedule has been developed only for the weekdays.



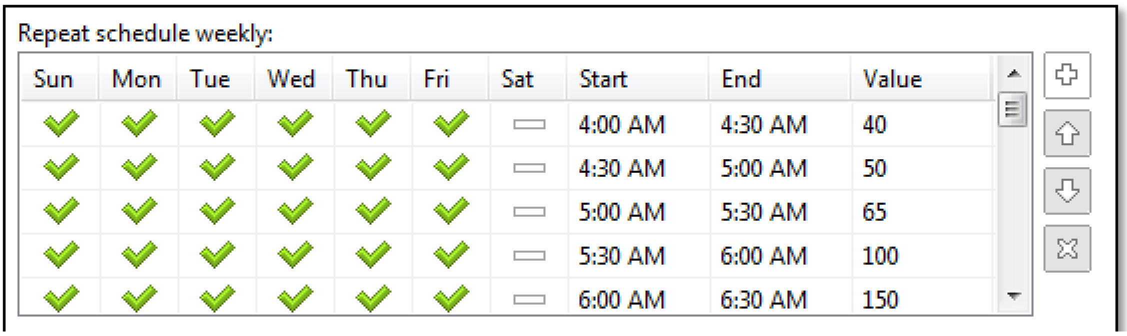
Repeat schedule weekly:

Sun	Mon	Tue	Wed	Thu	Fri	Sat	Start	End	Value
✓	✓	✓	✓	✓	✓	✓	3:52 AM	3:52 AM	1
✓	✓	✓	✓	✓	✓	✓	4:22 AM	4:22 AM	1
✓	✓	✓	✓	✓	✓	✓	5:02 AM	5:02 AM	1
✓	✓	✓	✓	✓	✓	✓	5:36 AM	5:36 AM	1
✓	✓	✓	✓	✓	✓	✓	5:56 AM	5:56 AM	1

Figure 7-3 Schedule created for current railway time table,

- **Passenger arrival schedule**

Another important inputis passenger arrival schedule, actually this could not take schedule but according to the data, passenger arrival rate can be forecast as a data for the passenger arrival schedule has been captured during the railway survey. The *Table 7.2* represent the average data captured form passenger arrival rate of the week day form 5:30 AM to 8: 00 AM. Those data contain passenger details of five stations such as Kalutara South, Kalutara North, Wadduwa and Panadura. If the time reach, the schedule gives an output value to the system and ped source crate a passengers as per the given instruction also it appears at the railway track. *Figure 7.4* illustrate the Kalutara South passenger arrival rate for 30 minutesinterval.



Repeat schedule weekly:

Sun	Mon	Tue	Wed	Thu	Fri	Sat	Start	End	Value
✓	✓	✓	✓	✓	✓	☐	4:00 AM	4:30 AM	40
✓	✓	✓	✓	✓	✓	☐	4:30 AM	5:00 AM	50
✓	✓	✓	✓	✓	✓	☐	5:00 AM	5:30 AM	65
✓	✓	✓	✓	✓	✓	☐	5:30 AM	6:00 AM	100
✓	✓	✓	✓	✓	✓	☐	6:00 AM	6:30 AM	150

Figure 7-4 Passenger arrival schedule of Kalutara South station

- **Capacity of train compartment**

There are different types of train models in SLR and those can be categorized mainly as two types such as general locomotives and Push pull types. In costal line SLR use S model push pull type for passenger transportation due to high passenger capacity rate in one compartment.

This survey was done for train number 8333 and it is Indian manufactured Class S11 train. This train was started 7:20 AM form KSS. Maximum velocity of the train observed as77 km/h. This type of train has rapid acceleration and deceleration, but many disturbances faced during the journey due to speed limitation, constriction and railway condition ect. Generally it has taken average 1 minute for acceleration and 0.45 minutes for deceleration. Four numbers of surveyors were involved for this study and they have stayed at three different compartments in the subjected train. The big issue of this survey was that some passengers are travelling through the compartments, so passenger count was assumed with no crossing through the compartment.

The capacity of the train is a factor which directly influence to the passenger queuing time. In this study data were obtain by only form the DMU such as S9, S10 and S11 because during the testing time period these were the trains running in coastal line from Kalutara South. In the class 09 type train wagon has an average of ten coaches, each S 10 and S 11 are having a seating capacity for 90 passengers thus; the total number of passengers is about nine hundred (900) excluding the standing passengers. The standing passengers per coach were about 70 passengers. Consequently, about 700 standing passengers were on the train. Assume that the 2nd class compartments also as a 3rd class compartment in capacity.

- **Length of The Train**

In the coastal railway, trains contain either one or two DMU or totally 10 complete passenger compartments with fully capacity. Most of trains are coupled with two DMU few trains are only single DMU.

- **Queuing Length**

Queuing length is representing passenger waiting time. As previously discussed queuing length mainly depends on the train capacity. When the train becomes fully crowded queuing time will be high. The objective function of the linear program is to minimize the total queuing time.

- **Track Length and Maximum Speed**

Track length represent the real distance between two railway stations and it is called as segment of railway. Distance table has been taken during the railway survey. Each segment has specific length, and speed limit. In addition to that there many number of railway crossings in the coastal line. Main problems are some of crossings has operators to control the gates some of them has no operators so during the journey and train operators have to be carefully to avoid accidents. In this study, assume to ignore speed limit by considering average speed of a train. Maximum speed has been achieved by the survey as $86\ km/h$ during the GPS capturing.

- **Acceleration and deceleration**

Average acceleration was taken by observing time and distance during acceleration its cruises speed and deceleration also taken by considering time and distance during stopping the train. Simple physical formulas have been used to calculate the acceleration and deceleration and also used velocity graph to verify the calculation.

$$\boldsymbol{a} = \frac{\boldsymbol{v}-\boldsymbol{u}}{\boldsymbol{t}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,

$v = \ max\ velocity \quad a = \ acceleration$

$t = \ time \quad\quad\quad u \ = initial\ velocity$

Assume that the minimum speed of the train as 0 km/h and maximum speed as per the height slope in the *Figure 7.5.* The figure has been mapped using the GPS device row data *Table 3.5*. Then the calculated average acceleration has been taken to the *Table 7.3*.

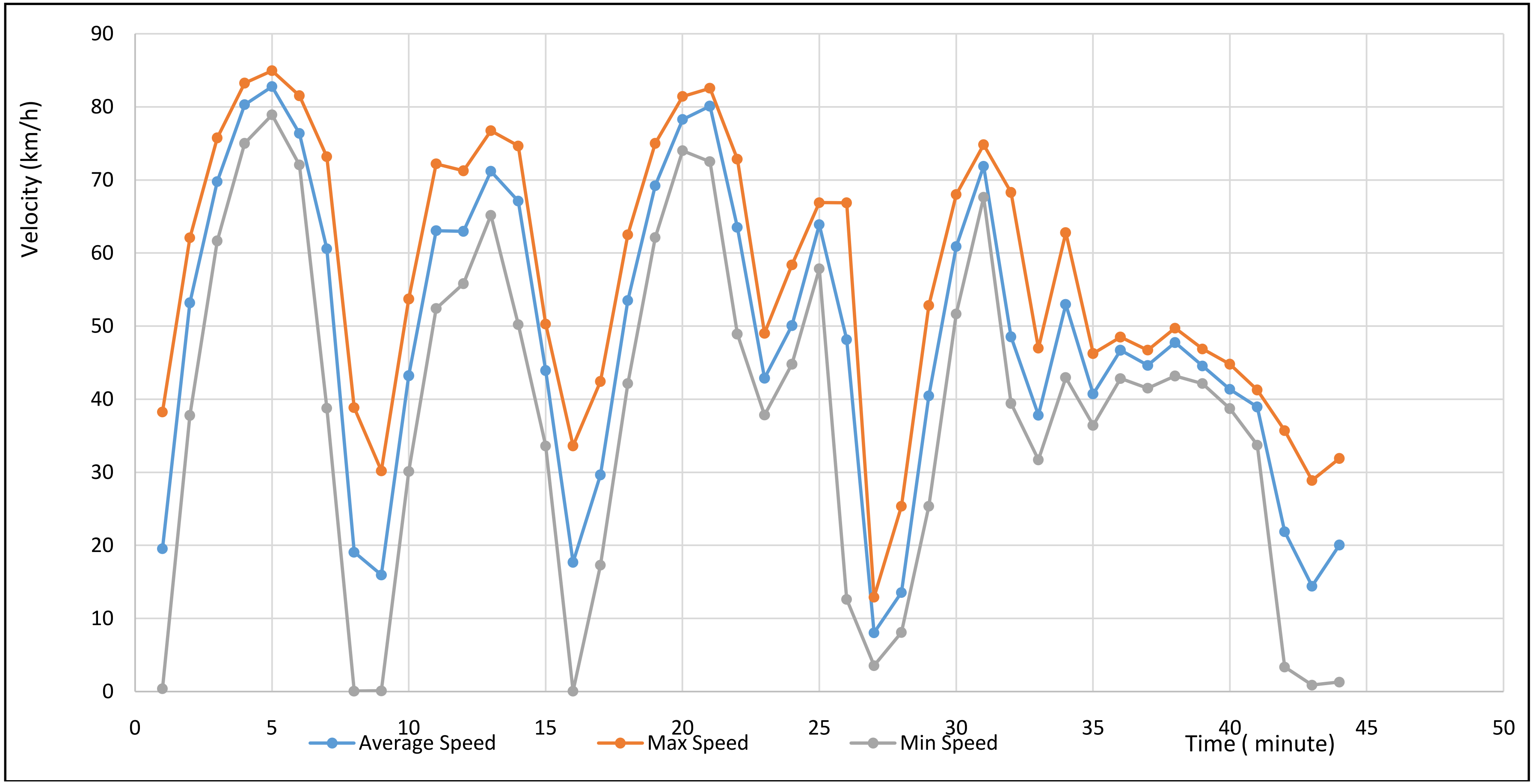


Figure 7-5Average, maximum and minimum velocity vs. time graph

Table 7-3 Average acceleration of S class DMU

$u\ (km/h)$	$v(\ km/h)$	$t\ (minuts)$	$a\ (ms^{-2})$
0	83.25	3	0.128
0	72.2	2	0.111
0	75	3	0.116
0	68	3	0.105
	Average Acceleration		0.115

Table 7-4 Average declaration of S class DMU

$u\ (km/h)$	$v(\ km/h)$	$t\ (minuts)$	$a\ (ms^{-2})$
73.18	0	1	0.339
50.29	0	1	0.233
66.87	0	1	0.310
	Average Declaration		0.294

- **Stopping time at the station**

Generally the stopping time at the station of passenger trains is about 1 minute.

Table 7-5Controlling parameters of model

Parameter	Value
Queuing Length	300
Train Length	11 rail cars
Train Speed	30 km/h
Acceleration	0.115 m/s
Deceleration	0.294 m/s

7.4. Model running for current time table

The current time schedule has been run by changing parameters four times to have clear observation. The data which observed by the model is containing in the *Table 7.6*. Parameters of the model are set as the *Table 7.5*. According to the data total pedestrian in the queue in KSS is 3010 for the 10 minute intervals. Then the average time wasting in the queue by the people is 15050 minutes, also average wasting time of KNS is 4315 minute by 863 passengers.

$$TQT_{Ped} = \sum passenger\ Waiting\ at\ the\ queue * AT_{Ped}$$

Where;

TQT_{Ped} = *Total queuing time of passengers*

AT_{Ped} = *Average time interval*

Table 7-6 Passenger queuing time observation in current train schedule

Time	KSS				KNS			
	Ped in Queue	Pick up	Queuing time	Trains	Ped in Queue	Pick up	Queuing time	Trains
5:30	45	0	225	0	12	0	60	0
5:35	0	70	0	1	18	0	90	0
5:40	10	70	50	1	0	28	0	1
5:45	28	70	140	1	5	28	25	1
5:50	40	70	200	1	13	28	65	1
5:55	0	138	0	2	23	28	115	1
6:00	33	138	165	2	1	64	5	2
6:05	85	138	425	2	9	64	45	2
6:10	135	138	675	2	22	64	110	2
6:15	0	293	0	3	35	64	175	2
6:20	25	293	125	3	20	99	100	3
6:25	65	293	325	3	40	99	200	3
6:30	125	293	625	3	64	99	320	3
6:35	0	498	0	4	94	99	470	3
6:40	125	498	625	4	3	225	15	4
6:45	0	763	0	5	37	225	185	4
6:50	80	858	400	6	0	297	0	5
6:55	270	858	1350	6	92	297	460	5
7:00	0	1328	0	7	0	439	0	7
7:05	195	1328	975	7	20	439	100	7
7:10	375	1328	1875	7	55	439	275	7
7:15	525	1328	2625	7	93	439	465	7
7:20	0	1868	0	8	0	574	0	8
7:25	20	1868	100	8	4	574	20	8
7:30	37	1868	185	8	9	574	45	8
7:35	57	1868	285	8	14	574	70	8
7:40	82	1868	410	8	20	574	100	8
7:45	112	1868	560	8	27	574	135	8
7:50	142	1868	710	8	35	574	175	8
7:55	177	1868	885	8	45	574	225	8
8:00	222	1868	1110	8	53	574	265	8
			15050				4315	

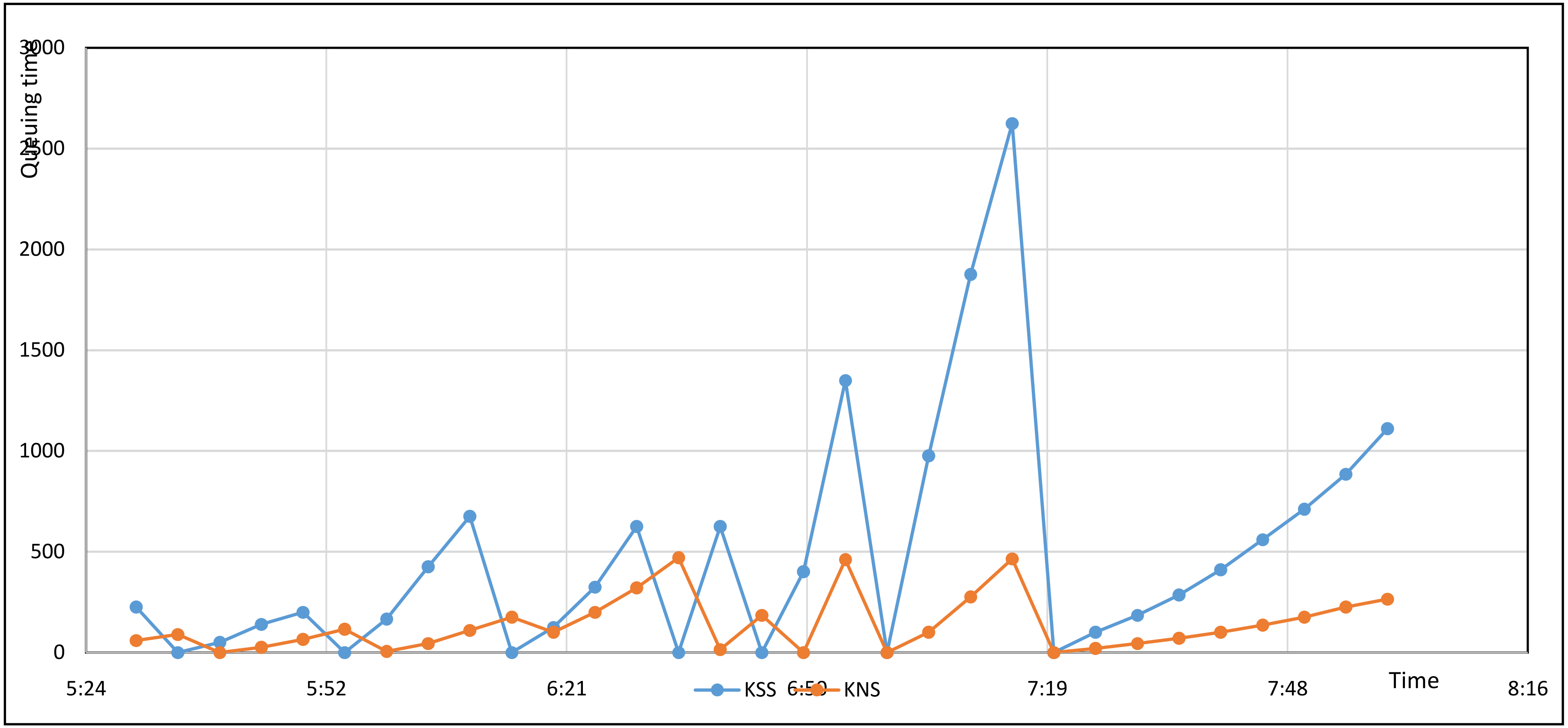


Figure 7-6 Simulation run of current train schedule

7.5. Calculation for a new timetable

The information of current train schedule has been analyses to get the time different between two trains. Three main stations have been included such as KSS, PNS and RTH. By considering the *Table 7.7, Table 7.8and Table 7.9* it has shown in the *Figure 7.*7 in graphical from. It is clear to confirm that the currently operating uneven time table. *Figure7.7*explains time different between trains and which are related to three main stations KSS, PNS and RTH. KSS pattern is somewhat different than other two because few trains are starting from it. But the graph is clarifying that irregularity of train time table. Sometime the time different between trains is more than 2 hours. This may cause for reduce the popularity of railway and suppose that the regularity of the timetable must be increase the popularity.

Table 7-7Time difference between trains at KSS

KSS					
Sequence NO	First train No	First train Time	Second Train No	Second Train Time	Time Difference
1	8302	3:52	8304	4:22	30
2	8304	4:22	8309	5:02	40
3	8309	5:02	8311	5:36	34
4	8311	5:36	8317	5:56	20
5	8317	5:56	8320	6:15	19
6	8320	6:15	8324	6:36	21
7	8324	6:36	8063	6:45	9
8	8063	6:45	8327	6:48	3
9	8327	6:48	8326	7:00	12
10	8326	7:00	8097	7:01	1
11	8097	7:01	8333	7:20	19
12	8333	7:20	8342	8:05	45
13	8342	8:05	8059	8:25	20
14	8059	8:25	8057	8:35	10
15	8057	8:35	8344	10:45	130
16	8344	10:45	8349	11:53	68
17	8349	11:53	8085	12:15	22
18	8085	12:15	8350	12:20	5
19	8350	12:20	8352	13:40	80
20	8352	13:40	8363	14:12	32
21	8363	14:12	8039	16:02	110
22	8039	16:02	8373	17:00	58
23	8373	17:00	8051	17:01	1
24	8051	17:00	8376	17:30	30
25	8376	17:30	8372	17:45	15

Table 7-8 Time difference between trains at PNS

PNS					
Sequence NO	First train		Second Train		Time Difference
	No	Time	No	Time	
1	8302	4:19	8304	4:49	30
2	8304	4:49	8309	5:29	40
3	8309	5:29	8311	6:05	36
4	8311	6:05	8310	6:10	5
5	8310	6:10	8317	6:25	15
6	8317	6:25	8316	6:30	5
7	8316	6:30	8320	6:55	25
8	8320	6:55	8324	7:01	6
9	8324	7:01	8863	7:05	4
10	8863	7:05	8327	7:06	1
11	8327	7:06	8326	7:19	13
12	8326	7:19	8097	7:20	1
13	8097	7:20	8328	7:30	10
14	8328	7:30	8333	7:46	16
15	8333	7:46	8335	8:05	19
16	8335	8:05	8342	8:33	28
17	8342	8:33	8057	8:51	18
18	8057	8:51	8339	9:15	24
19	8339	9:15	8336	9:35	20
20	8336	9:35	8344	11:11	96
21	8344	11:11	8349	12:16	65
22	8349	12:16	8085	12:36	20
23	8085	12:36	8350	12:48	12
24	8350	12:48	8352	14:05	77
25	8352	14:05	8363	14:34	29
26	8363	14:34	8355	15:00	26
27	8355	15:00	8365	16:10	70
28	8365	16:10	8039	16:27	17
29	8039	16:27	8367	17:05	38
30	8367	17:05	8378	17:40	35
31	8378	17:40	8373	17:45	5
32	8051	17:21	8373	17:45	24
33	8373	17:45	8376	17:50	5
34	8376	17:50	8372	18:00	10
35	8372	18:00	8375	18:39	39

Table 7-9 Time difference between trains at RTH

RTH					
Sequence NO	First train		Second Train		Time Difference
	No	Time	No	Time	
1	8302	4:42	4021	5:10	28
2	4021	5:10	8304	5:12	2
3	8304	5:12	4077	5:50	38
4	4077	5:50	8309	5:52	2
5	8309	5:52	8311	6:26	34
6	8311	6:26	8310	6:33	7
7	8310	6:33	8317	6:46	13
8	8317	6:46	8316	6:58	12
9	8316	6:58	8320	7:07	9
10	8320	7:07	8324	7:30	23
11	8324	7:30	8327	7:35	5
12	8327	7:35	8328	7:53	18
13	8328	7:53	8325	7:59	6
14	8325	7:59	8333	8:06	7
15	8333	8:06	8335	8:27	21
16	8335	8:27	8330	8:44	17
17	8330	8:44	8341	9:09	25
18	8341	9:09	8339	9:38	29
19	8339	9:38	8336	10:02	24
20	8336	10:02	8344	11:34	92
21	8344	11:34	8350	13:33	119
22	8350	13:33	8352	14:28	55
23	8352	14:28	8363	14:59	31
24	8363	14:59	8355	15:22	23
25	8355	15:22	8365	16:37	65
26	8365	16:37	8039	16:47	10
27	8039	16:47	8362	16:50	3
28	8362	16:50	8366	17:19	29
29	8366	17:19	8367	17:32	13
30	8367	17:32	8378	18:01	29
31	8378	18:01	8373	18:03	2
32	8373	18:03	8373	18:22	19
33	8373	18:22	8372	19:02	40

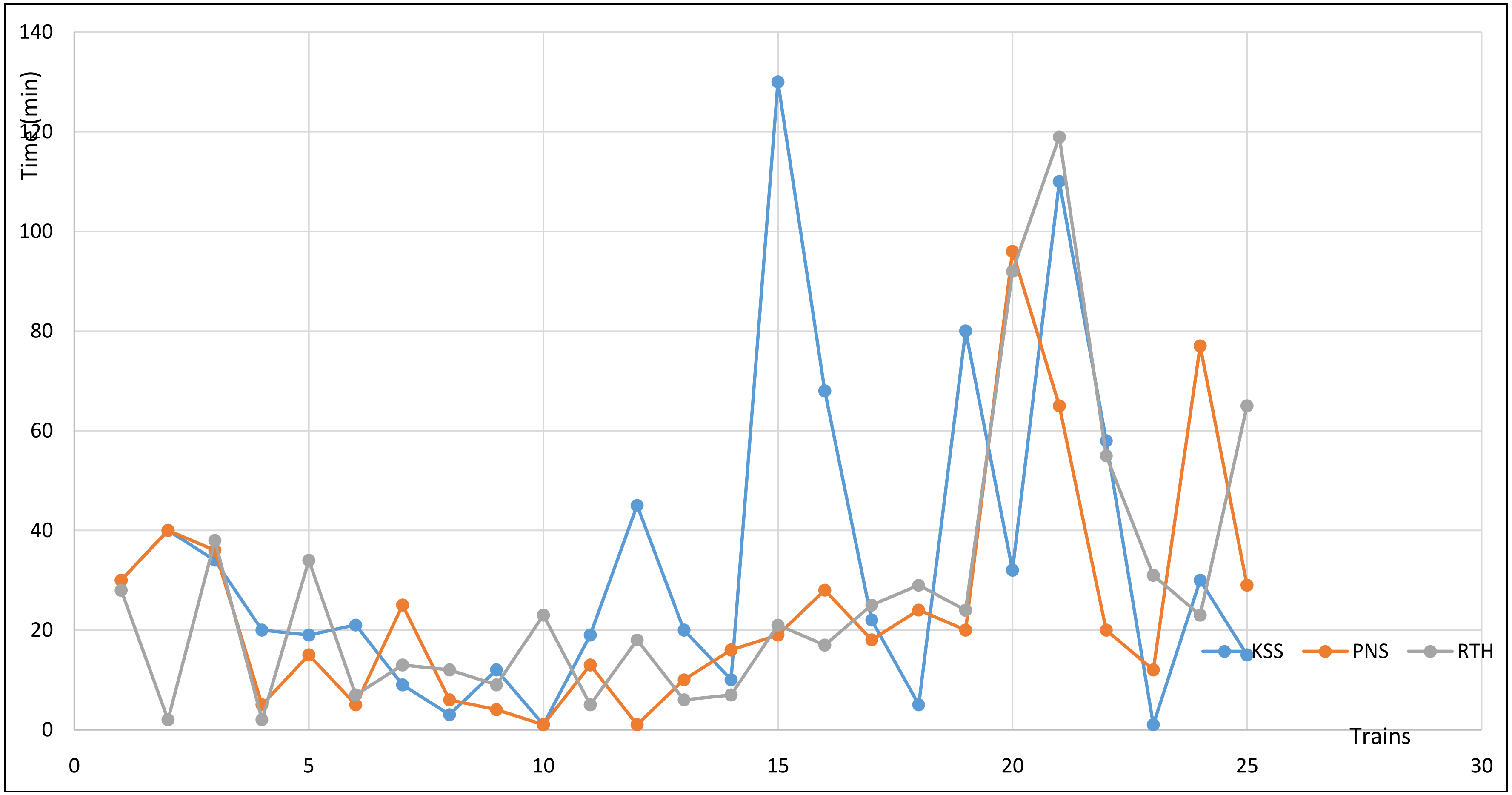


Figure 7-7 Time difference between train

7.6. Proposed time table

New train time table has been introduced by considering current time table, but major difference of this time table is that trains are running based on regular interval. It has proposed to increase train length according to the passenger demand. In addition to that it has followed the model by changing inters arrival time for 10 minutes, 15 minutes and 20 minutes for KSS and KNS stations.

Passenger demand pattern of a day depends upon the current railway timetable. As previously discussed the irregularity of the time table will cause for dissatisfaction of the passengers. When considering the current timetable it mainly focused only office employees. As identified in the previously discussed details, the peak time of the Kalutara South is 5:30AM to 8:30 AM. Ten numbers of trains havebeen found in the current schedule during that period of time. Calculated the time between trains without changing resources of railway, by changing the train arrival pattern as 10 minutes, 15 minutes and 20 minutes for KSS and KNS stations the following data has been observed by the model.

7.6.1. Inter arrival time as 10 minute

After setting the inter arrival time as 10 minutes form Kalutara South(KSS), the passengers in the queue had been observed as the Table 7.11. It contains five columns for time, number of passengers in the queue, number of passenger pickup, number trains and passenger queuing time. Average passenger queuing time has been calculated by taking medium of each interval.

Table 7-10Model output for 10 minutes interval

Time	Number of Passengers	Pick up	Trains	Passenger Queuing time
5:30	0	0	0	0
5:35	45	0	0	225
5:40	70	0	0	350
5:45	0	80	1	0
5:50	18	80	1	90
5:55	0	119	2	0
6:00	19	119	2	95
6:05	0	171	3	0
6:10	52	171	3	260
6:15	0	273	4	0
6:20	20	273	4	100
6:25	0	318	5	0
6:30	40	318	5	200
6:35	0	418	6	0
6:40	80	418	6	400
6:45	17	606	7	85
6:50	157	606	7	785
6:55	21	917	8	105
7:00	211	917	8	1055
7:05	47	1281	9	235
7:10	242	1281	9	1210
7:15	55	1648	10	275
7:20	205	1648	10	1025
7:25	1	1648	11	5
7:30	21	1867	11	105
7:35	0	1867	12	0
7:40	20	1905	12	100
7:45	0	1905	13	0
7:50	30	1950	13	150
7:55	0	1950	14	0
8:00	35	2010	14	175
	1406	2090		7030

According to the *Figure 7.8*, it is clear to say that passenger arrival rate is increased, and also passenger in the queue is also increased. But total times of passengers are about 7030 minutes. This value is less than current passenger queuing time. But main problem of that is more resources are required for run trains under this condition, at least 14 numbers of trains are required.

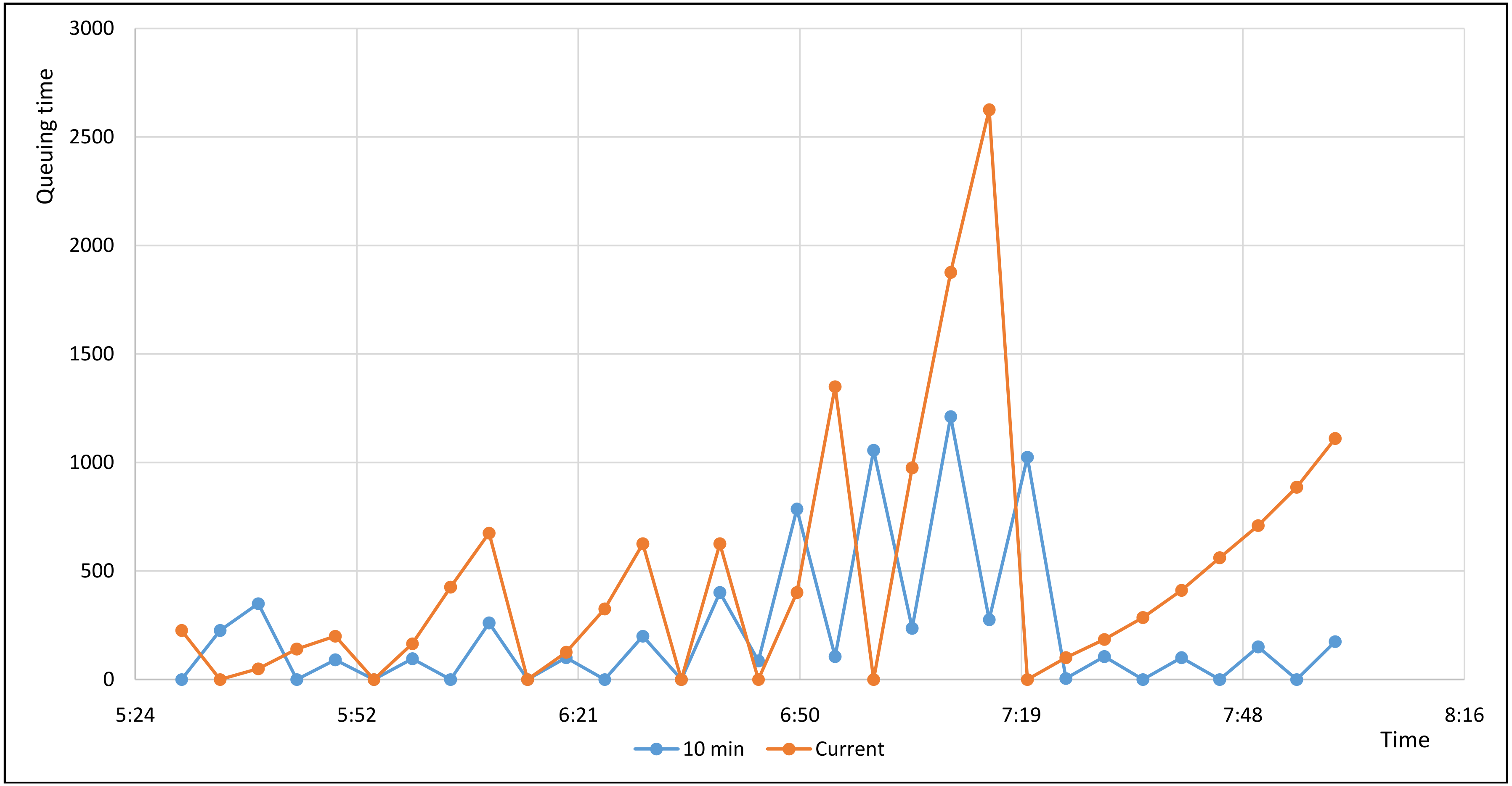


Figure 7-8Model output for 10 minutes interval

7.6.2. Inter arrival time as 15 minute

After setting the inter arrival time as 15 minutes form Kalutara South(KSS), the passengers in the queue had been observed as the *Table 7.11*. It contains five columns for time, number of passengers in the queue, number of passenger pickup, number of trains and passenger queuing time. Average passenger queuing time has been calculated by taking medium of each interval.

According to the *Figure 7.9*, it is clear to say that passenger arrival rate is increased, and also passenger in the queue is increased. But total time of passengers is about 11485 minutes. This value is less than current passenger queuing time. Only need 9 numbers of trains.This schedule is very near to reach the resources utilization as current schedule. Passenger arrival rate was used as current system. But it concluded that passenger queuing time is reduced. Because of these reasoning 15minutes inter arrival time could be the purpose.

Table 7-11Model output for 15 minutes interval

Time	Number of Passengers	Pick up	Trains	Passenger Queuing time
5:30	0	0	0	0
5:35	45	0	0	225
5:40	70	0	0	350
5:45	80	0	0	400
5:50	0	98	1	0
5:55	21	98	1	105
6:00	40	98	1	200
6:05	0	171	2	0
6:10	52	171	2	260
6:15	102	171	2	510
6:20	0	293	3	0
6:25	25	293	3	125
6:30	65	293	3	325
6:35	1	417	4	5
6:40	81	417	4	405
6:45	206	417	4	1030
6:50	18	745	5	90
6:55	193	745	5	965
7:00	383	745	5	1915
7:05	24	1304	6	120
7:10	219	1304	6	1095
7:15	399	1304	6	1995
7:20	21	1832	7	105
7:25	36	1832	7	180
7:30	56	1832	7	280
7:35	0	1905	8	0
7:40	20	1905	8	100
7:45	45	1905	8	225
7:50	0	1980	9	0
7:55	30	1980	9	150
8:00	65	1980	9	325
	2297			11485

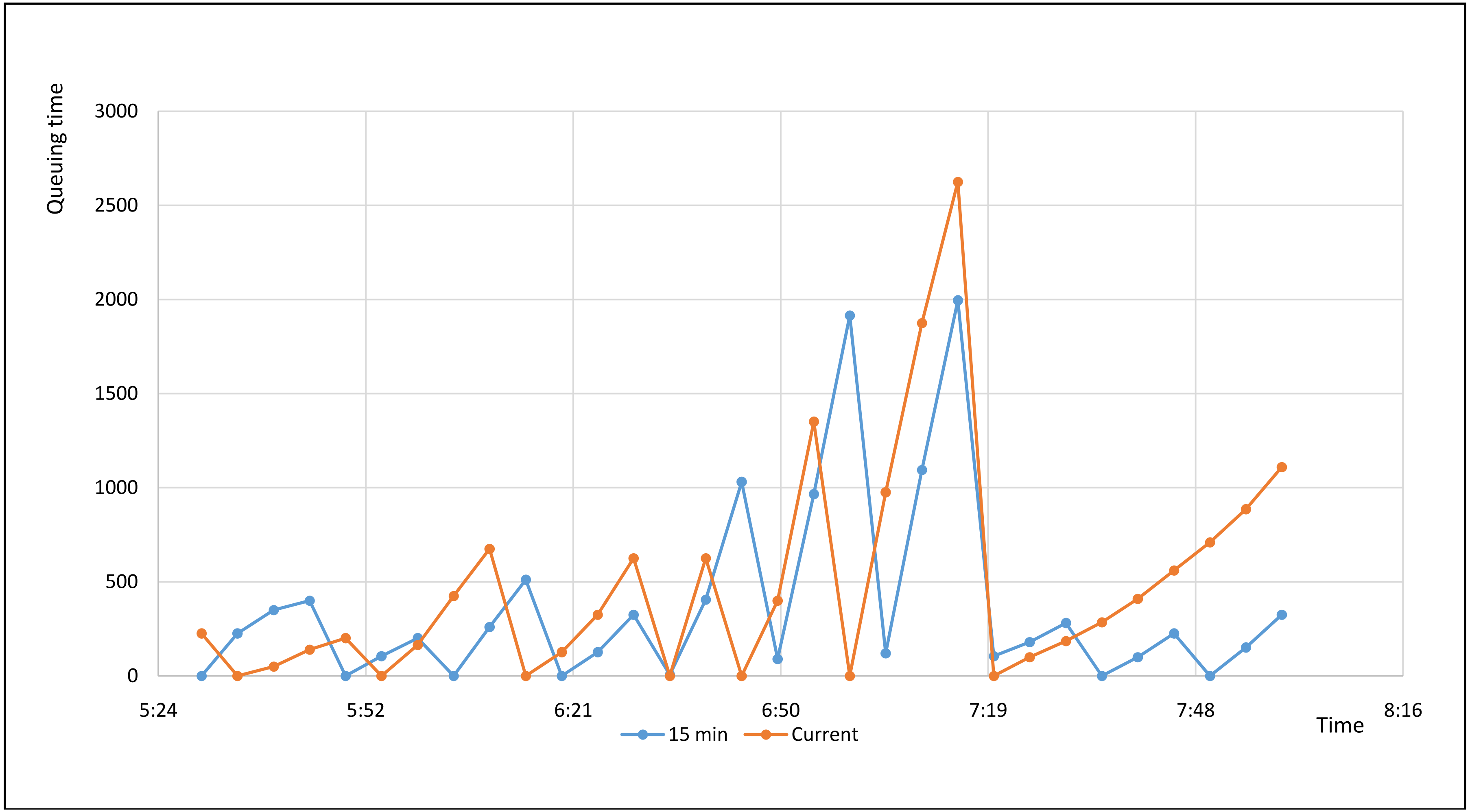


Figure 7-9Model output for 15 minutes interval

7.6.3. Inter arrival time as 20 minute

After setting the inter arrival time as 20 minutes form Kalutara South(KSS), the passengers in the queue had been observed as in the Table 7.13. It contains five columns for the time, number of passengers in the queue, number of passenger pickup, number of trains and passenger queuing time. Average passenger queuing time has been calculated by taking medium of each interval

According to the Figure 7.10, it is clear to say that passenger arrival rate is increased, and also passenger in the queue is increased. But total times of passengers are about 16880 minutes. This value is more than current passenger queuing time. But only need 7 numbers of trains.

Table 7-12Model output for 20 minutes interval

Time	PED in Queue	Pick up	Trains	Passenger Queuing time
5:30	0	0	0	0
5:35	45	0	0	225
5:40	70	0	0	350
5:45	0	80	1	0
5:50	18	80	1	90
5:55	39	80	1	195
6:00	58	80	1	290
6:05	1	170	2	5
6:10	53	170	2	265
6:15	103	170	2	515
6:20	123	170	2	615
6:25	0	318	3	0
6:30	40	318	3	200
6:35	100	318	3	500
6:40	180	318	3	900
6:45	7	616	4	35
6:50	147	616	4	735
6:55	322	616	4	1610
7:00	512	616	4	2560
7:05	41	1287	5	205
7:10	236	1287	5	1180
7:15	416	1287	5	2080
7:20	566	1287	5	2830
7:25	0	1868	6	0
7:30	20	1868	6	100
7:35	37	1868	6	185
7:40	57	1868	6	285
7:45	0	1950	7	0
7:50	30	1950	7	150
7:55	60	1950	7	300
8:00	95	1950	7	475
	3376			16880

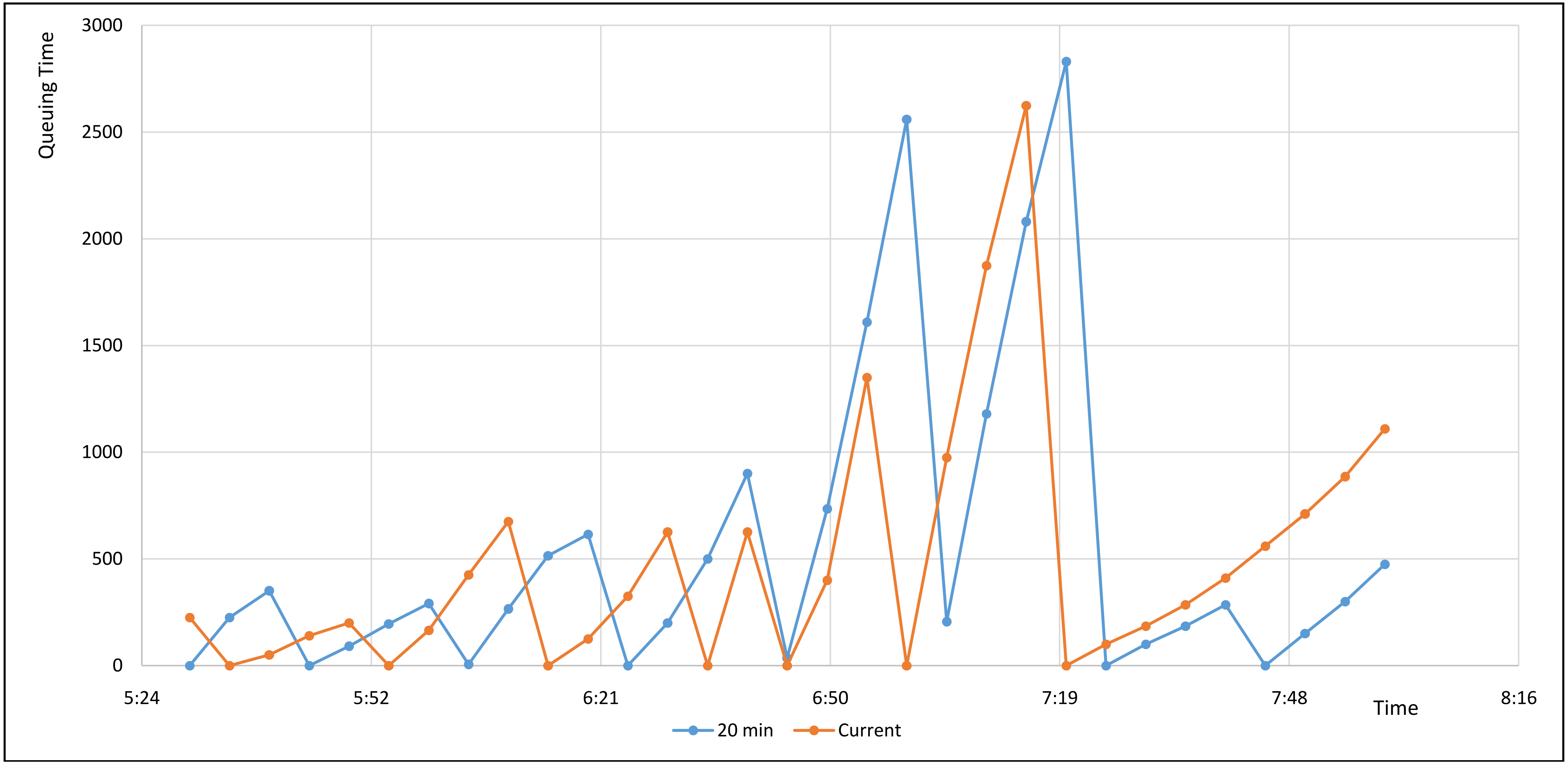


Figure 7-10 Model output for 20 minutes interval

According to the data summary of running model it can be further summarised as Table 7.13. It is clear to say that the total passenger queuing time will reduce when decreasing the inter arrival time of the trains and also below it is verified that passenger queuing time is less than current time table for Kalutara South after 15 minute intervals. By utilizing the current resources as the current railway schedule 15 minutes time interval is the best option for new time table.

Table 7-13Passenger queuing time summery

Train schedule	Kalutara South	Trains
Current Timetable	15050	9
10 min	7030	15
15 min	11485	9
20 min	16880	7

7.7. Mathematical explanation to queuing time

Generally passenger queuing time for the one minute frequency can be given by,

$$QT_t = tx_1 + (t-1)x_2 + \cdots \ldots + (t-i)x_i + \cdots .. + x_t$$

Where,

$$QT_t = Passenger\ queuing\ time$$

$$t = time\ intervel$$

$$x = number\ of\ passngers\ at\ a\ time$$

Assume that the passenger arrival rate is constant then

$$QT_t = (\ t + (t-1) + (t-2) + \cdots \ldots .. + 1)x$$

Therefore,

$$QT_{10} = 55x$$

$$QT_{15} = 120x$$

$$QT_{20} = 210x$$

$$QT_{30} = 465x$$

According to that it is clear to say that the queuing time will reduce, when reducing inter arrival rate.

7.8. Model validation

In practice it may be difficult to achieve such a full validation of the model because the system being modeled does not yet exist. As for most models, there are three separate aspects which had been considered during model validation such as Assumptions, Input parameter values and distributions, Output values and conclusions.

Sample space has been selected for the passenger count in the queue and observed passengers in the sample space and calculates the average queuing time. Then it has multiplied by the total area in the queue.

7.8.1. Real system measurement

The real system has been measured by using a photographic method. The photograph has been captured in a selected area of the platform. This has been followed on 18/08/2017 at the Kalutara South railway station. The *Figure 7.11* shows the captured image during the observation period. The passenger count captured by the photographic method has been **s**ummarised in the table given below. The area of the platform contains half of the total platform length. But sometimes, in the busy time platform No. 1 also used for pick up the passengers.

Figure 7-11 Captured image form the Kalutara South railway station

Table 7-14 Real system measurement

Time	Number of Passengers	Actual	Model Data
5:30	45	225	225
5:35	50	250	225
5:40	3	15	0
5:45	11	55	50
5:50	29	145	140
5:55	50	250	245
6:00	2	10	0
6:05	21	105	165
6:10	54	270	425
6:15	106	530	675
6:20	10	50	0
6:25	25	125	125
6:30	50	250	325
6:35	83	415	625
6:40	150	750	0
6:45	105	525	625
6:50	180	900	0
6:55	10	50	10
7:00	15	75	960
7:05	33	165	0
7:10	175	875	975
7:15	300	1500	1875
7:20	500	2500	2625
7:25	11	55	0
7:30	40	200	100
7:35	55	275	185
7:40	70	350	285
7:45	90	450	410
7:50	120	600	560
7:55	150	750	710
8:00	180	900	885

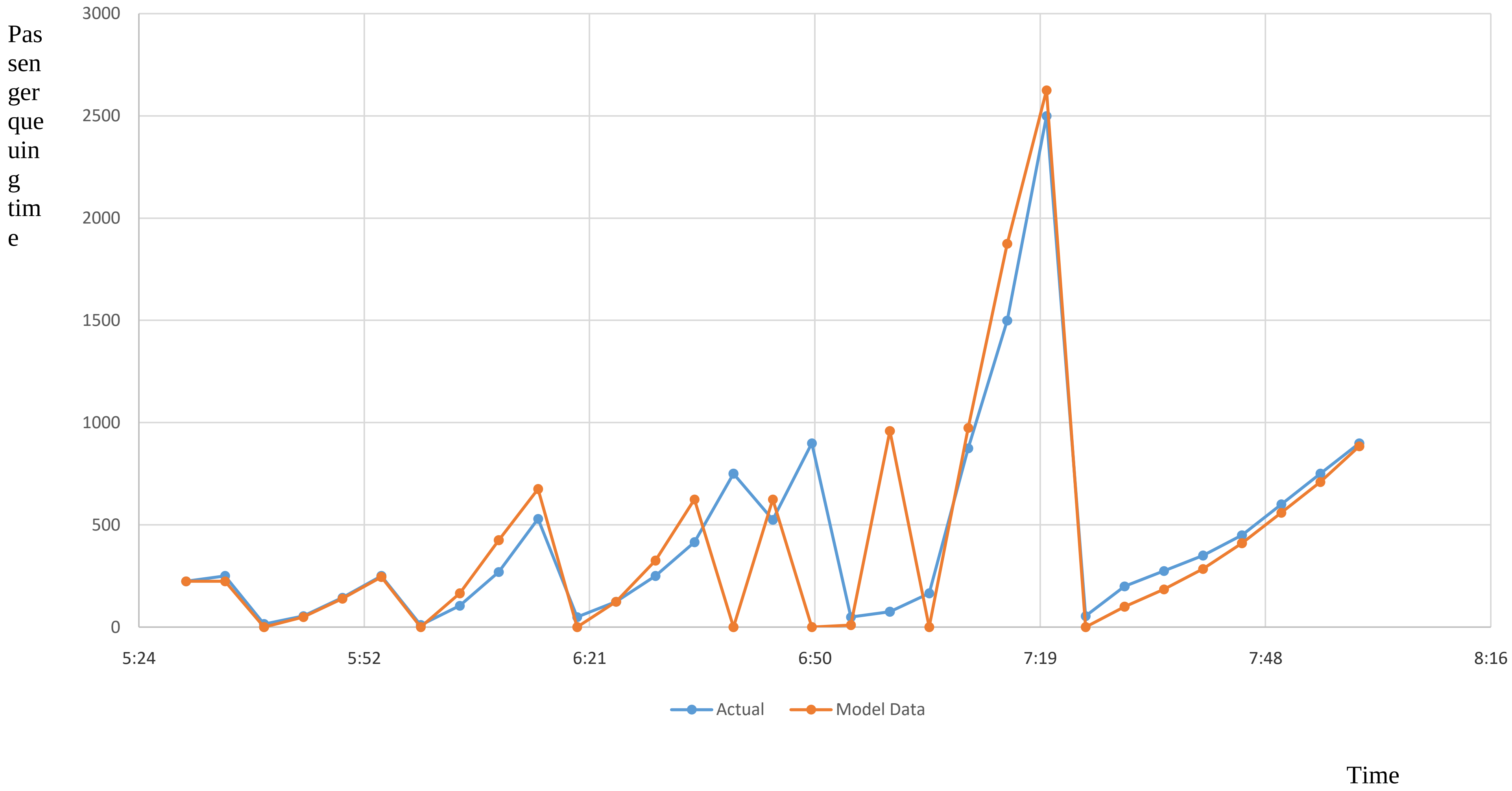


Figure 7-12Real and model output

Initially the real system and the model started form the same stage because both were trains which arrived at the scheduled time and departure as well. Then the model and the real system result followed the same Patten but only the model shows zero reading in some cases. The Model has been created to pick up all available passengers in the platform so that is the reason for observing zero readings but in general condition,all passengers may not get in to the train because of several reasons, so in this case has been assumed that the all passengers got in to the train.

Until 6:35 AM trains were runs under the given time table but after 6:35 AM trains started to get delayed so that actual system and model output deviate until 7:05 AM. After that again both results shows near same reading and overlap the graph.By using this point of view it can guessed, if the trackwas very busy, trains may start with delay, because solution must be found to reduce the delays at the busy time.

In despite of delays, the actual results and the model result gives closeness value in the output. In this result it has been verified that the model gives near real output. In this way model can be verified.

7.8.2. Root mean square error (RMSE)

Root mean square error was calculated for this study for the four regions such as5:30 AM to 6:00 AM, 6:05 AM to 6:35 AM, 6:40 AM to 7:10 AM and 7:15 AM to 8:00 AM. Values of RMSE for four regions are containing in the table 7-15 and the reference data for the RMSE calculation is containing in the table 7-16.

According to the RMSE values it shows lower error for the regions of 5:30 AM to 6:00 AM, 6:05 AM to 6:35 AM, and 7:15 AM to 8:00 AM.

7-15RMSE values

Time Range	RMSE
5:30-8:00	283.5873
5:30-6:00	12.10077
6:30-6:35	120.1041
6:40-7:10	578.8134
7:15-8:00	136.6108

7-16 RMSE data

Time	Number of Passengers	Actual	Model Output	Error	Absolute error	$Error^2$
5:30	45	225	225	0	0	0
5:35	50	250	225	25	25	625
5:40	3	15	0	15	15	225
5:45	11	55	50	5	5	25
5:50	29	145	140	5	5	25
5:55	50	250	245	5	5	25
6:00	2	10	0	10	10	100
6:05	21	105	165	-60	60	3600
6:10	54	270	425	-155	155	24025
6:15	106	530	675	-145	145	21025
6:20	10	50	0	50	50	2500
6:25	25	125	125	0	0	0
6:30	50	250	325	-75	75	5625
6:35	83	415	625	-210	210	44100
6:40	150	750	0	750	750	562500
6:45	105	525	625	-100	100	10000
6:50	180	900	0	900	900	810000
6:55	10	50	10	40	40	1600
7:00	15	75	960	-885	885	783225
7:05	33	165	0	165	165	27225
7:10	175	875	975	-100	100	10000
7:15	300	1500	1875	-375	375	140625
7:20	500	2500	2625	-125	125	15625
7:25	11	55	0	55	55	3025
7:30	40	200	100	100	100	10000
7:35	55	275	185	90	90	8100
7:40	70	350	285	65	65	4225
7:45	90	450	410	40	40	1600
7:50	120	600	560	40	40	1600
7:55	150	750	710	40	40	1600
8:00	180	900	885	15	15	225

7.8.3. Regression analysis

Regression analysis is a quantitative method used to test the nature of relationships between a dependent variable and one or more independent variables. In validation of this model the total time frame had been break in to four regions such as 5:30 AM to 6:00 AM, 6:05 AM to 6:35 AM, 6:40 AM to 7:10 AM and 7:15 AM to 8:00 AM.

To calculate r^2 values for the model followed the equation given below.

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - (\sum x)^2}\sqrt{n\sum y^2 - (\sum y)^2}}$$

Where,

$x = output\ passenger\ queuing\ time\ from\ the\ real\ system$

$y = output\ passenger\ queuing\ time\ from\ the\ model$

$n = number\ of\ samples\ in\ selected\ region$

- ***Region 1: Actual vs. Model from 5:30 AM to 6:00 AM***

Table 7-17Actual vs. Model output from 5:30AM to 6:00 AM

Time	*Actual(x)*	*Model Output(y)*	x^2	y^2	xy
5:30	225	225	50625	50625	50625
5:35	250	225	62500	50625	56250
5:40	15	0	225	0	0
5:45	55	50	3025	2500	2750
5:50	145	140	21025	19600	20300
5:55	250	245	62500	60025	61250
6:00	10	0	100	0	0
	Σx	Σy	Σx^2	Σy^2	Σxy
	950	885	200000	183375	191175

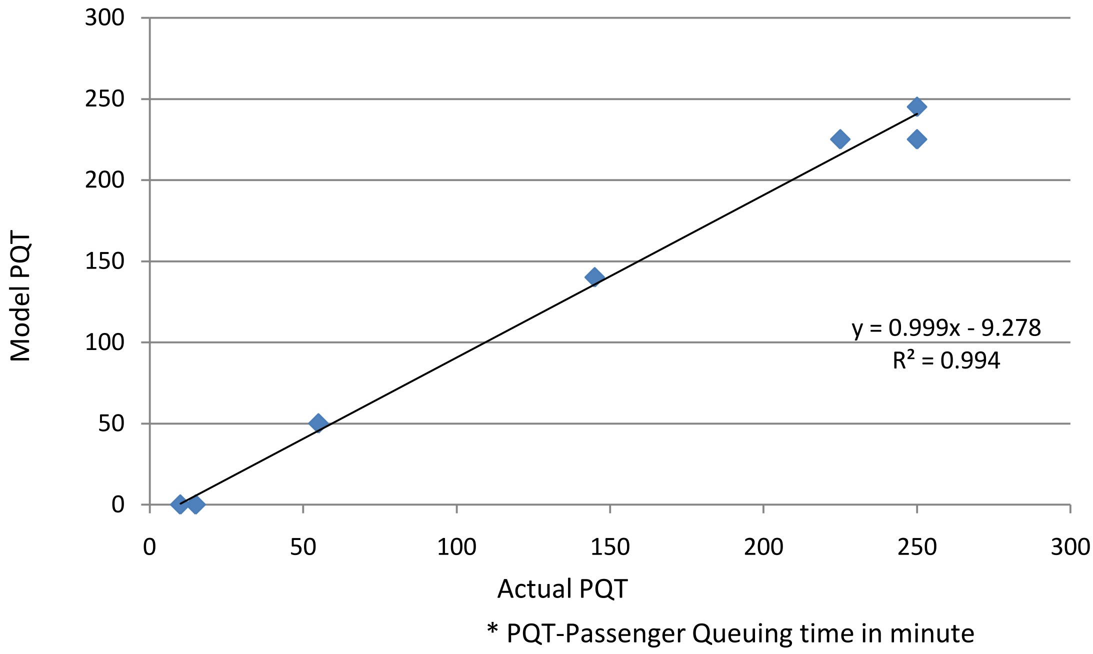


Figure 7-13Actual vs. Model output from 5:30AM to 6:00 AM

In the region 1 r^2 value is 0.994 and it is very close to 1 so that it can conclude that the real system and model output are same.

- ***Region 2: Actual vs. Model output from 6:05 AM to 6:35 AM***

Table 7-18 Actual vs. Model output from6:05AM to 6:35 AM

Time	*Actual(x)*	*Model Output(y)*	x^2	y^2	xy
6:05	105	165	11025	27225	17325
6:10	270	425	72900	180625	114750
6:15	530	675	280900	455625	357750
6:20	50	0	2500	0	0
6:25	125	125	15625	15625	15625
6:30	250	325	62500	105625	81250
6:35	415	625	172225	390625	259375
	Σx	Σy	Σx^2	Σy^2	Σxy
	1745	2340	617675	1175350	846075

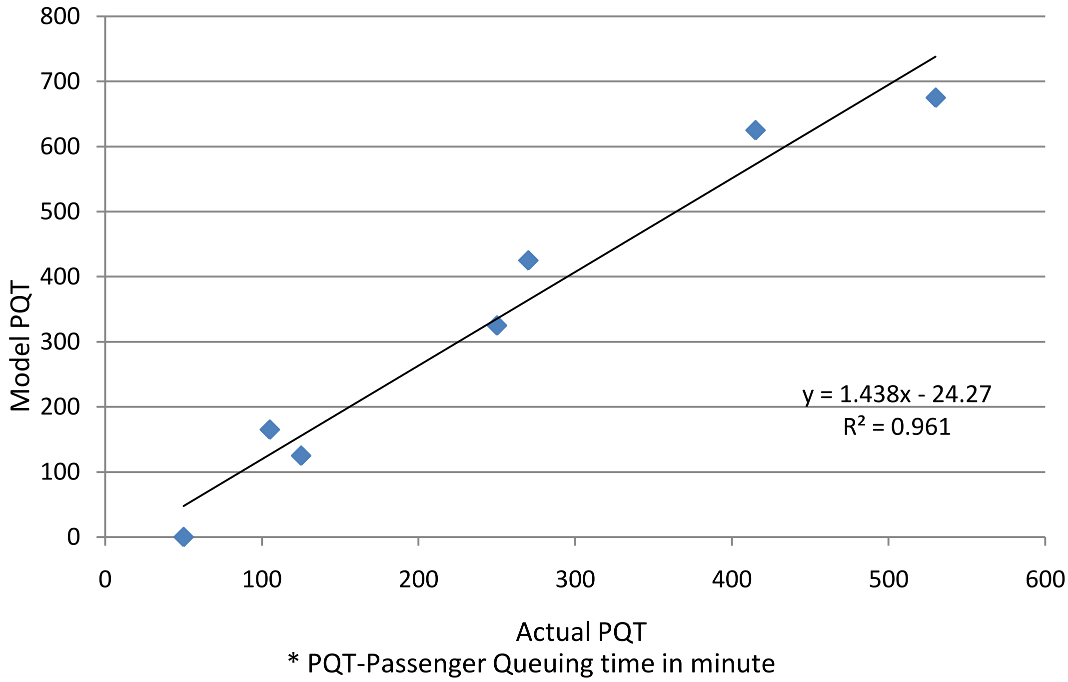


Figure 7-14 Actual vs. Model output from 6:05AM to 6:35 AM

In the region 2 r^2 value is 0.961 and it is very close to 1 so that it can conclude that the real system and model output are same.

- ***Region 3: Actual vs. Model output from 6:40 AM to 7:10 AM***

Table 7-19 Actual vs. Model output from 6:40AM to 7:10 AM

Time	*Actual(x)*	*Model Output(y)*	x^2	y^2	xy
6:40	750	0	562500	0	0
6:45	525	625	275625	390625	328125
6:50	900	0	810000	0	0
6:55	50	10	2500	100	500
7:00	75	960	5625	921600	72000
7:05	165	0	27225	0	0
7:10	875	975	765625	950625	853125
	Σx	Σy	Σx^2	Σy^2	Σxy
	3340	2570	2449100	2262950	1253750

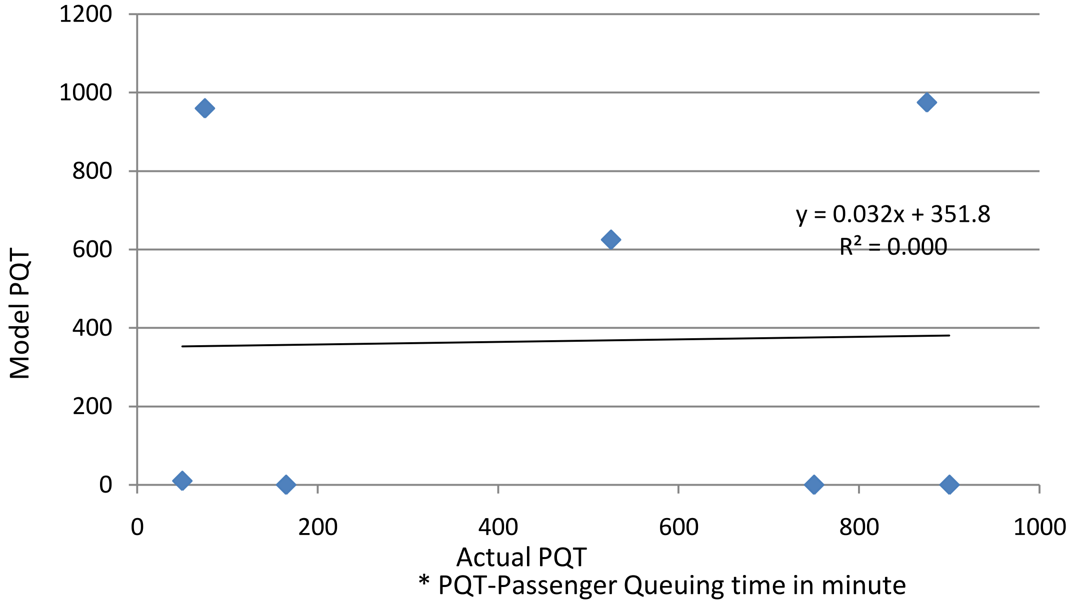


Figure 7-15 Actual vs. Model output from 6:40AM to 7:10 AM

In the region 3 r^2 value is 0.000 and it is far away from 1. Due to the complexity increases in the station the current model not enough to simulate complex double line railway once the two trains in the two s flat form at the same time and same direction model show different output.

- ***Region 4: Actual vs. Model output from 7:15 AM to 8:00 AM***

Table 7-20 Actual vs. Model output from 7:15AM to 8:00 AM

Time	*Actual(x)*	*Model Output(y)*	x^2	y^2	xy
7:15	1500	1875	2250000	3515625	2812500
7:20	2500	2625	6250000	6890625	6562500
7:25	55	0	3025	0	0
7:30	200	100	40000	10000	20000
7:35	275	185	75625	34225	50875
7:40	350	285	122500	81225	99750
7:45	450	410	202500	168100	184500
7:50	600	560	360000	313600	336000
7:55	750	710	562500	504100	532500
8:00	900	885	810000	783225	796500
	Σx	Σy	Σx^2	Σy^2	Σxy
	7580	7635	10676150	12300725	11395125

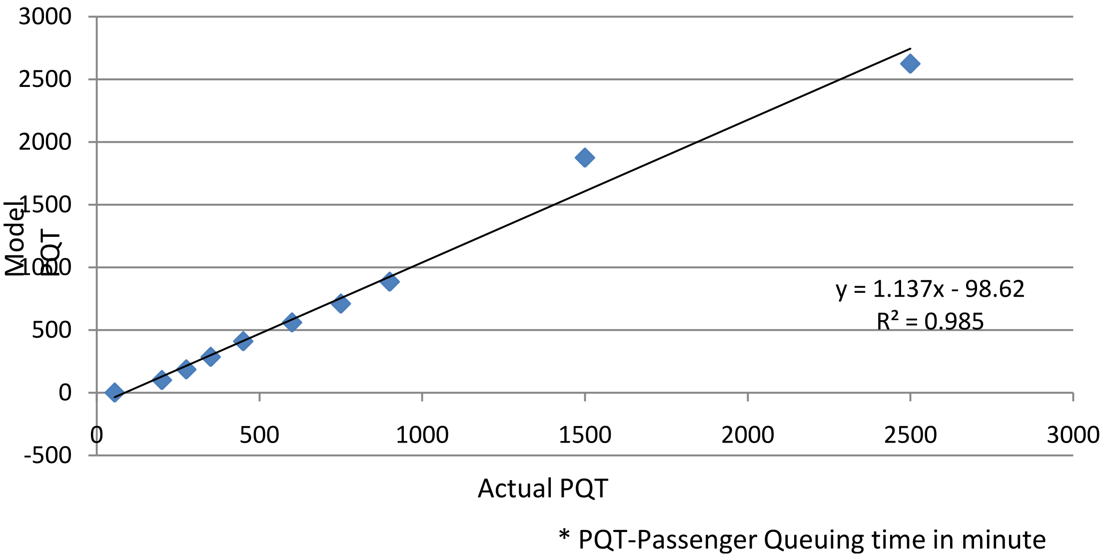


Figure 7-16 Actual vs. Model output from 7:15 AM to 8:00 AM

In the region 4 r^2 value is 0.985 and it is very close to 1 so that it can conclude that the real system and model output are same.

8 Conclusion

Sri Lanka is still not having good transportation network especially in the city area which has high traffic jam at the peak hours. Several researches had been followed to prevent traffic problems in Sri Lanka. This case study had introduced some important concepts to develop and synchronize the transport network throughout the country. The initial step was focused on Sri LankaRailway, which is one of the famous transportation medium in the 19th century. Proper scheduling and planning of SLR resources, good start can achieve for synchronize transport in Sri Lanka. Modern technology barriers will cause for slow development in SLR. This study observed that the new concept for train scheduling is needed for SLR.

The case study was able to find some issues in current railway schedule. Uneven inter arrival time is making poor popularity in rail transport. According to the current timetable it shows more than one hour intervals in day time, so that it may cause for unpopularity of railway. Form 5:30 AM to 8:00 AM is the busiest time period for Kalutara to Colombo track because of the highest passenger demand.

It has created a model to simulate railway system for the coastal network form Kalutara South to Colombo Fort and it is able to simulated and problems faced during application. Initially the model has run for the current schedule and observed the passenger queuing time at the station. The total queuing time of the KSS station during the specific time period and for the current timetable is 15050 minutes. KNS total queuing time is about 4315 minutes.

Instead of current schedule, proposed a new regular interval time schedule for SLR, the new time table created until met specific properties such as easy to remember, to increase popularity, safe, comfortable, fast and low cost journey. New train schedule has been created for 10 minute, 15 minute, 20 minute inter arrival times and observed the passenger queuing time of the station. In this new system KSS passenger queuing times are 7030 minutes, 11485 minutes, 16880 minutes. According to those data if the inter arrival time**is** below 15 minutes passenger queuing time is lower than the current system.

The model has been verified form running the current railway system and observing passenger count at the station. Validation result for the actual and model output has analyse for r^2 regression r^2 values has been calculated for four separate regions such as 5:30 AM to 6:00 AM, 6:05 AM to 6:35 AM, 6:40 AM to 7:10 AM and 7:15 AM to 8:00

AM. Region 1, 2 and 4 shows the heights r^2 values such as 0.994, 0.961 and 0.985. It can be seen, in the difference between the current schedule in the model and the actual passenger time is very narrow. So that it is clear to say the actual schedule queuing time and model output is matched for single line railway. Because of that the model is able to run for the proposed train schedule and also it can be seen that the real system with the propose schedule output are the same.

Practical problems could be detected and by changing required parameters in the model and within the regulations it is able to give an optimal solution for the system. This will be of helpful to train planning decision makers to plan proper train schedules and plan to fully utilize their resources. Concepts and ideas behind this project could be used for future development of synchronize transportation throughout Sri Lanka. Synchronize transport with buses and trains are very important to escape from current traffic problems. Railway and Public transportation quality improvement directly influence for reduction of the cost and it helpstoreduce traffic in urban areas. Also this will help to minimize cost and improve the economy of country.

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Appendix 1

Table 9-1Current railway time table

Station	8302	4021	8304	4077	8309	8311	8310	8317	8316	8320
KSS	3:52		4:22		5:02	5:36		5:56		6:15
KNS	3:57		4:27		5:07	5:41		6:02		6:20
WDS	4:09		4:39		5:19	5:53		6:13		6:32
PIS	4:14		4:44		5:24	5:59		6:19		6:37
PNS	4:19		4:49		5:29	6:05	6:10	6:25	6:30	6:42
EUS	4:25		4:55		5:35		6:15		6:36	6:49
KWS	4:28		4:58		5:38		6:18		6:40	6:52
MOR	4:32		5:02		5:42	6:17	6:23	6:37	6:45	6:56
LUN	4:36		5:06		5:46		6:26		6:50	7:01
ANG	4:39		5:10		5:49		6:29	6:42	6:54	7:04
RTH	4:42	5:10	5:12	5:50	5:52	6:26	6:33	6:46	6:58	7:07
MTL	4:46		5:16		5:56		6:36	6:51	7:03	7:11
DHS	4:50	5:13	5:20	5:53	6:01			6:56	7:08	7:15
WWS	4:55	5:18	5:25	5:58	6:05		6:45	7:02	7:14	7:20
BAM	4:59	5:26	5:29	6:07	6:09	6:40	6:49	7:07	7:19	7:24
KOL	5:03		5:33			6:44	6:53	7:11	7:24	7:29
SIS	5:06		5:36		6:16	6:48	6:56	7:16	7:29	7:33
SEC					6:19	6:51	6:58	7:18	7:32	7:37
COF	5:10	5:35	5:40	6:17	6:22	6:54	7:02	7:22	7:35	7:40

Station	8313	8324	8318	8063	8327	8326	8097	8328	8325	8333
KSS		6:36		6:45	6:48	7:00	7:01			7:20
KNS		6:43				7:04				7:25
WDS		6:54				7:10				7:36
PIS		7:00								7:41
PNS	6:55	7:05		7:01	7:05	7:19	7:20	7:30		7:46
EUS	6:59							7:35		7:52
KWS	7:02							7:38		7:55
MOR	7:06	7:19					7:33	7:42	7:50	7:59
LUN	7:09	7:24						7:46	7:53	
ANG	7:12	7:27						7:49	7:56	
RTH		7:30			7:20			7:53	7:59	8:06
MTL	7:16							7:57	8:03	
DHS	7:20	7:38						8:01	8:07	8:12
WWS			7:25	7:28				8:06	8:12	
BAM	7:29	7:45		7:32	7:35	7:48	7:54	8:10	8:20	8:19
KOL	7:33	7:50		7:36	7:39	7:53	7:59	8:14	8:20	8:24
SIS	7:36	7:54		7:39	7:42	7:57	8:03	8:17	8:23	8:27
SEC	7:39	7:58		7:42	7:45	8:01	8:07	8:20	8:26	8:30
COF	7:42	8:02	7:37	7:45	7:45	8:04	8:10	8:23	8:29	8:33

Station	8331	8335	8330	8342	8059	8057	8341	8346	8339	8336
KSS				8:05	7:56	8:35				
KNS				8:10						
WDS				8:21						
PIS				8:25						
PNS		8:05		8:33		8:51			9:15	9:35
EUS		8:10		8:40					9:20	9:41
KWS		8:13		8:44					9:23	9:45
MOR	8:05	8:17		8:49		8:58	9:00		9:27	9:50
LUN	8:07	8:21					9:03		9:31	9:54
ANG	8:10	8:24	8:40				9:06		9:34	9:58
RTH		8:27	8:44				9:09		9:38	10:02
MTL	8:16	8:31		9:00		9:06	9:13	9:15	9:42	10:07
DHS	8:20	8:35	8:49				9:17	9:19	9:46	10:12
WWS	8:25	8:40	8:55				9:22		9:51	10:17
BAM	8:29	8:44	9:01	9:13				9:30	9:55	10:23
KOL	8:32	8:47	9:04	9:16			9:30	9:34	9:59	10:27
SIS	8:35	8:50	9:08	9:20			9:33	9:38	10:02	10:31
SEC	8:38	8:53	9:11					9:41	10:05	
COF	8:41	8:56	9:14	9:24	8:43	9:32	9:37	9:44	10:08	10:34

Station	8344	8349	8085	8350	8352	8363	8355	8356	8365	8039
KSS	10:45	11:53	12:15	12:20	13:40	14:12				16:02
KNS	10:50			12:25	13:45	14:18				
WDS	11:01			12:36	13:56	14:29				
PIS	11:06			12:42	14:00	14:35				
PNS	11:11	12:16	12:36	12:48	14:05	14:34	15:00		16:10	16:27
EUS	11:17			13:11	14:11		15:05		16:16	
KWS	11:20			13:15	14:14		15:08		16:20	
MOR	11:24	12:35		13:20	14:18	14:49	15:12		16:25	16:40
LUN	11:28			13:25	14:22	14:53	15:16		16:29	
ANG	11:31			13:29	14:25	14:56	15:19		16:33	
RTH	11:34			13:33	14:28	14:59	15:22		16:37	16:47
MTL	11:38		12:56	13:38	14:32		15:26	16:10	16:42	16:51
DHS	11:42			13:44	14:36	15:05	15:30	16:14	16:47	
WWS	11:44			13:49	14:41		15:35	16:19	16:53	
BAM	11:51			13:54	14:45	15:14	15:39	16:24	16:57	
KOL	11:55			13:58	14:49	15:17	15:43	16:28	17:01	
SIS	11:58			14:02	14:52	15:20	15:46	16:31	17:05	
SEC	12:01			14:05		15:23		16:34	17:08	
COF	12:04	13:03	13:15	14:08	14:56	15:26	15:50	16:37	18:11	17:14

Station	8362	8366	8367	8378	8373	8051	8373	8376	8372	8375	8390
KSS					17:01	17:00		17:30	17:45		22:22
KNS					17:25			17:35			
WDS					17:36			17:42		18:30	
PIS					17:40					18:35	
PNS			17:05	17:40	17:45	17:21	17:45	17:50	18:00	18:39	22:38
EUS			17:11	17:45					18:05	18:45	
KWS			17:15	17:48					18:09	18:48	
MOR	16:45	17:10	17:20	17:53	17:55	17:36		18:00	18:13	18:52	22:47
LUN		17:13	17:24	17:55					18:16	18:56	
ANG		17:16	17:28	17:58					18:19	18:59	
RTH	16:50	17:19	17:32	18:01	18:03		18:03		18:22	19:02	
MTL	16:54	17:23	17:36	18:04	18:07	17:47	18:07		18:26	19:06	
DHS	16:58	17:27	17:40	18:08	18:11	17:51	18:11		18:30	19:10	
WWS		17:32	17:45	18:13	18:16		18:16		18:35	19:15	
BAM	17:05	17:36	17:50	18:17			18:20	18:23	18:39	19:19	23:06
KOL	17:09	17:40	17:54	18:20	18:24		18:24	18:27	18:43	19:23	
SIS	17:12	17:43	17:58	18:23	18:27			18:30	18:46	19:26	23:13
SEC	17:15	17:46	18:01	18:26	18:30			18:33	18:49		
COF	17:18	17:49	18:04	18:29	18:33	18:05	18:33	18:37	18:52	19:30	23:16

Appendix 2

UNIVERSITY OF MORATUWA

MASTER OF ENGINEERING IN MANUFACTURING SYSTEMS ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING
RAIL PASSENGER SURVEY QUESTIONNAIRE

Thank you for participating in this survey. I would like to mention that the information provided below will collect data by a student who is enrolled for Masters Manufacturing system engineering University of Moratuwa to enhance the academic knowledge and for no other purpose. Furthermore, all the answers you provide in this survey will be kept as confidential. The research findings will be recommended for implementation to enhance good service for passengers who are using theSri Lanka Railway.

This survey will take about only 5 minutes of your valuable time to complete.

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1. SECTION 1: TRAIN DETAILS

1.1. Please fill in the scheduled departure time of the train you caught after being given this questionnaire. Use the 24 hr clock e.g. 17: 25

1.2.You were given this questionnaire before boarding a train at Colombo Fort. At which station did you get off this train? Please write in the name of the station:

Kalutara South	Kalutara North	No 1	Wadduwa	Panadura	Egoda Uyana
Korala wella	Moratuwa	Lunawa	Angulana	Rathmalana	Mt Lavinia
Wella watta	Bambalapitiya	Kollupitiya	Slave Island	Sectaries	

1.3.Did this journey involve you travelling on a rail replacement bus or coach service today?

Yes………………………………………………………………………………… ☐
No……………………………………………………………………………………☐

1.4. Did you continue your journey by train after getting off at this station? (Please remember not to include underground travel).

Yes……………………………………………………………………………………☐
No………………………………………………………………………………… ☐

1.5.Please underline the name of your final destination station:

Kalutara South	Kalutara North	No 1	Wadduwa	Panadura	Egoda Uyana
Korala wella	Moratuwa	Lunawa	Angulana	Rathmalana	Mt Lavinia
Wella watta	Bambalapitiya	Kollupitiya	Slave Island	Sectaries’	

1.6.Please underline the names of any other stations at which you changed trains before reaching your final destination:

Kalutara South	Kalutara North	No 1	Wadduwa	Panadura	Egoda Uyana
Korala wella	Moratuwa	Lunawa	Angulana	Rathmalana	Mt Lavinia
Wella watta	Bambalapitiya	Kollupitiya	Slave Island	Sectaries'	

2. SECTION 2: YOUR JOURNEY TODAY

2.1.What was the main purpose of the trip you were making when given this questionnaire?

- Daily commuting to/from work ………………………………………………………… ☐
- Less regular commuting to/from work ……………………………………………….. ☐
- Daily commuting for education (to/from college/school/university) …………………… ☐
- Less regular commuting for education (to/from college/school/university) …………….. ☐
- On company business (or own if self-employed) ……………………………………….. ☐
- On personal business (job interview, dentist etc.) ……………………………………… ☐
- Visiting friends or relatives ……………………………………………………………… ☐
- Shopping trip ………………………………………………………………………… ☐
- Travel to/from holiday ………………………………………………………………. ☐
- A day out ……………………………………………………………………………. ☐
- Sport ………………………………………………………………………………… ☐
- Other leisure trip …………………………………………………………………….. ☐

2.2.And were you on your outward or return journey when you were given a questionnaire?

Outward ☐	One way trip only ☐	Return ☐

2.3.How did you buy your ticket for your journey today?

- In advance - booked over phone…………………………………………………….. ☐
- In advance at station…………………………………………………………………. ☐
- In advance via travel agent…………………………………………………………… ☐
- In advance - via the internet/a website……………………………………………. ☐
- On the day of travel at a station ticket office…………………………………………. ☐
- On the day of travel - ticket collected at station……………………………………… ☐
- On the day of travel on the train……………………………………………………… ☐
- On the day of travel - via the internet/a website……………………………………… ☐
- On the day of travel - via Apps………………………………………………………. ☐
- Used a season ticket…………………………………………………………………. ☐
- Ticket was organized for me…………………………………………………………. ☐
- Season……………………………….. ……………………………………………….. ☐

2.4.When did you buy your ticket for your journey today?

Today ☐	In last fortnight ☐	In last week ☐	In last month ☐	In last two month ☐

2.5.Is your ticket for your journey today?

First class ☐	Second class ☐	Standard Class ☐

2.6.Did you experience any delay either on this train or because the train you had planned to catch there was cancelled? Again, please think only of the train you first boarded at Colombo fort station directly after receiving the questionnaire

No delay ☐	Yes - minor delay ☐	Yes - serious delay ☐

2.7.What sort of delay did you experience? (tick all that apply)

- The train was late departing at the beginning of my journey………………………… ☐
- The train was late arriving at my destination……………………………………… ☐
- The train I had planned to catch was cancelled…………………………………… ☐
- Could not get on train as it was overcrowded……………………………………… ☐
- Took longer than expected to buy train ticket……………………………………….. ☐
- Train I took to this station was late and I missed my connection…………………….. ☐
- Crowding at station meant it took a long time to reach my platform and I missed my train…………………………………………………………………………………..... ☐
- Lack of/poor information caused a delay to my journey…………………………..… ☐

2.8.How long was your delay?

3. **SECTION 4: ACCESS TO RAIL NETWORK**

3.1.Which methods of transport did you use to get toKalutra South station where you were handed the questionnaire? (tick all that apply)

- On foot/walked……………………………………………………………….. ☐
- Bicycle (parked at or near station)………………………………………………… ☐
- Bicycle (taken onto train)………………………………………………………… ☐
- Motorbike……………………………………………………………………… ☐
- Bus/Coach……………………………………………………………………… ☐
- Taxi……………………………………………………………………………… ☐
- Car parked at or near station……………………………………………………. ☐
- Car - dropped off……………………………………………………………….. ☐

3.2. Which methods of transport did you use to get from the station when you finished your train journey? (tick all that apply)

On foot/walked ☐	Bicycle (parked near station) ☐	Bicycle (taken onto train) ☐	Motorbike ☐
Bus/Coach ☐	Taxi ☐	Car parked at or near station ☐	Car – picked up ☐

3.3. Thinking about the whole journey you were making, of which the train journey was a part, how long did the whole journey take from the time you started out until the time you got to your final destination?

Less than 30 minutes ☐	30 - 59 minutes ☐	1 hour - 1 hour 59 minutes ☐
2hours - 2 hours 59 minutes ☐	3 hours - 3 hours 59 minutes ☐	4 hours or more ☐

4. SECTION 4: Further development

4.1. What time schedule will help you to minimize journey time

4.2. What kind of improvement of SLR wills you propose?

4.3. What are the special requirement regarding your journey

Thank you for your help in completing this questionnaire.

Appendix 3

Table 9-2Passenger Survey Result

	Questions	P1	P2	P3	P4	P5	P6
1	Scheduled departure time	0.29	0.29	0.29	6.58	7.20	7.00
2	Final Destination	KOL	KOL	KOL	Petta	Dematagoda	petta
3	Purpose of travel	Work	work	work	work	work	business
4	How to get the ticket	Season	season	season	season	Titcket	Titcket
5	When did u buy ticket	Last month	Last month	Last month	Last month	today morning	today morning
6	Ticket class	E	E	E	E	E	2nd class
7	Delay	0	0	0	0	yes	yes
8	What sort of delay	NONE	NONE	NONE	NONE	10min	10min
9	How to access rail network	Car drop	Staff Van	Bus	Bus	walk	Car drop
10	Total Travel time by train	50 min	50 min	50 min	55 min	1h 10min	1h
11	Total Travel time by other	35	15	15		10min	15min
12	Disturbance					Signal issue	Signal issue

	Questions	P7	P8	P9	P10	P11	P12
1	Scheduled departure time	7.00	6.18	6.18	6.58	7.00	6.58
2	Final Destination	BAM	RTH	RTH	COF	PAN	BAM
3	Purpose of travel	Work	TEC	TEC	work	Class	Work
4	How to get the ticket	Season	Season	Season	season	Tiket	Season
5	When did u buy ticket	Last Month	Last Month	Last Month	Last month	today morning	Last week
6	Ticket class	E	E	E	E	2	E
7	Delay	Yes	0	0	0	0	0
8	What sort of delay	20Min	None	None	NONE	NONE	NONE
9	How to access rail network	Bus	Bike	Bus	Staff Van	Walk	Walk
10	Total Travel time by train	50Min	45Min	45Min	55 min	20Min	50min
11	Total Travel time by other	5min	10Min	20min	10Min	30 Min	5 min
12	Disturbance	another train has broken	RTH		WEL		

	Questions	P13	P14	P15	P16	P17	P18
1	Scheduled departure time	6.45	6.45	6.45	7.04	7.04	7.20
2	Final Destination	Rathmalana	Petta	Kollupitiya	Maradana	Petta	Maradana
3	Purpose of travel	Tec	Work	Work	Work	Business	Work
4	How to get the ticket	Ticket	Season	Ticket	Ticket	Ticket	Season
5	When did u buy ticket	today morning	Last Month	today morning	today morning	today morning	Last Month
6	Ticket class	E	E	E	E	E	2
7	Delay	0	0	0	0	0	0
8	What sort of delay	NONE	NONE	NONE	NONE	NONE	NONE
9	How to access rail network	Bus	Bus	Bus	Staff Van	Bus	Walk
10	Total Travel time by train	1h	1h30min	1h	1h	1h	1h15min
11	Total Travel time by other	10min	30min	10min	10min	45min	5 min
12	Disturbance						

	Questions	P19	P20	P21	P22	P23	P24
1	Scheduled departure time	6.18	6.18	7.20	6.18	7.20	6.18
2	Final Destination	Petta	Wellawatta	Moratuwa	Mt.Lav	Moratuwa	Kollupitiya
3	Purpose of travel	Work	Class	Class	Work	Work	Work
4	How to get the ticket	Ticket	Ticket	Ticket	Season	Season	Season
5	When did u buy ticket	today morning	today morning	today morning	Last Month	Yesterday	Last Month
6	Ticket class	E	E	E	E	E	E
7	Delay	Yes	0	0	0	Yes	0
8	What sort of delay	2Min	NONE	NONE	NONE	5Min	NONE
9	How to access rail network	Bike	Van drop	Bike	Walk	Walk	Bus
10	Total Travel time by train	1h10min	50min	30min	45min	30min	1h
11	Total Travel time by other	5min	45min	30min	30min	10min	10min
12	Disturbance	Signal Issue				Delay start	

	Questions	P25	P26	P27	P28	P29	P30
1	Scheduled departure time	8.10	7.00	7.00	8.10	6.35	6.35
2	Final Destination	Maradana	dematagoda	dematagoda	Petta	Petta	Maradana
3	Purpose of travel	Work	Work	Work	Work	Work	Work
4	How to get the ticket	Season	Season	Season	Season	Season	Season
5	When did u buy ticket	2 weeks ago	Last week	2 weeks ago	Last month	Today	Last Month
6	Ticket class	E	E	2	E	E	E
7	Delay	Yes	Yes	Yes	0	0	0
8	What sort of delay	5Min	5mIn	5Min	NONE	NONE	NONE
9	How to access rail network	Car drop	Bus	Bus	Van drop	Bus	Bus
10	Total Travel time by train	1h	1h20min	1h20min	1h	1h30min	1h 45min
11	Total Travel time by other	10min	5min	5min	20min	15min	15min
12	Disturbance	Signal Drop	Signal Drop	Signal Drop			

	Questions	P31	P32	P33	P34	P35	P36
1	Scheduled departure time	6.05	6.05	6.05	7.00	7.00	8.36
2	Final Destination	Kollupitiya	Bambalapitiya	Kollupitiya	dematagoda	Negambo	Petta
3	Purpose of travel	Work	Work	Work	Work	Work	Work
4	How to get the ticket	Ticket	Ticket	Season	ticket	Season	Season
5	When did u buy ticket	today morning	today morning	Last Month	today morning	Last week	Last week
6	Ticket class	E	E	E	2	E	E
7	Delay	0	0	Yes	0	0	0
8	What sort of delay	NONE	NONE	2Min	NONE	NONE	NONE
9	How to access rail network	Bus	Bus	Bike	Bike	Bike	Car drop
10	Total Travel time by train	1h	50min	55min	1h20min	2h 15min	1h 10min
11	Total Travel time by other	30min	20min	5min	10min	12min	5min
12	Disturbance			Slow			

	Questions	P37	P38	P39	P40	P41	P42
1	Scheduled departure time	8.50	8.50	7.20	8.36	5.57	7.20
2	Final Destination	MAR	MAR	MAR	Petta	Slave Island	Moratuwa
3	Purpose of travel	Work	Work	Work	for trip	work	Campus
4	How to get the ticket	Ticket	Ticket	Season	Ticket	Season	Season
5	When did u buy ticket	today morning	today morning	2 weeks ago	today morning	Today	Last Month
6	Ticket class	E	E	E	E	E	E
7	Delay	0	0	0	0	0	0
8	What sort of delay	NONE	NONE	NONE	NONE	NONE	NONE
9	How to access rail network	Bus	Walk	Walk	Bus	Bus	Walk
10	Total Travel time by train	1h 10min	1h 10min	45min	1h10min	55min	40min
11	Total Travel time by other	20min	20min	5min	10min	12min	5min
12	Disturbance			Slow			

	Questions	P43	P44	P45	P46	P47	P48
1	Scheduled departure time	7.04	7.04	8.50	7.20	8.36	5.57
2	Final Destination	Maradana	Maradana	Petta	Panadura	Maradana	Kollupitiya
3	Purpose of travel	Work	Work	Work	Class	Work	Work
4	How to get the ticket	Season	Season	Season	Season	Season	Season
5	When did u buy ticket	Last Month	Last Month	Last Month			
6	Ticket class	E	E	E	E	E	E
7	Delay	0	0	0	0	0	0
8	What sort of delay	NONE	NONE	NONE	NONE	NONE	NONE
9	How to access rail network	walk	Bus	Car Drop	Car Drop	Bus	Walk
10	Total Travel time by train	1h10	1h30min	1h 30min	25min	25min	1h
11	Total Travel time by other	20min	15min	10min	10min	20min	15min
12	Disturbance						

Questions	P49	P50	P51	P52	P53	P54
Scheduled departure time	7:20	7:00	7:20	6:58	7:00	7:00
Final Destination	SLI	COF	COF	BAM	KOL	COF
Purpose of travel	Work	Work	Work	Work	Work	Work
How to get the ticket	Season	Season	Season	Season	Season	Season
When did you buy ticket	Last Month	Last Month	Last month	Last month	Last month	Last month
Ticket class	Class 3	Class 3	Class 3	Class 3	Class 2	Class 3
Delay	NO	NO	yes	yes	NO	NO
What sort of delay	0	0	5	12	0	0
How to access rail network	BUS	CAR	CAR	STAFF VAN	BUS	BUS
Total Travel time by train			80	50	54	70
Total Travel time by other			40	20	50	80
Disturbance						

Questions	P55	P56	P57	P58	P59	P60
Scheduled departure time	6:58	7:20	7:20	8:10	7:00	7:00
Final Destination	BAM	KOL	COF	BAM	RTH	SEC
Purpose of travel	Study	Work	Work	Work	Work	SPECIAL
How to get the ticket	Season	Season	Season	Season	Season	Ticket
When did you buy ticket	Last month	Last month	Last month	Last month	Last month	Morning
Ticket class	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3
Delay	NO	NO	yes	NO	yes	yes
What sort of delay	0	0	2	0	1	5
How to access rail network	WALK	CAR	BUS	M/BIKE	BUS	STAFF VAN
Total Travel time by train	55	75	80 Min	75 Min	38 Min	57 Min
Total Travel time by other	20	20	30 Min	10 Min	50 Min	30 Min
Disturbance						

Questions	P61	P62	P63	P64	P65	P66
Scheduled departure time	6:58	8:10	7:00	6:18	7:00	6:45
Final Destination	KOL	MOR	RTH	BAM	MAR	KOL
Purpose of travel	Work	Study	Work	Work	Work	Work
How to get the ticket	Season	Season	Season	Season	Season	Season
When did you buy ticket	Last month	Last month	Last month	Last month	Last month	Last month
Ticket class	Class 2	Class 3	Class 3	Class 2	Class 3	Class 3
Delay	NO	NO	NO	yes	yes	NO
What sort of delay	0	0	0	10	8	0
How to access rail network	WALK	WALK	BUS	BUS	BUS	STAFF VAN
Total Travel time by train	55 Min	45 Min	35 Min	36 Min	80 Min	55 Min
Total Travel time by other	15 Min	10 Min	30 Min	55 Min	30 Min	15 Min
Disturbance						

Questions	P67	P68	P69	P70	P71	P72
Scheduled departure time	7:20	7:00	7:20	6:58	7:00	7:20
Final Destination	BAM	KOL	DEM	RTH	KOL	DEH
Purpose of travel	Work	Work	Work	Work	Work	Study
How to get the ticket	Season	Season	Season	Season	Season	Season
When did you buy ticket	Last month	Last month	Last month	Last month	Last month	Last month
Ticket class	Class 3	Class 3	Class 2	Class 3	Class 3	Class 3
Delay	NO	NO	NO	yes	yes	yes
What sort of delay	0	0	0	2	3	15
How to access rail network	BUS	WALK	M/BIKE	STAFF VAN	M/BIKE	WALK
Total Travel time by train	65 Min	58 Min	85 Min	35 Min	55 Min	60 Min
Total Travel time by other	35 Min	10 Min	10 Min	20 Min	15Min	5 Min
Disturbance						

Questions	P73	P74	P75	P76	P77	P78
Scheduled departure time	6:18	7:20	7:00	8:10	6:58	7:20
Final Destination	KOL	MOR	PAN	MAR	COF	MAR
Purpose of travel	Work	Work	Study	Work	Work	Work
How to get the ticket	Season	Season	Season	Season	Season	Season
When did you buy ticket	Last month	Last month	Last month	Last month	Last month	Last month
Ticket class	Class 3	Class 3	Class 3	Class 3	Class 3	Class 2
Delay	NO	NO	NO	NO	yes	NO
What sort of delay	0	0	0	0	20	0
How to access rail network	WALK	BUS	CAR	BUS	BUS	STAFF VAN
Total Travel time by train	75 Min	40 Min	22 Min	85 Min	60 Min	85 Min
Total Travel time by other	10 Min	100 Min	5 Min	30 Min	15 Min	20 Min
Disturbance						

Questions	P79	P80	P81	P82	P83	P84
Scheduled departure time	7:00	6:58	6:58	7:00	6:05	7:20
Final Destination	KOL	BAM	MOR	KOL	COF	MOR
Purpose of travel	Study	Work	Work	Work	Work	Study
How to get the ticket	Season	Season	Season	Season	Season	Season
When did you buy ticket	Last month	Last month	Last month	Last month	Last month	Last month
Ticket class	Class 2	Class 3	Class 3	Class 3	Class 2	Class 3
Delay	yes	NO	NO	NO	NO	yes
What sort of delay	5	0	0	0	0	2
How to access rail network	BUS	BUS	BUS	BUS	M/BIKE	M/BIKE
Total Travel time by train	55 Min	50 Min	30 Min	55 Min	72 Min	45 Min
Total Travel time by other	50 Min	20 Min	20 Min	15 Min	10 Min	15 Min
Disturbance						

Questions	P85	P86	P87	P88	P89	P90
Scheduled departure time	7:20	8:36	7:00	6:58	7:20	8:10
Final Destination	KOL	KEL	BAM	COF	SEC	GAM
Purpose of travel	Work	Work	Work	Work	Study	work
How to get the ticket	Season	Season	Season	Season	Ticket	Season
When did you buy ticket	Last month	Last month	Last month	Last month	Morning	Last month
Ticket class	Class 3	Class 3	Class 3	Class 3	Class 3	Class 2
Delay	yes	NO	NO	NO	yes	NO
What sort of delay	8	0	0	0	12	0
How to access rail network	M/BIKE	CAR	BUS	WALK	WALK	BUS
Total Travel time by train	70 Min	85 Min	50 Min	55 Min	75 Min	105 Min
Total Travel time by other	20 Min	20 Min	55 Min	10 Min	10 Min	25 Min
Disturbance						

Questions	P91	P92	P93	P94	P95	P96
Scheduled departure time	6:58	7:00	8:10	6:05	8:10	7:20
Final Destination	BAM	RTH	COF	DEM	WEL	PAN
Purpose of travel	work	Work	Work	Work	Work	Work
How to get the ticket	Season	Season	Season	Season	Season	Season
When did you buy ticket	Last month	Last month	Last month	Last month	Last month	Last month
Ticket class	Class 3	Class 3	Class 3	Class 2	Class 3	Class 3
Delay	yes	yes	NO	NO	yes	yes
What sort of delay	10	8	0	0	13	20
How to access rail network	BUS	WALK	WALK	BUS	CAR	CAR
Total Travel time by train	50 Min	30 Min	75 Min	85 Min	75 Min	20 Min
Total Travel time by other	15 Min	12 Min	5 Min	20 Min	10 Min	15 Min
Disturbance						

Questions	P97	P98	P99	P100
Scheduled departure time	8:10	6:58	7:00	7:20
Final Destination	WEL	BAM	SEC	COF
Purpose of travel	Work	Study	Work	Work
How to get the ticket	Season	Season	Season	Season
When did you buy ticket	Last month	Last month	Last month	Last month
Ticket class	Class 3	Class 2	Class 3	Class 3
Delay	NO	NO	NO	NO
What sort of delay	0	0	0	0
How to access rail network	BUS	BUS	BUS	CAR
Total Travel time by train	75 Min	50 Min	55 Min	75 Min
Total Travel time by other	20 Min	10 Min	60 Min	15 Min
Disturbance				