ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF ELECTRICAL AND COMPUTER ENGINEERING

TRAIN SCHEDULING OF ADDIS ABABA LIGHT RAIL TRANSIT SYSTEM

A Thesis
Presented to
Addis Ababa University
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In Partial Fulfillment
of the requirements for the Degree
Master of Science in Electrical Engineering for Railway Systems

By: G/Aftse G/Michael Teklu

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Approval by Board of Examiners

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Declaration

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in this or any other university, and all sources of materials used for the thesis have been fully acknowledged.

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Place: Addis Ababa

Date of Submission: __________________

This thesis has been submitted for examination with my approval as a university advisor.

Dr. YalemzewdNegash ___________________________

Advisor Signature

ABSTRACT

Train scheduling is the process of timetabling and train assignment along a given train network. The key objective of this project is to design an efficient train scheduling of Addis Ababa Light Rail Transit system which minimizes passenger waiting time and operational costs without jeopardizing passenger safety.

There are many approaches/techniques that are used to model and implement train scheduling especially for light rail transit systems that have many intermediate stations. In this thesis reviewing previous relevant literatures with a special attention paid to the light rail transit systems, quantitative analysis and simulation methods are being used. The scheduling is being generated using two separate rule-based systems that are off peak hours and peak hours. The main components of train scheduling such as trains, stations, routes are being described or specified with their constructive parameters. The mathematical model components proposed are being analyzed, and the extent that reflects real business practice is being presented. It was uncovered that the objective function which includes both the service level objective (minimizing passenger travel and waiting time) and the operational objective (minimizing the number of trains) especially for the Addis Ababa Light Rail Transit (AALRT) system as it is new in Ethiopia.

Finally, this paper is focused on the constraints involved on the current system that can be used to generate an efficient train scheduling which is being modeled, solved the model, validated the model via simulation and verified the results in such a way that the schedule is made to be displayed at any station to show the trains allocated along that route with their arrival and departure times on the operating time of whole day to satisfy the desired service levels.

Key words: Train Scheduling, Addis Ababa Light Rail Transit System, Quantitative Modeling, Simulation.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ACRONYMS

AALRT	Addis Ababa light rail transit
CAP	Capacity of trains operating on the networks routes.
Co	The Vehicle operating cost per minute
C_p	The passenger waiting time cost per minute
C_v	The In-vehicle time cost per minute
C#	Programming language
d^k_{ij}	The Demand from station i to station j along train route k
E	Element of
E-W	East-West
Fk	Frequency along route k
i,j	Station name
K	Route name
Km/h	kilo meter per hour
M	Stands for the total number of fleet available.
n	The number of people getting into the train at a time or (No. of doors X Capacity of each door).
N	Set of nodes on the train network.
N-S	North- South
N_t	Number of trains
P	Time period
P_a	The number of persons alignting at a station.
P_b	The number of persons boarding at a station.
P_{in}	Passenger inflow to station
P_{out}	Passenger outflow from station
P_{prev}	Passenger quantity on train at previous station
q_{ij}^k	Passenger flow on link i-j of train route k.
$(q_{ij}^k)_{max}$	Maximum Passenger flow on link i-j of train route k.
S-N	South-North
SR	Set of station routes
T_a	The time for each passenger to alight the train.
T_b	The time for each passenger to board the train.
T_{arr}	Arrival time
T_{dep}	Departure
T_{dw}	Dwell time
T_{ho}	Head on time
Tk	The Round trip time for trains along route k, including dwell time
T_{oc}	The time it takes to close and open the doors.
T_{pass}	Arrival time of passenger
T_{trav}	Travel time from station i to j
t^k_{vij}	The In-vehicle time of passengers traveling from station i to j along route k;
$t^k_{wt,ij}$	The Waiting time of passengers traveling from station i to station j along route k
W-E	West-East
$\forall$	For all
$\sum$	Summation

GENERAL CONCEPTS

Dwell time: is the length of time any train stops at any station.

End of route: is the last point/destination of any train route.

End time: is the time on which any train stops operation.

Route: is the direction/way of train runs through on the specified network.

Route length**:** is distance travel from a point of origin to a point of destination along a specified route.

Route name: is the name given for routes along specified railway network.

Start of route: is the beginning/origin of a route.

Start time: is the time on which any train starts operation.

Start time interval/head on time: is the time difference between successive trains on the same route.

Station: is the place where passengers alight and board or place where trains stop along the train route in my case.

Station code: is an identification code given to a station specifying one from other.

Station name: is the name given to a station along specified route.

Station number: is the number given to a station with respect to the starting of any route.

Train*:* is a locomotive or vehicle which transports passengers or freight through railway road.

Train capacity: is the capacity of a train which can carry at rated load or over load.

Train code: is the identification code given to trains allocated along any route.

Train registration date: is the date on which any train is registered for scheduling.

1. INTRODUCTION

Train scheduling is the process of timetabling and assigning/allocating trains along specified train route in such a way that any train's arrival and departure time is defined and can be displayed at any station. The need of railway transport system is increasing from time to time in almost all parts of the world due to population growth. Railway transport system is economical especially if it is electrical powered and can easily satisfy passengers demand. This thesis is supposed to focus on train scheduling of new Addis Ababa Light Rail Transit (AALRT) system which is passenger transportation system project launched in 2012 under the administration of Ethiopian Rail way Corporation (ERC) that hasn't been implemented anywhere in our country yet. It is known that Addis Ababa is the capital city of Ethiopia as well as Africa in which different international diplomats are hosted and the population size of the city is increasing from time to time that can't be accommodated by the present public and private vehicle transportation system. So, the only alternative to reduce transportation problem in Addis Ababa is rail way transportation system that is supposed to be implemented in the first phase of rail way project as part of the growth transformation plan (GTP) and will be extended to the other parts (corridors) of our city or country as it is being done in mostly populated cities in the world.

The urban transportation systems have come under heavy strain as we see in Addis Ababa affecting the quality of life of urban dwellers. Lack of mass transportation facilities has resulted in heavy shift of commuter patronage to private and intermediate transport (leading to an imbalance in the modal spilt) and consequently, a huge increase in number of intermediate and private vehicle ownership. Encouraging optimal use of existing and proposed public transport (railway system) will be an effective way of achieving the desired modal share between different modes of transport. Public transport system can be made attractive, in terms of quicker travel, convenience and comfort to the user. This will also increase the efficiency of each public transport mode available as they will act as complimentary to each other instead of competing.

Railroad transportation will further grow for both passenger and freight transportation. These developments increase the demand for denser timetables or schedules. When increasing the density of timetable, scheduling trains becomes more and more difficult. The reasons are a lot of restrictions and limits. Examples for these factors are the track topology, rolling stock, human resources and service requirements. An automatic generation of conflict-free train scheduling in reasonable time can be very helpful in order to evaluate several alternative timetables. Therefore, the interest in automatically generating railway's train scheduling has increased over the past years. Railway transportation has played a major role in the economic development in the last two centuries. It represented a major improvement in land transport technology and has obviously introduced important changes in the movement of freight and passengers. Over the last few years, railway traffic has increased considerably, which has created the need to optimize the use of railway infrastructures. This is, however, a very difficult task. Thanks to developments in computer science and advances in the fields of optimization and intelligent resource management, railway managers can optimize the use of available infrastructures, obtain more robust timetables, and obtain useful conclusions about capacity of their topology[19], [20].

Public transportation problem affects country's economy. So, it is important to raise the capacity of public transportation system and quality of service at reasonable cost, in order to prevent problems caused by individual means of transport such as pollution, congestion and social discrimination [1].

The most essential schedule of transportation systems especially in Railway transportation system is the train scheduling ; Constructing a timetable or train scheduling is part of the overall transit planning process, a choice of service frequency for each route, and allocations of vehicles and crews to routes [2],[3].

2. BACKGROUND

It is known that train scheduling of AALRT is not implemented yet, because the project hasn't been completed. So, the purpose of this thesis is to define the critical objectives, determine the key components and identify the key issues for developing a comprehensive mathematical model for train scheduling of light rail transit system to assign trains efficiently along both corridors i.e. East-West and North-south to- and -fro for each four routes.

2.1. Railway Transport Planning

Railway transport planning is a highly complex task. Too many objects interact with each other to be manageable simultaneously. Various sub problems of different nature like network design, scheduling or routing occur, and the solutions of most of those sub problems depend on the solutions of the other sub problems. Due to severe competition from other transportation modes, the rail industry is eager to improve its operational efficiency and rationalize its planning decisions. Different demands on the railway transport service come from different departments such as marketing department takes care of the passengers' wishes like minimization of travel time, pleasant changes from one train to another (short waiting time, opposite platforms) and logistic department pay attention to the cost aspects which is responsible for the efficient usage of rolling material and personnel.

The planning process is divided into several steps as shown in figure 2.1.

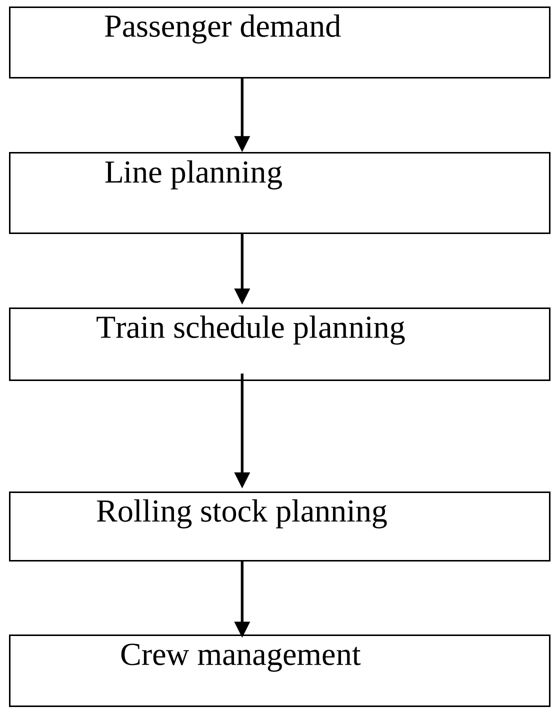


Figure 2.1: Hierarchical railway transport planning

Passenger Demand

On the first step of railway planning, the passenger demand has to be analyzed. As a result, the amount of travelers wishing to go from certain origins to certain destinations will be known. In order to establish a customer-oriented transportation service, the passenger demand or traffic volume must be given or estimated. The conventional form of passenger demand data is a so-called origin-destination matrix (OD-matrix). An entry (i,j) of this matrix gives the number of people wishing to travel from location(station)/origin i to location(station)/destination j. A number of cost-intensive interviews of customers may form a basis for statistical methods of estimating the overall demand. Other approaches are traffic censuses on the network and mathematical programming methods that generate OD-matrices. The passenger demand (Boarding & Alighting at each station on all routes along E-W and N-S corridors of the initial stage) surveyed by transport minister on both corridors (East-West and North-South) and the forecast is shown on appendix G and 1->22 and 6->27 indicate station numbers that are to mean from station 1 to station 22 and from station 6 to station 27 and vice versa respectively through intermediate stations that is being received from AALRT project office.

Line Planning

As a subsequent task, lines will be determined, i.e. routes where trains run. Also, the frequencies for the lines will be determined. A line will be given by a route and a corresponding frequency. The route is given by a path in the railroad track network. The frequency determines how often this line will be served in accordance to the schedule period. Line planning is a way of selecting lines from a set of feasible lines subject to certain constraints and pursuing certain objectives. Some possible constraints are that there must be enough lines (or trains respectively) to carry all passengers, the capacity of tracks must not be exceeded the trains available. Common objectives are minimization of costs or maximizing the number of travelers with a direct connection. The line plan serves as direct input for the train scheduling problem, where arrival and departure times for the lines have to be found. Furthermore, the line plan determines which travelers have to change a train during their trip and thus need acceptable connection times. As it is known there are two lines along E-W and N-S corridors and four routes to travel to or fro as we see on figure2.2.

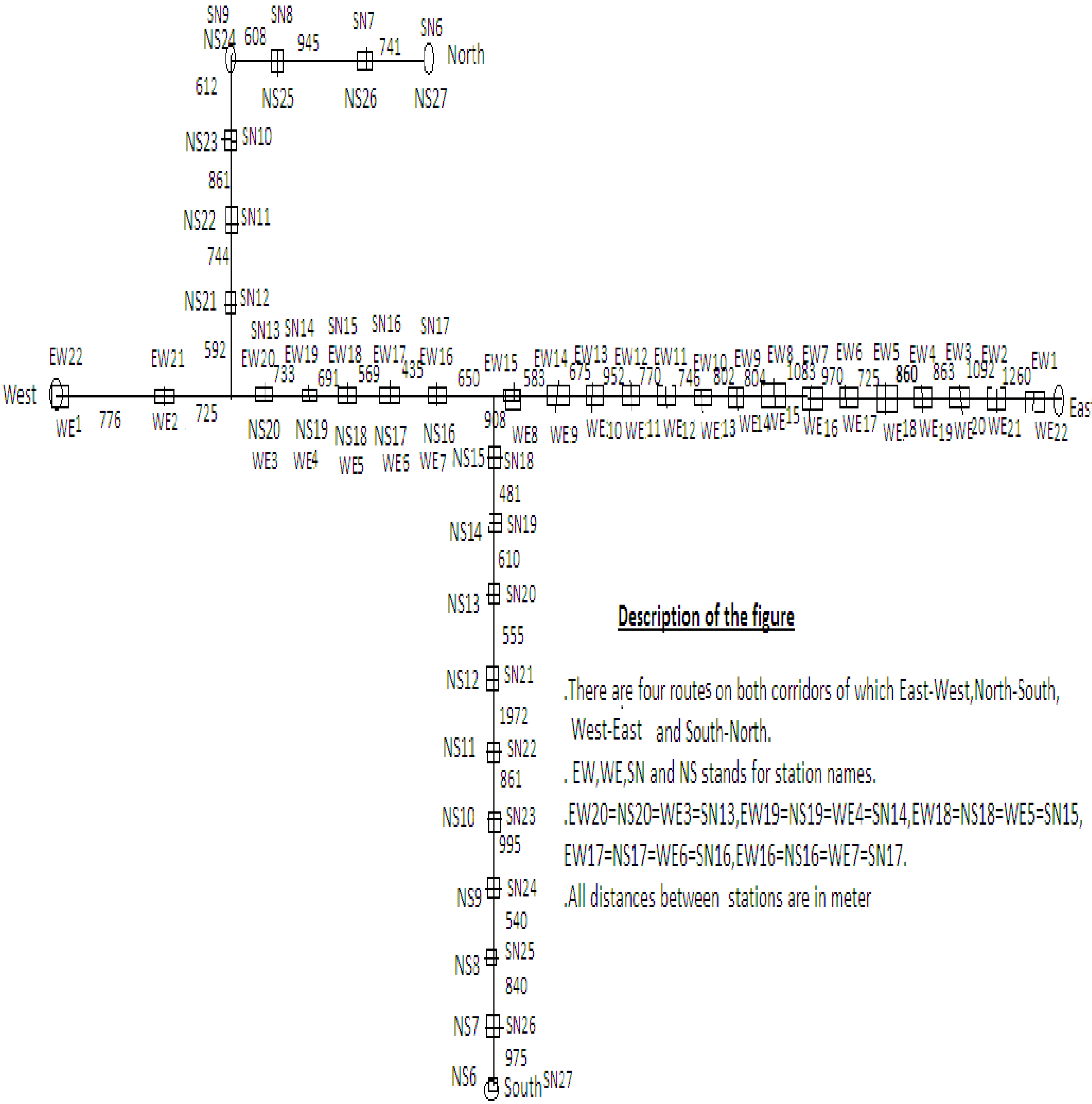


Figure 2.2: Addis Ababa Light Rail Transit system network along both corridors

Time table Planning

In the time table planning step, all arrival and departure times of the lines are fixed for all trains of the line, which should be done in order to subject to the periodicity of the system.

The time table constitutes the backbone of public rail transport planning. The generation of train Scheduling will be the core subject of this thesis. In general, time table for public transports are periodical, i.e. the schedule is being repeated after a basic time period or for short period. For example, for public buses in Addis Ababa schedules are reviewed every month. The assignment of engines and coaches to these trips (or trains respectively) is done in a subsequent step.

Rolling Stock Planning

The engines and coaches have to be assembled to make trains, which are assigned to lines. This is called planning of rolling stock. The trips established by the train scheduling must be performed by some vehicles (motor unit &coaches). Optimization methods for vehicle scheduling in public transportation will be very important. Since the dispatch of rolling stock and personnel has the main influence on the overall transport service costs.

Crew management

Crew management not only consists of dispatching train crews, but also local staff like cleaning staff or ticket office staff, which means the distribution of personnel in order to guarantee that each train will be equipped with the necessary staff.

2.2. Elements of train scheduling

The main elements in train scheduling that should be considered as cost functions are train operating cost, in-vehicle travelling cost and passenger waiting time cost collectively. The problem of train scheduling is to optimally allocate transit units among available routes and obtain the optimal train fleet size. Considering the Origin–Destination flows to be given and fixed, the number of passengers using each path will be a function of the transit allocation, because of the proportionate frequency criterion will be assigned according to the demand of each route. Thus scheduling can be considered as an optimization problem. For the operation of the light rail transit, the user and the operator which are the two agencies that will be involved have conflicting objectives to be satisfied in a single objective function. User will be concerned with waiting time, level of service, least in-vehicle time, etc. Operator will be concerned with minimizing fleet size, vehicle operation cost, maximizing profit, etc. different researches have been done on train scheduling and The objective function of train scheduling was taken as minimization of operating cost of trains (operator cost) subjected to load factor constraint and waiting time constraint [4].

Note: Refer for all symbols used in formulas below on page –vii.

And interpreted as:

$$C_o = \sum_{AllK\varepsilon SR} fk \text{ X } Tk \tag{2.1}$$

The authors in [5] tried to approach in such a way'' objective function of train scheduling as minimization of in-vehicle time of the passenger (user cost).''

And formulated as:

$$C_v = \sum_{\mathrm{AllK\varepsilon SR}} \sum_{i=1}^{n} \sum_{j=1}^{n} [0.5(d^k{}_{ij}\frac{fk}{\sum fk}) \text{ X } t^k{}_{vij}] \tag{2.2}$$

The objective function of train scheduling was taken as minimization of passenger waiting time cost (user's cost) subjected to load factor constraint and waiting time constraint only [21].

And formulated as:

$$C_p = \sum_{AllK\varepsilon SR} \sum_{i=1}^{n} \sum_{j=1}^{n} [0.5(d^k{}_{ij}\frac{fk}{\sum fk}) \text{X } t^k{}_{wt,ij}] \tag{2.3}$$

Even [4], [5] and [21] have contributed for train scheduling optimization independently, they haven't tried to optimize all costs interactively even these costs are conflicting to each other as the operator cost component consists of minimizing the total vehicle operating cost. Here, the user's and operator's objectives are conflicting in nature, for example, decrease in waiting time will result in increase in vehicle operating cost for the operator. Also, the in-vehicle travel time is a variable and is a function of dwell time. The dwell time is again a function of total boarding and alighting at any station, which in turn will depend on the frequency/headway chosen on each iteration. So, train scheduling can be efficient if it accommodates all these costs as much as possible. In doing so, the implications of the emerging train scheduling will be discussed, components of the mathematical models will be proposed, and the extent of their reflection in real business practices will be analyzed. Finally, fundamental issues and primary elements of a simple model in association with general train scheduling will be presented and simulated.

3. PROBLEM STATEMENT AND SCOPE

As we see in Addis Ababa the transport demand is more than the transport supply can handle because of the fact that population growth is faster than that of transport facility. Thus, long queues for long time especially at peak hours are becoming usual that affects working time, hence productivity. Deploying train transport system without efficient time table and/or train scheduling, the problem may not be solved. So, no question that ‘’an efficient train scheduling for the light-rail transit" system is indispensible or a must.

A model, with the aim of minimizing average passenger travel time, waiting time and minimizing number of trains required to save power consumption so as to minimize cost is being proposed and developed in this thesis.

The scope of this thesis is to develop an efficient train scheduling model using appropriate technique or analytical method and simulate using HTML web page design and C#(C-sharp) programming languages on Visual studio IDE and ASP.net controller software of the system, which is supposed to be implemented at operational level only.

4. OBJECTIVES

4.1. General Objective

It is obvious that, nowadays, efficient and reliable public transportation is a critical task for metropolis (big cities like Addis Ababa).In this paper; it is being tried to develop an efficient train scheduling of Addis Ababa Light Transit (AALRT) system so as to satisfy passenger demand by minimizing passenger waiting time and reduce operating cost.

4.2. Specific Objective

The time a passenger spends waiting for transport is a very critical element for evaluating passenger service level as we see in Addis Ababa. Typically, railway passengers face different types of waiting due to different causes such as:

- Improper line scheduling (Rolling stock allocation problem)
- Crew absence
- Rolling stock breakdown
- Power supply interruption
- Shortage of Rolling stocks at peak hours etc.

The specific objective of this thesis is to develop dynamic train scheduling of AALRT system so as:

- To minimize the average waiting of passenger(s)
- To minimize the travel time of passenger(s)
- To minimize the number of trains required to allocate on both corridors
- To develop system software using HTML web design and C# programming languages developed on Visual studio IDE with ASP.net controller and evaluate the system by simulation.

5. LITERATURE REVIEW

In the past, many researchers have developed train scheduling systems with different approaches.

One approach that has been developed:

The objective function of train scheduling was taken as minimization of operating cost of trains (operator cost) subjected to load factor constraint and waiting time constraint [4]. And

The objective function of train scheduling was taken as minimization of passenger travel time cost (user's cost) subjected to load factor constraint and waiting time constraint only [21].

The main problem of their approaches were the waiting time of Passengers (user cost) and in-vehicle time of the passenger (user cost) were not included in their objective function and the dwell time (which influences both the operator and user cost) was considered as a constant that shouldn't be. In my study it is attempted to improve upon these limitations. Also, to apply proportionate frequency criterion for assigning demand on the overlapping stations and it is supposed to solve timetable scheduling and resource assignment problem interactively.

In this thesis development it has being reviewed many literatures that are relevant to my work in addition to the above literatures. Timetabling is the process of assigning events and resources to timeslots subjected to constraints [5]. The tasks of public transportation are to meet the increasing demands of all kinds of passengers by high quality of service based on limited number of vehicles [6].

Hyper Genetic algorithm (GA) or hyper-GA development is advantageous for scheduling geographically distributed training staff and courses [16]. They aimed to maximize the total priority of courses which are delivered in the period while minimizing the amount of travel for each trainer.

The quality of timetable is determined by earliness of scheduled classes [17]. Here, a genetic algorithm was employed to schedule classes as early in the morning as possible, while minimizing the number of holes in a student's schedule. Minimizing the number of conflicts is achieved by number of conflict by a large number and then selecting the best individuals in a population according to smallest fitness value.

Development of a recovery model which involves two related processes, these are determination of revised or amended train schedule and adjustment/ repair of the associated driver duties respectively [18].

Optimal stop-schedules for the train scheduling problem for trains have investigated with respect to various performance criteria that deliver traffic on a line station to the maximization of sub modular functions [15], [14].

Investigations on relationships among basic parameters of the fixed-route transit system operation with number of stations and headway have been done. The assumption of equal spacing of stations along a route does not hold well in reality [12]. Similar constraint framework as part of a decision support model which is based upon combinatorial optimization and simulation can be used [13].

Simulation Model Network (Simone) is a simulation environment developed with the purpose of determining the robustness of a timetable and the stability of a railway network, and thereby improves the quality and stability of the timetables from a set of different criteria and describes the architecture and features of the simulation program [9]. It does this by determining bottlenecks in the network, by examining the number of delayed departures for all the stations in the network. Simone can also be used for analyzing delays and exploring causes and effects of delays for different layouts of railway infrastructures and timetables. Simone can simulate an entire railway network. Quality in timetables depends on network properties such as correspondences between trains and use of shared capacity. Central in Simone is the timetable, which drives the activities. When there are no disturbances all trains run according to schedule. When disturbances occur Simone inspects the different types of delays (primary and secondary) and the user gets extensive information on the delays and delay propagation in a specific simulation. Simone also provides other information and statistics on the states of the trains and stations in the model. This makes it useful for comparing the robustness and punctuality of different timetables. It provides insight on the performance of different timetable and infrastructure combinations. An advantage is the possibility of simulation an entire railway network.

Various concepts are described within simulation of train traffic for use in both planning and train scheduling [10]. They describe the development of a new simulator system which can contribute to improved methods for train traffic planning, experiments for developing new systems and training of operators. It explains the purpose of using simulation in train traffic planning in general. It also explains the difference between simulation as a planning tool and as a learning tool. There is also a thorough description of other purposes of simulation e.g. understanding the behavior of the system, as a base for difficult decisions, or for controlling the system. [7] describes different heuristic measures of stability, the reason for using these measures is that analytical methods are practical only for simple system, and simulation methods are very time consuming, so in practice the most widely used measures are heuristic. The author chooses to focus on measures which can be used in advance for example in the design phase or to estimate the reliability of a proposed schedule. In practice the percentage of services which are on time, and the percentage which is more than 5 or 10 minutes late, is often used as a measure of reliability. These percentages are obtained from the frequency of the distribution of the lateness; therefore they cannot be used as a measure in advance. It should be noted that even though the measures in the article are meant to be used in advance some past information is needed to determine the distribution of the occurrence of delays.

The concepts of reliability in connection with public railway systems are presented in [11]. Reliability is a key factor in transportation to preserve a high customer service level.

The possibility of deriving causal relationships for train delays can be described using several approaches for the study of primary and secondary delays are reviewed in the report [8]. The focus is on secondary delays and especially on how the amount of secondary delays can be related to the amount of primary delays and the capacity utilization. First the author presents some theories on calculating delay. The author connects the theories about delays to capacity. Obviously a timetable becomes more robust if it contains slack or buffer time. To increase the buffer time in a timetable is the same as to reduce the capacity. The discussion about delays therefore involves the discussion about capacity utilization. If there is lack of capacity the risk for disturbances increases.

6. METHODOLOGY

The following methodology have been employed in this thesis as listed below and carried out orderly.

- Literature Review
- Mathematical analysis using Analytical method
- Modeling
- Algorithm development, interface design and Simulation

6.1. Analytical method

When using an analytical method a mathematical model is developed using some or all available data for the system. Analytical methods are often used to find optimal or near-optimal solutions to given problems. Depending on the input data, analytical methods are used for different measures like delay or cost analysis. Analytical methods are often mathematically demanding, but do not require much input, until they can be used without knowing the exact train scheduling. Because the input data is sparse the methods often make a lot of assumptions, which may result in less reliable results. The computational time for analytical methods is usually rather small, hence these methods are good for quick evaluations and many different solutions can be evaluated within a short range of time. For this reason analytical methods are of good use when planning future investments, where uncertainty and lack of realistic input, knowledge is dominating the situation. Analytical methods are used for strategic decisions in the early planning process and are usually only practical for very simple structured systems. An analytical solution method will be the solution of a periodic event scheduling problem which is used to solve problems of periodic train scheduling.

Some technical documents/parameters that can be used for mathematical analysis are being received from Ethiopian Railway Corporation that is forecasted for both corridors of AALRT system for the coming four years.

Train capacity and desription:

Doors=4 on both sides,2-for alighting and 2-for boarding.
Seats=65,
Rated capacity=254 (when 6-persons stand per meter square).
Over load capacity=317 (when 8-persons stand per meter square).
Length=30m;

Speed:

Maximum operating speed=70kmph;
Average travelling speed=20kmph;

Number of passengers per day:
East-West route=60,760.
West-East route=60,751.
North-South route=60,283.
South-North route=60274.

Distance:
East-West corridor=16.764KM.
North-south corridor=16.274KM.

Working length of time per day:
From 5:00 am to 11:00 pm =18 hours.

Peak hours:
7:00-9:00AM.
5:00-7:00PM.

Number of stations:
East-West corridor=22.
North-south corridor=22.
5-stations are common for both corridors.

Dwell time :
25-35sec.

Head on time :
4 min for peak hours and 7.5 min off peak hours.

6.1.1. Proposed Procedure

The methodology is being implemented in such a way that using two-level of analysis. In the first level, minimum frequency of trains and then the number of trains required on each route with guarantee of load feasibility is determined by considering each route individually. Then by summing up the number of trains each route fleet size will be determined.

In second level by taking the fleet size of first level as upper bound, the load feasibility is being checked by considering all routes individually.

Solution for the problem

Given the above parameters, the optimal values can be obtained and helps to allocate resources on the routes of both corridors so as to provide efficient train scheduling. The values that should be obtained are calculated using train scheduling formulas such as number of trains allocated at peak hours and off peak hours, dwell time at every station, head on time, arrival and departure time of assigned train at a station of each route. There are some considerations that should be bear in mind like the time needed to board or alight every passenger and a door to be closed or opened takes 1-2 second which are mostly used in some countries of the world.

First Level

1) Number of trains:

Can be calculated using two methods as shown below:

A) The number of trains of each route at each trip is calculated as follows;

$$N_t = \frac{(Fk\ X\ Tk)}{Time\ period} \qquad (6.1)$$

Where:

- Tk –(2 X single trip time + dwell time at all stations) . And it is known that the time for single trip of each route at an average speed of 20kmph is almost max of 50min so may be less than this if speed increase above 20kmph dwell time of 1min.
- Time period is the total oprating time per day i.e. 18-hours.

But to find the number of trains that should be allocated on route at a time,first the number of trips on each route should be calculated using the following formula:

Frequency along route k:

$Fk=((q_{ij}^{k})_{max})/(2Xtrain\ capacity)$, (6.2)

q_{ij}^{k} has a value 60,517 passengers on average on each route per day;

Fk =60517/634

=95.45~~96 trips per route.

Then the number of trains that should be allocated on each route will be as follows:

$$N_t = \frac{(Fk\ X\ Tk)}{Time\ period} \qquad (6.3)$$

$$=\frac{(96X114)}{(18X60)}$$

=10.13 ~~ 10 trains per route.

Or

$N_t =(P + T_{dw})/ T_{ho}$ (6.4)

=(50.28+22)/7.228

=10

B) As shown below our objective is to allocate/provide efficient fleet size.

Fleet size

Fleet size should satisfy the following formula as it can be described by:

$\sum_{K=1}^{SR}(TkXFk) \leq M = (Tk\ X\ Fk\ )/2$ (6.5)

= (0.838 X 96)/2

=40.224

Because time for single trip along route K in seconds,time for single trip along any route is almost 50.28min that is equal to 0.838sec.

This result shows that almost the same to the number of trains along all routes at peak hours. So, it is feasible as expected to be allocated/assigned along all routes.

So, on both above calculations show that around 10 trains are allocated along each route and total of 40 trains along all routes will be allocated at peak hours. But, if we assume head on time at off peak hours is 12 min the number of trains along each route will be 8 and a total of 32 trains along all four routes. This output shows that cost effective allocation of trains along all routes that can satisfy the passenger demand because it considers the passenger demand and waiting time so as to save running time and operating cost.

Second Level

2) Load Feasibility;

$CAP \times Fk \geq (q^{k}_{ij})_{max}$ ∀ $k \varepsilon SR$

CAP =317(over load rating of each train) X number of trains at single route i.e. 10,

Fk=96,

$(q^{k}_{ij})_{max}$=60,5017(passengers transported per day per route),

Load Feasibility;

=> 317 X 96 X 10 ≥ 60,5017

=> 304,320 ≥ 60,5017,which is always true so that it is feasible.

So, as we see above the load feasibility equation is satisfied.

Dwell time:

Dwell time is calculated by the formula:

T_{dw} =(Pa X T_a + P_b X T_b + T_{oc})/n (6.7)

Given:

$P_a = P_b$ =317or 254 (maximum and rated train capacity).

$T_a = T_b$=1sec.

T_{oc}=2sec.

n=4 (assume capacity of 3- passengers can go through).

Solution:

T_{dw} =(317 X 1sec + 317 X 1sec +2sec)/(3 X 4)

=53sec~~1min (at peak hours).

Or

=(254 X 1sec + 254 X 1sec +2sec)/(3 X 4)
=42.5sec (at off peak hours).

Head on time(may be equivalent to waiting time) :

Head on time is the time difference between successive trains along the same route. So, head on time at peak hours and at off peak hours are calculated as follows.

Head on time at peak hours ;

T_{ho} =(operating time + dwell time)/N_t (6.8)
=(50.28min+22min)/10
=7.228min (So this is less than that of it was said 7.5min on the design).

Head on time at off peak hours ;
We can assume head on at off peak hours time is 12min.

Arrival time :

Arrival time is the time at which a train reaches a station. Arrival time of train at any station is the summation of operating time (running time) of a train and dwell time from or at preceding station. Since the average distance between successive stations is 0.77km and as mentioned above average speed is 20kmph then the arrival time of a train at any station is 3-4min.

Departure time:

Departure time is the time at which train leaves a station. Departure time of train at any station is the summation of operating time (running time) of a train, dwell time at preceding station and dwell time at the same station that becomes approximately 4-5min.

6.2. Modeling of proposed train scheduling

Train scheduling is critical operating plan in railway system and a lot of extensive work has been done to improve the performance of train scheduling systems on different parts of the world, but it is new for Ethiopia since it has no Light rail transit system up to now. Given the origin–destination (O–D) points or stations matrix along the routes for the transit trips (during design period) and the train network (with the required attributes) that is done by Ethiopian railway corporation (ERC) or Contractor based on the transport/passenger demand data that is provided by transport minister, the problem of train scheduling is to optimally allocate transit units on all available routes of the AALRT system and obtain the optimal train fleet size. The design of routes and setting of frequencies, critically determine the system's performance from both the operator and user point of view. Significant savings in resources can be made by reorganization of train routes and frequency to suit the actual travel demand.

6.2.1. Inputs for train scheduling

Train scheduling by it, is an optimization problem because it consists of allocating trains on a given route subjected to some constraints. So, based on the analytical method output an efficient train scheduling will be implemented by accommodating the following parameters.

Model Parameters

- Number of trains: Total number of trains available/allocated for train scheduling on each route and made 10 at peak hours, 8 at off peak hours.
- Trains capacity: Passenger capacity of each train is 254 of each when 6-persons per square meter stand and with 65-seats and 317 of each when 8-persons per square meter stand with 65-seats.
- Headway time/Head on time: Minimum time difference between the departure of train from a station and arrival of next train to the same station that is supposed to be 7 min at peak hours and 12 min at off peak hours.
- Minimum dwell time: Minimum dwell time is the time for trains stop time at each station at peak hours and supposed to be 45 sec.
- Maximum dwell time: Maximum dwell time is the time for train stop at each station at off peak hours and supposed to be 1 min.
- Minimum run time: Minimum time that a train needs to cover distance between two successive stations because of speed limits is 1.4 min.
- Inflow of passengers: Number of passengers coming to a specific station between specific time intervals that is supposed to be 60500 per day on each route and when we divide in to 22 it gives as 2750 on average.

- Outflow of passengers: Number of passengers leaving a specific station between specific time intervals and can be assumed as number of inflow of passengers supposing that no one can live at a station.

Model Variables

- Station index: Station index shows the sequence of stations according to path/route of trains and it increases from 1 to 22 along each route.

- Trip start time of train: Time that a train starts its trip/operation during any day.
- Arrival time of train: Arrival time of a train to a specific station and it is the summation of running time and dwell time of preceding station.
- Departure time of train: Departure time of a train is the time at which any allocated train along any route leaves from a specific station.
- Run time: Run/Travel time is the time at which any train which takes between two successive stations.
- Passenger travel time: Duration of a passenger's time on train.
- Number of passengers at station: Number of passengers at a specific station for a specific time interval.
- Number of passengers on train at a station: Number of passengers on train at a specific station for a specific time interval and equal to train capacity.
- Trip duration: Duration of trip for each train from start station to end/destination station.

Model Constraints /Certain Terminologies

Certain constraints specific to train scheduling models are tried to be explained below.

1. Number of passengers on train at a specific time interval must be smaller than the maximum passenger capacity of train in order to minimize passenger waiting time.

$$CAP < 317 \tag{6.7}$$

2. The departure time of first train from the first station must be greater or equal to start hour of trips.

T_{dep} of train 1 from first station $\geq$ 5:00 AM (6.9)

3. Arrival time of final train to the final station (along each route) at final trip must be smaller than finish hour of trips to reach on time.

T_{arr} of final train at final trip $<$ 11:00 PM (6.10)

4. The time difference between departure and arrival of a train at a specific station must be greater than minimum dwell time and must be smaller than maximum dwell time.

$(T_{dw})_{min} <$ (Departure time – Arrival time) $< (T_{dw})_{max}$ (6.11)

5. A train's arrival time to a station must be greater or equal to the time of departure from the previous station plus headway time or equal to running time and dwell time at previous station.

T_{arr} to a station $\geq$ $(T_{dep} + T_{ho} + T_{dw})$ from preceding station (6.12)

6. Travel duration between two stations must be greater than minimum travel duration between stations according to speed limits.

$T_{trav} > (T_{arr}$ to a station - T_{dep} from preceding station) (6.13)

7. Travel time of a passenger is equal to run time of train between stations plus time difference between arrival time of passenger to the station and arrival time of train to the station.

$$T_{pass} = (T_{trav} + (P_{arr} - T_{arr})) \tag{6.14}$$

8. Total trip duration for each trip is equal to time difference between arrival times of train to final station minus departure time of train from the first station.

$$Tk = (T_{arr})_{\text{to final station}} - (T_{dep})_{\text{from the first station}} \tag{6.15}$$

9. Total Passenger quantity on train, at specific station for a specific time interval equal to passenger quantity on train at previous station plus inflow of passenger to the station minus outflow of passengers from the station.

CAP = (P_{prev} on train at station i + (P_{in} to station i – P_{out} from station j)) (6.16)

6.3. Simulation method

The study of Train scheduling can be approached in different ways. Some problems can be solved by several different approaches. In this part the method of simulation will be described and an elaboration on why simulation is used in this thesis will be presented.

Simulation is a collection of methods to imitate the behavior of a system or it is the process of designing and creating a computerized model of the real system for the purpose of conducting experiments to give an understanding of the behavior of the system. The modeling itself is crucial to the outcome of the experiments, since the outcome depends on the representation in the model as well as the analysis. Therefore detail data should be collected for the modeling, since a higher level of detail will give more accurate results, even though it is sometimes at the expense of longer running times for the simulations.

An advantage of simulations is the ability to deal with very complicated dynamic models of correspondingly complex systems. As opposed to analytical methods simulation can be used to get a precise picture of a given situation. Simulation can also be used to test different values of parameters to analyze the results of parameter tuning. Simulation requires entire data sets of the system to display the development in the system. In contrast to analytical methods a simulation tool does not give a solution as output. By repeating the simulation (batch simulation) the results can be evaluated and improvements for the situation might be seen. The drawbacks of simulation, contrary to analytical methods, is that it is very time consuming and requires very detailed data sets as input. Furthermore simulation does not result in an optimal solution (or at least there is no way of testing whether a solution is optimal). In many situations changes in plans occur frequently both for long term, medium and short term plans, therefore simulation might be too time consuming to be used as a decision tool. However simulation is the best method to use when reliable and trustworthy results are needed. As for railway systems simulation methods give the most detailed representation and today simulation is the only reasonable way to model the details of the complex interaction between different trains and the interaction between the trains and the infrastructure.

Simulation can be used both as a learning tool and as a planning tool.

When simulation is used as a learning tool, the model is used by the operator, to possibly learn how to operate the system in real-time conditions. When simulation is used as a planning tool it is most often used for experimenting with different scenarios with the purpose of obtaining an optimal or best plan for the system e.g. layout and production schedules.

A simulation model is categorized as either macroscopic or microscopic depending on the level of detail. In this project only macroscopic simulation will be considered because details like signals, weather or human behavior are omitted.

Finally simulation in connection with planning a new system could be to find a good solution when planning a new production of train scheduling.

Phases/steps of simulation method:

1. *Problem formulation*: First the problem must be specified precisely.

2. *Data*: Determine whether enough data is available and collect the necessary data.

3. *Assumptions*: Determine if it is possible or necessary to build a model of the entire system or if limitations assumptions can be made. The level of detail should be specified.

4. *Solution methodology*: Determine how the given problem can be solved and whether it is possible to solve the problem by simulation given the obtained data.

5. *System specifications*: In this phase information about the system is collected. To build a simulation model, a good understanding of the system is required.

6. *Model formulation and construction*: Considerations about how the model should be build and actually building the model.

7. *Verification and validation*: Examining whether the model is behaving as expected (verification) and behaving in the same way as the real system (validation).

8. *Experimentation and analysis:* Running the simulation and analyzing the data according to the desired output.

9. *Results and conclusion.*

Following the above steps, I have tried to go through and design an algorithm in how the train scheduling can be simulated using visual studio software.

Algorithm for train scheduling

1. Prepare data and design the interface.
2. Develope a data base
3. Feed the setup like peak hours,off peak hours,stations,routes,trains descriptions.
4. Activate all trains at peak hours ,and if not deactivate some.
5. First select any train randomly from the existing in the data base and check that train to which route is allocated and include all stations along that route.
6. Then select the starting station of that route to give starting time for which that train at that station starts opration.
7. And then calculate the departure time of that train at that station as:

Departure time=Starting time + Dwell time.

8. Then go to /sellect the next station along that route and calculate

the arrival and departure time at that station as:

Arrival time = Running time + Departure time from previous station and

Departure time= Arrival time + Dwell time

9. The same step is repeated for all trains along that route.
10. The same step is followed for all trains along all routes…

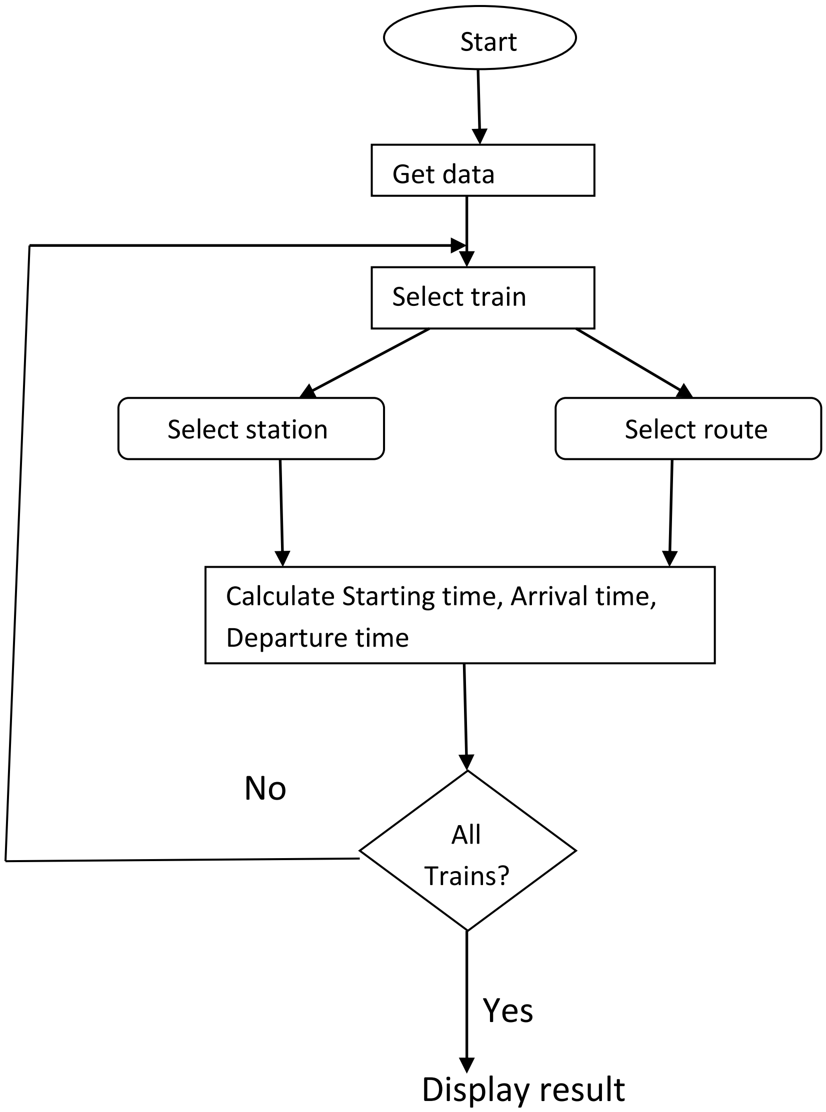


Figure 6.1: Flow chart of programming for scheduling

7. SIMULATION SETUP FOR TRAIN SCHEDULING

At part the simulation setup to implement the model for train scheduling system along with the designed user interface will be described. The software material that is used to develop the system components and the prototype along with the assumptions used to model the train scheduling will be feed in detail as it commands. Some assumptions are taken for the components that are used in modeling for the challenges faced in implementing the initial design and a means to solve the problem.

7.1. Feeding data on the user interface

The designed model for train scheduling is tried to be simulated by Visual studio IDE using C# and HTMLwebpage design programming languages that consists of ASP.net controller that run on Firefox web browser. The data base is created using MSsql data base engine. The input components used for train scheduling such as setting, station, route and train with their descriptive parameters are feed respectively like below.

User Interface Page

The home page that is used to simulate train scheduling has headings of home, trains, routes, stations, setting and address as we see on figure 7.1.

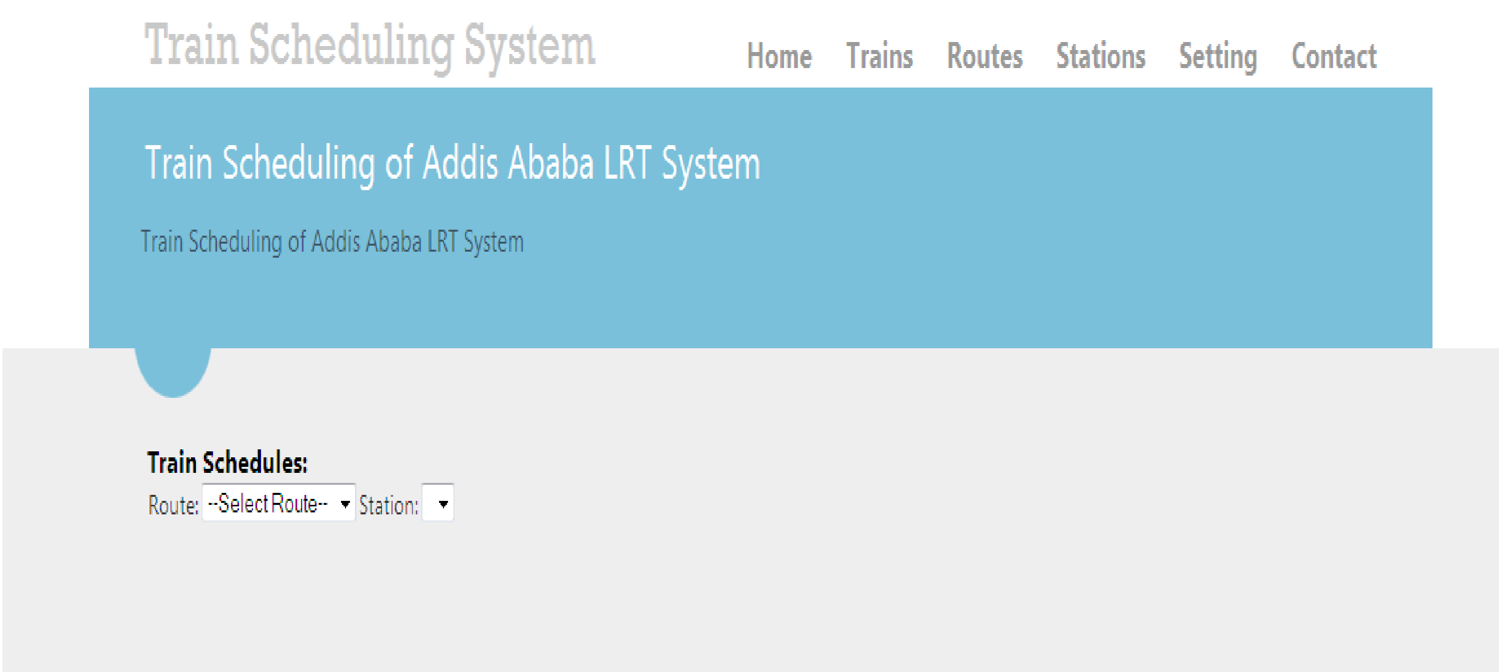


Figure 7.1: User interface

7.1.1. Feeding Setting parameters for train scheduling

As we see below these are the prerequisites for train scheduling and they have to be feed these parameters. The parameters that are specified for scheduling are start time, end time, dwell time, speed, start time interval (head on time), peak hour interval during morning and peak hour interval during evening. After these parameters have feed according to design requirements seems like below:

Table 7.1: Parameters setting for scheduling

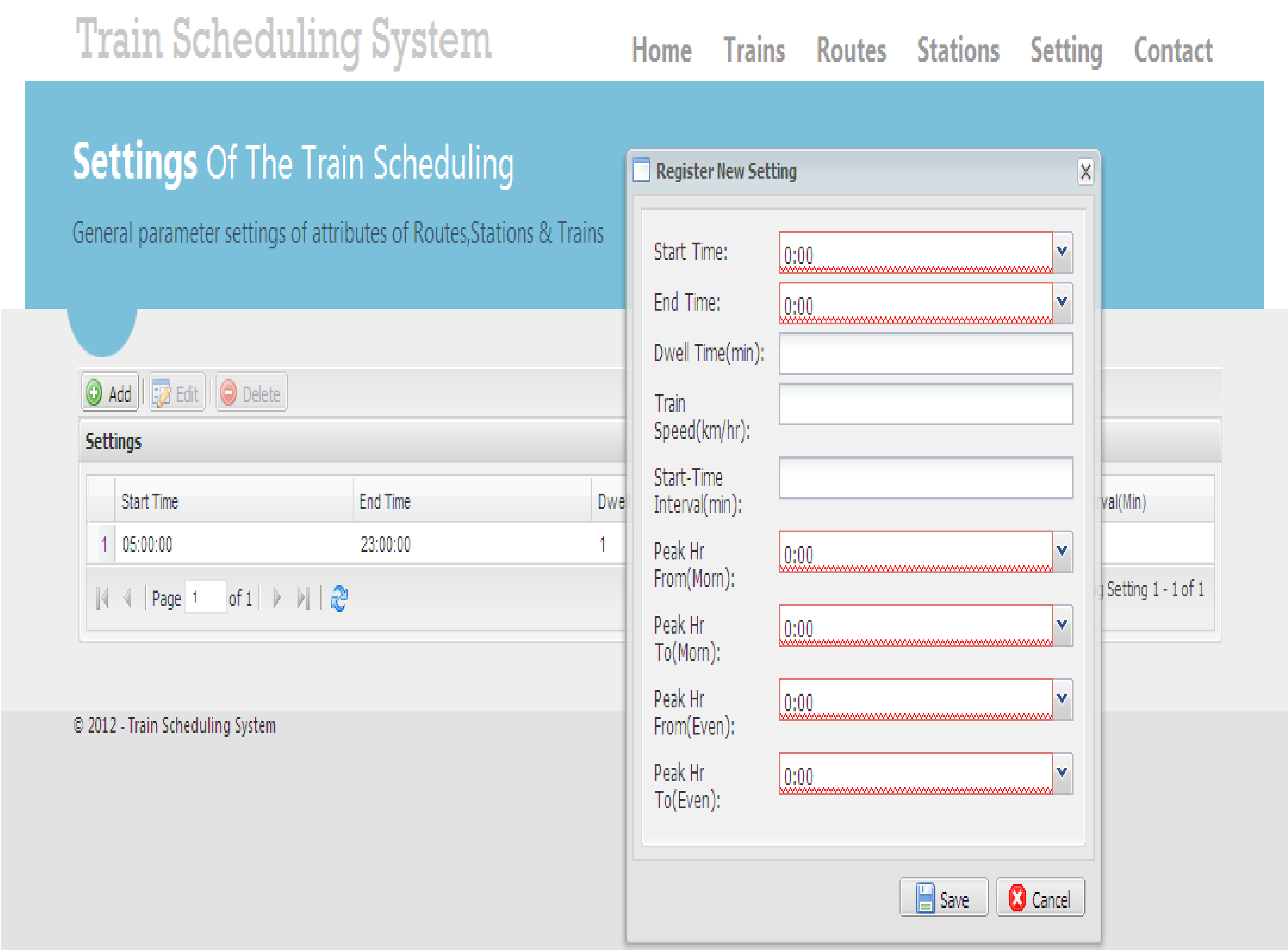
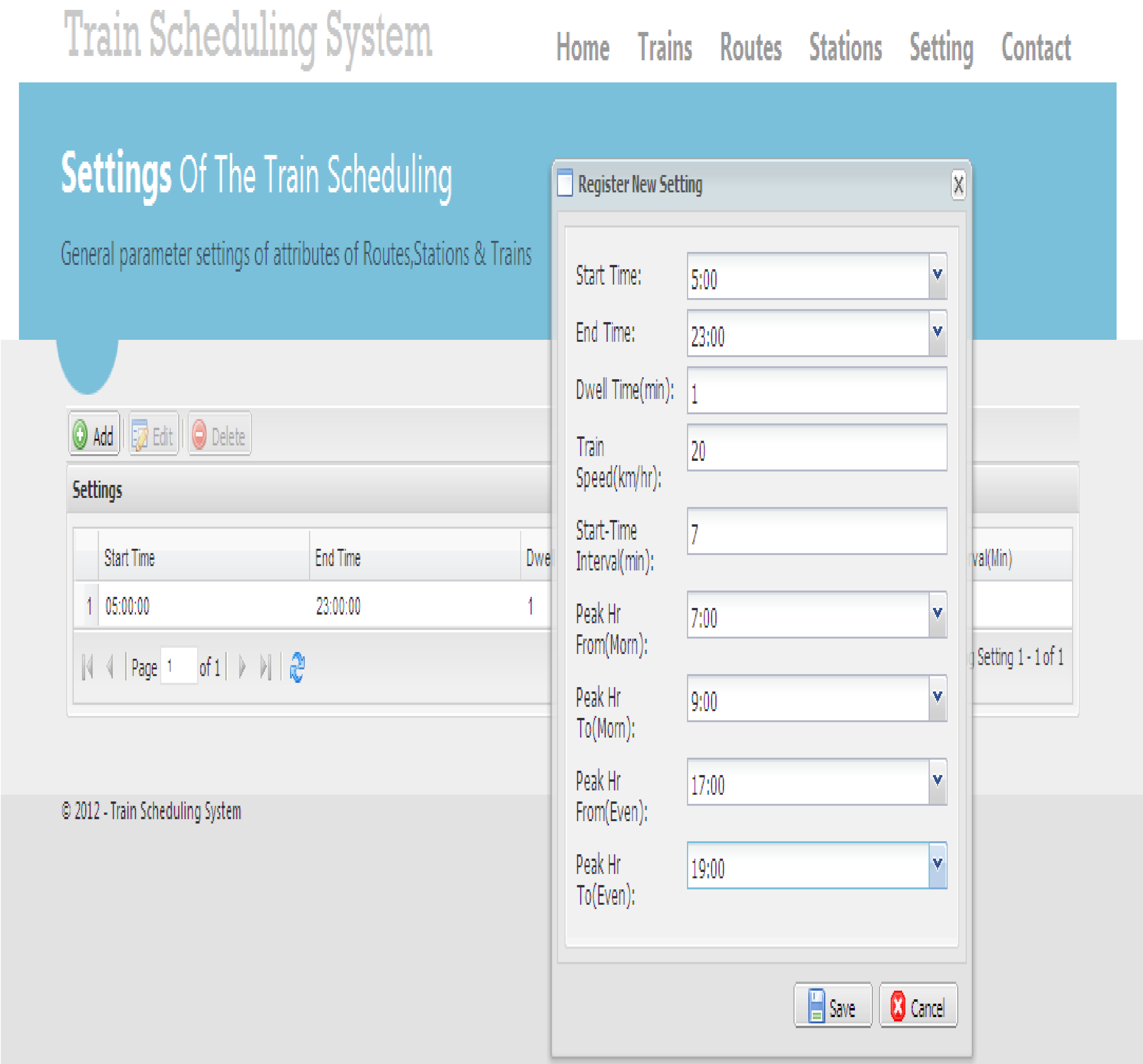


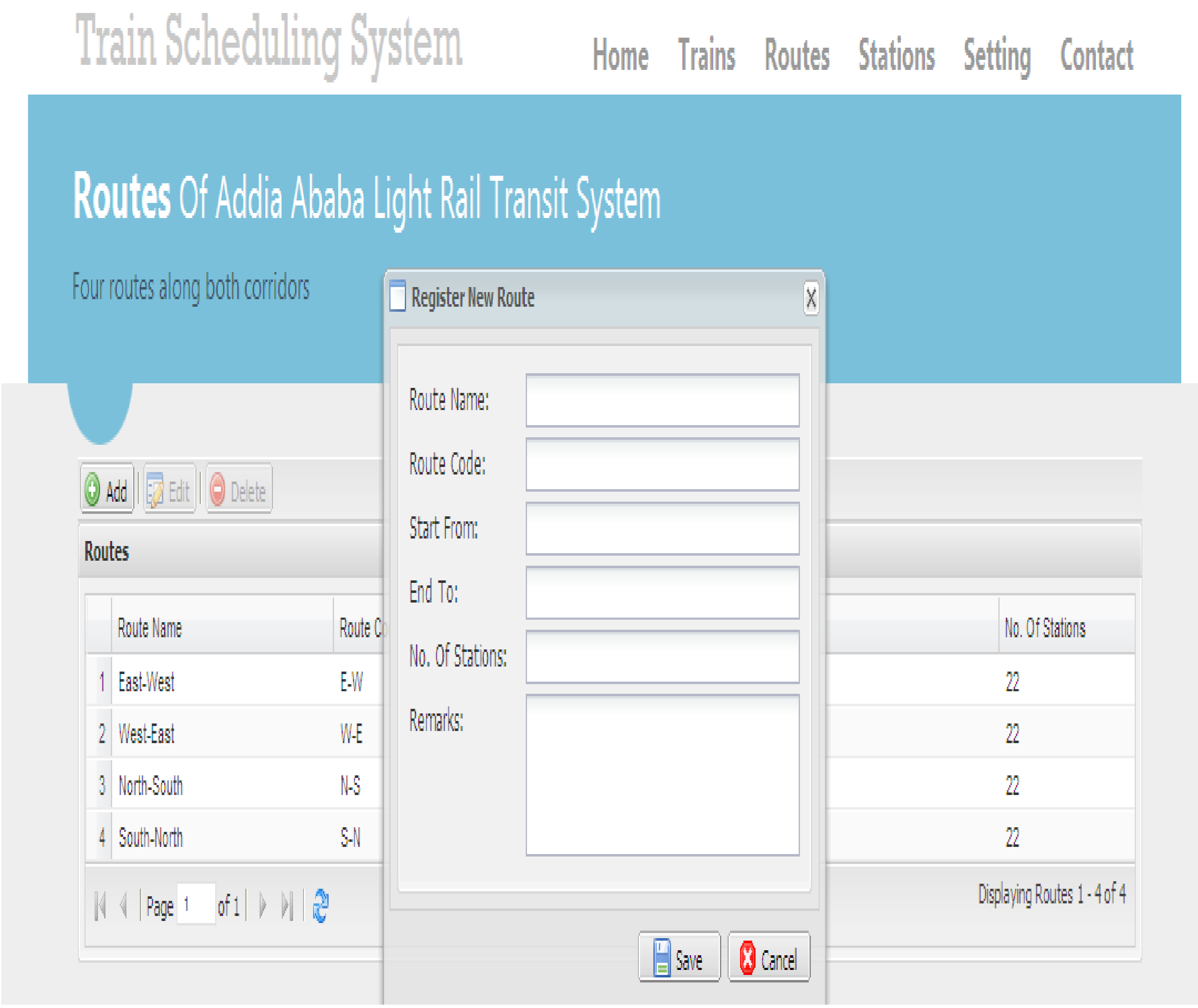
Table7.2**: P**arametersSetting for scheduling after specification



7.1.2.Feeding routes attributes specification

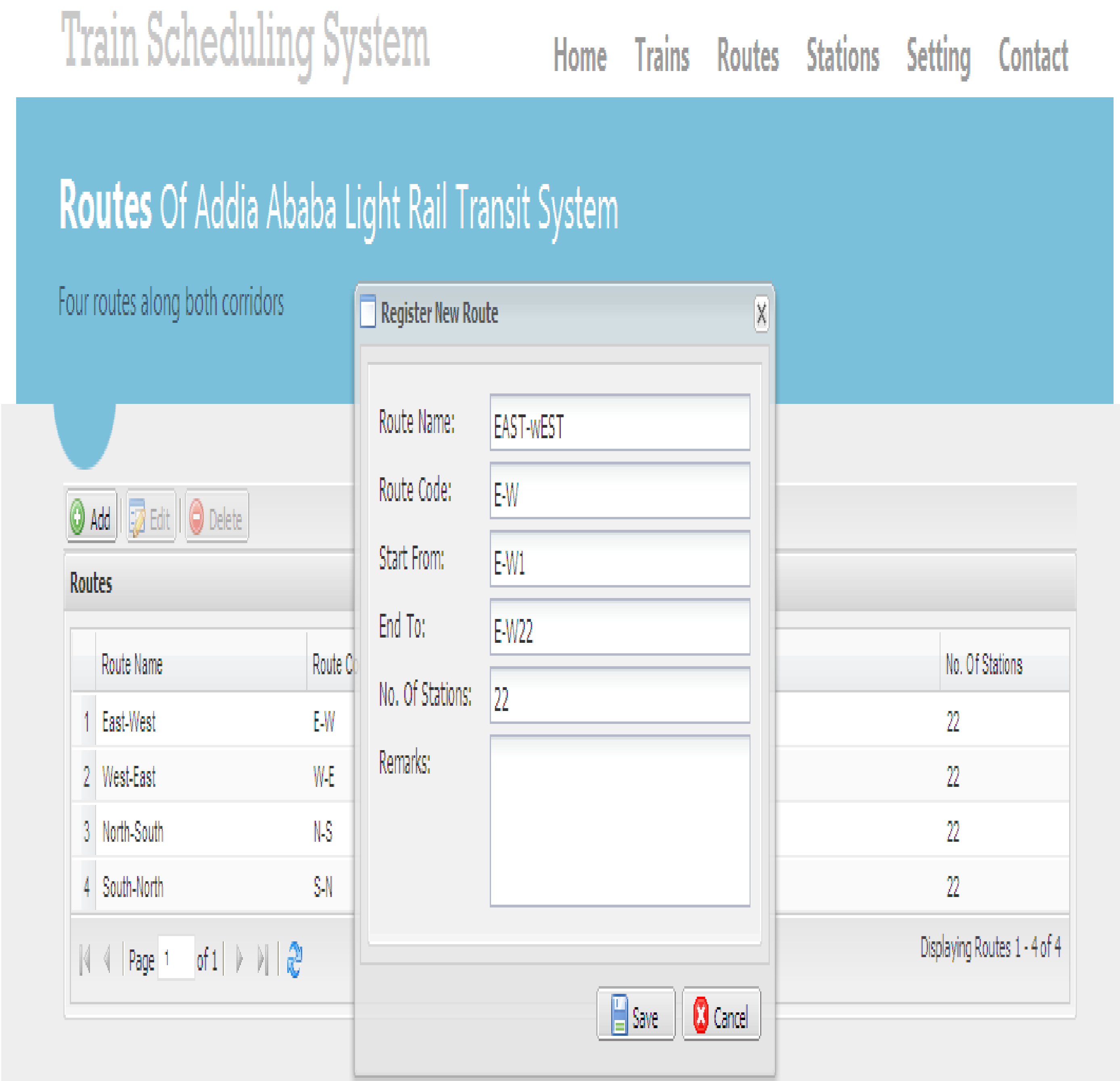
According to our case there are four routes along both corridors of East-West and North-South and specified with their descriptive parameters like route name, route code, starting of route, ending of that route and the number of stations along that route that are same for all routes like below.

Table 7.3: Route parameters Setting



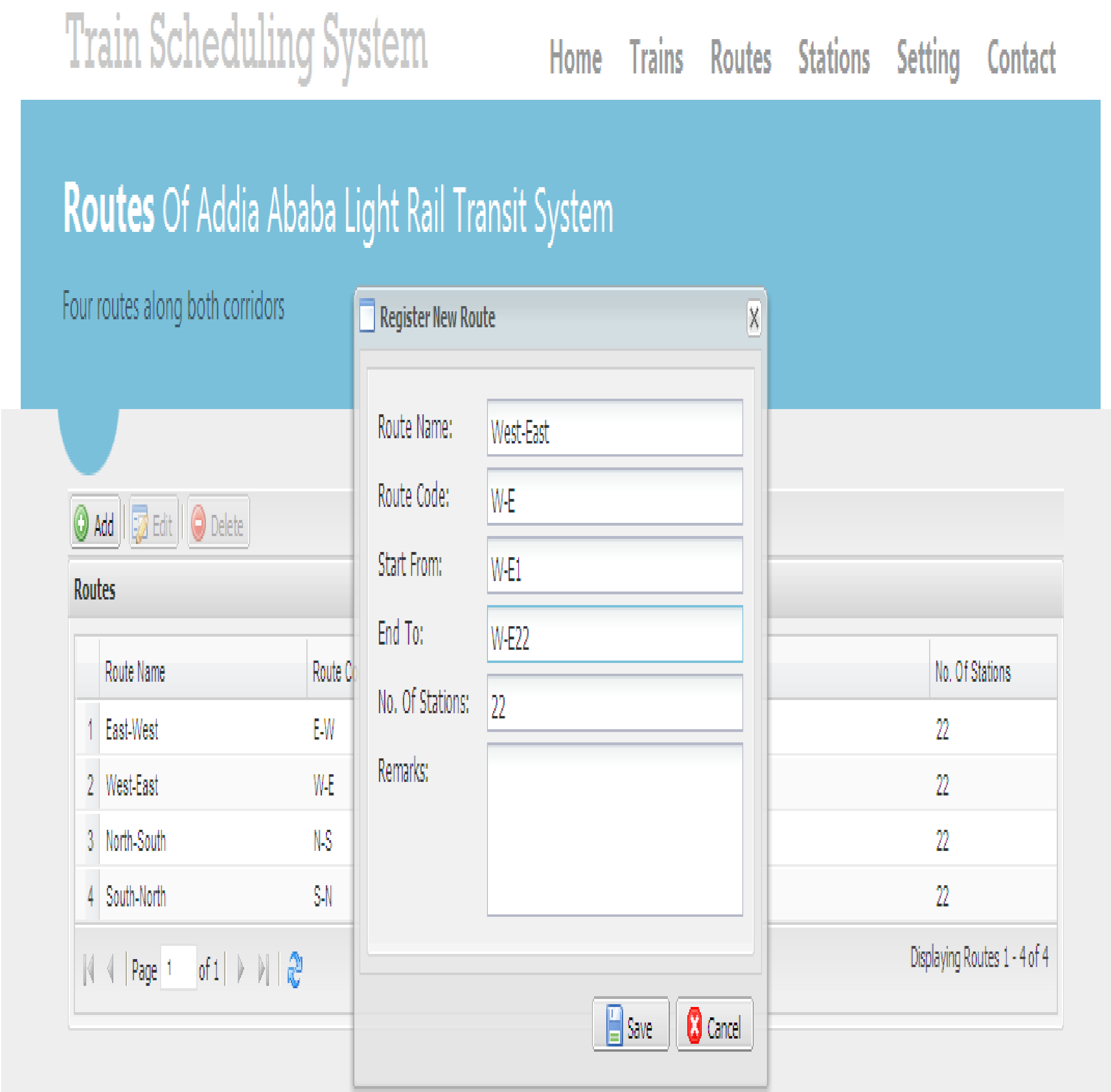
After the route parameters feed for the East-West route:

Table 7.4: E-W route parameters Setting



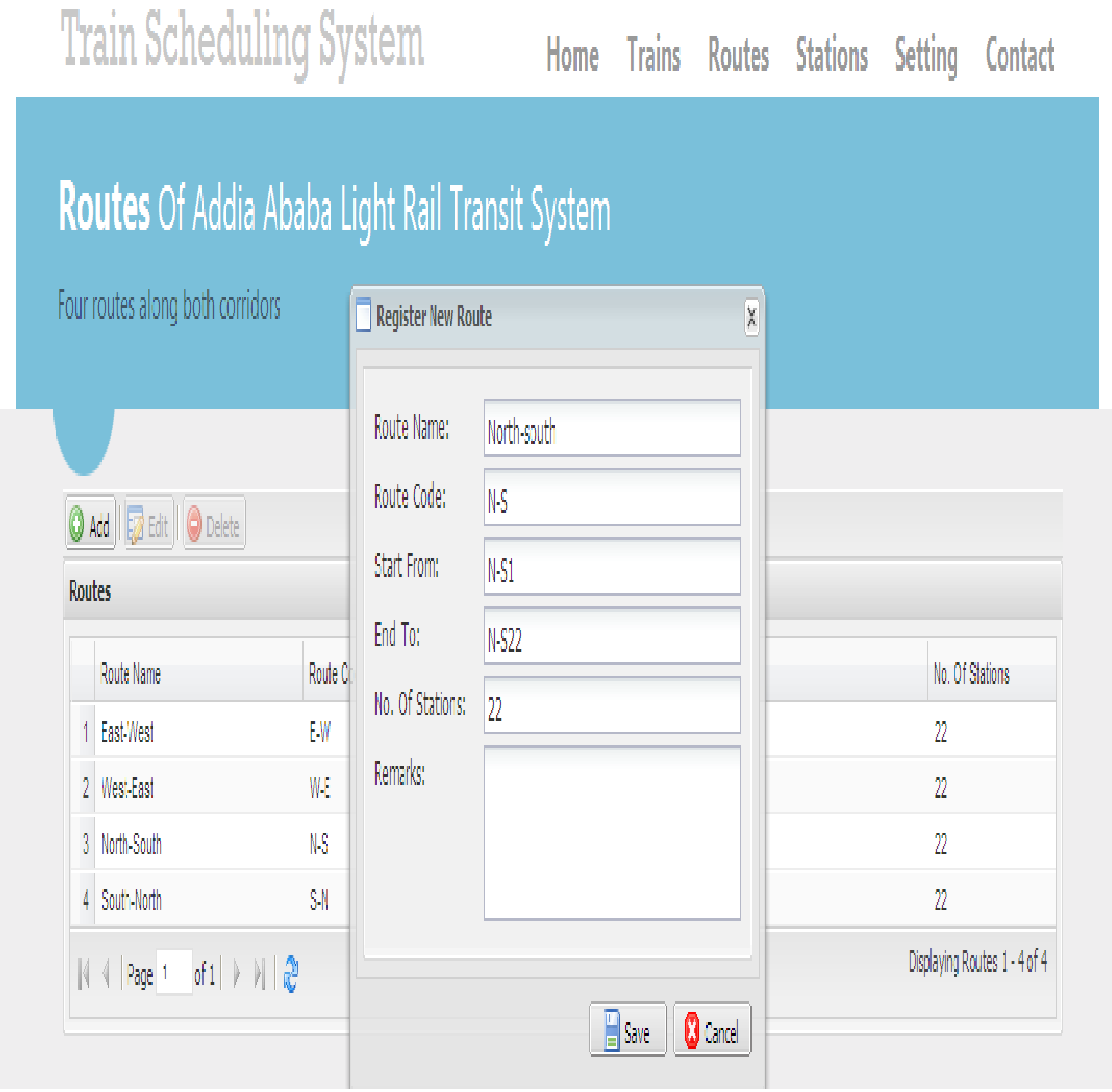
After the route parameters feed for the West-East route:

Table 7.5: W-E route parameters Setting



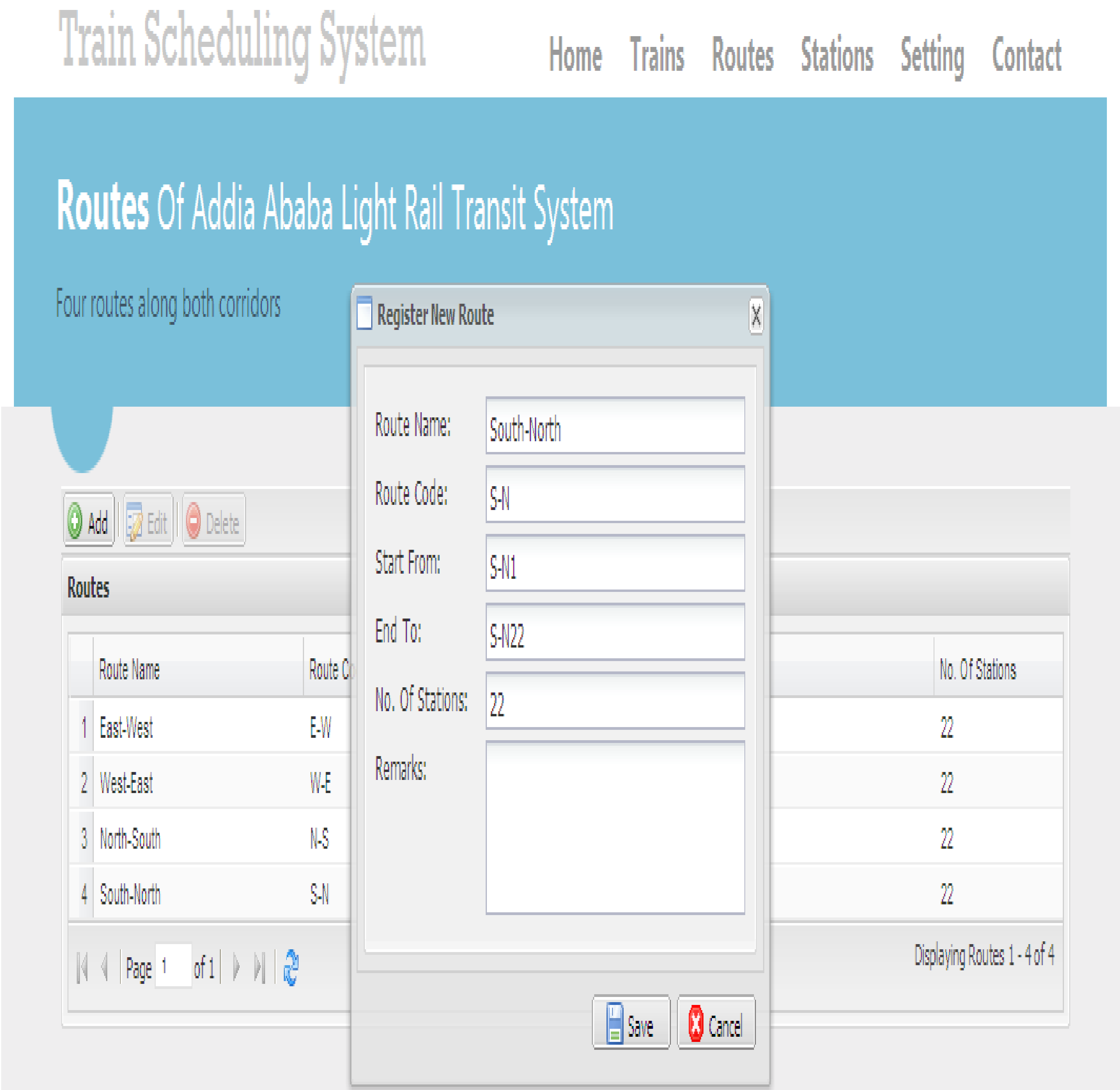
After the route parameters feed for the North-South route:

Table 7.6: N-S route parameters Setting



After the route parameters feed for the South-North route:

Table 7.7: Setting of S-N route after parameters specification

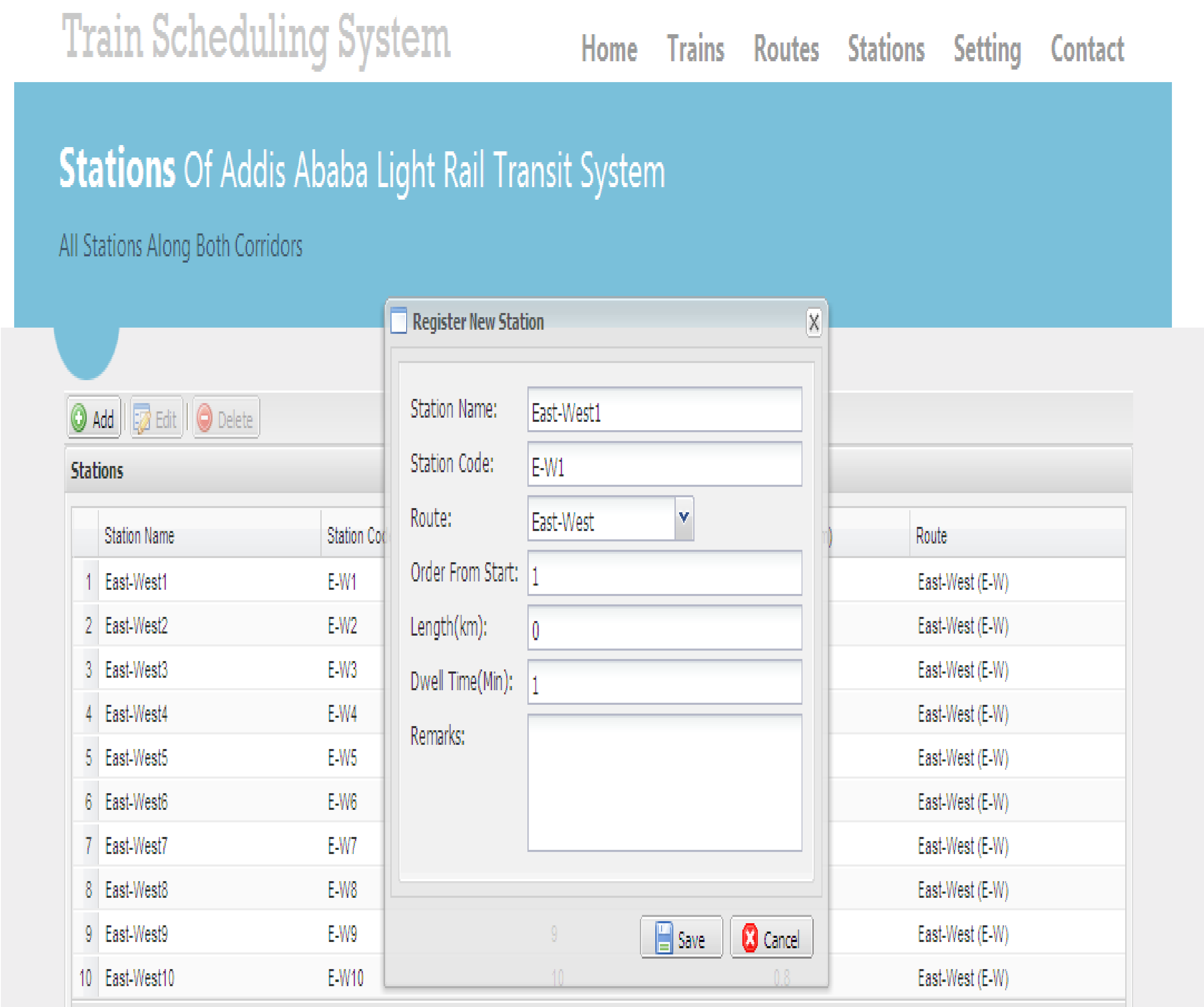


7.1.3.Feeding Stations attributes specication

Stations are places where passengers alight and board after trains have stopped. According to our case there are 22 stations along four routes on both corridors of East-West and North-South and specified with their descriptive parameters like station name, station code, route, order from start, distance from its preceding station if no set as 0 and dwell time which seem like below.

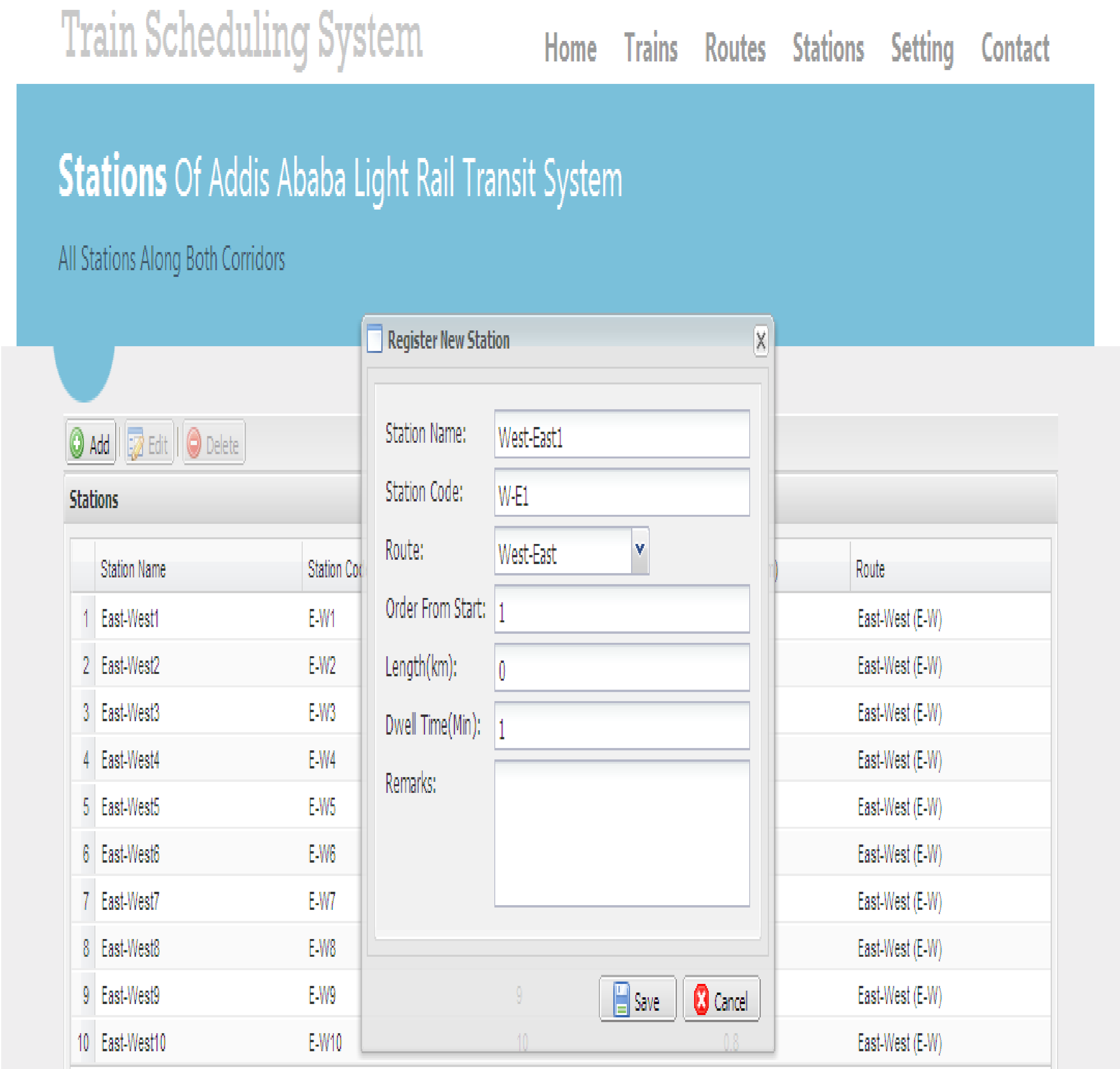
For stations along East-West route:

Table 7.8: E-W routestation parameter Setting



For stations along West –East route:

Table 7.9: W-E routestation parameter Setting

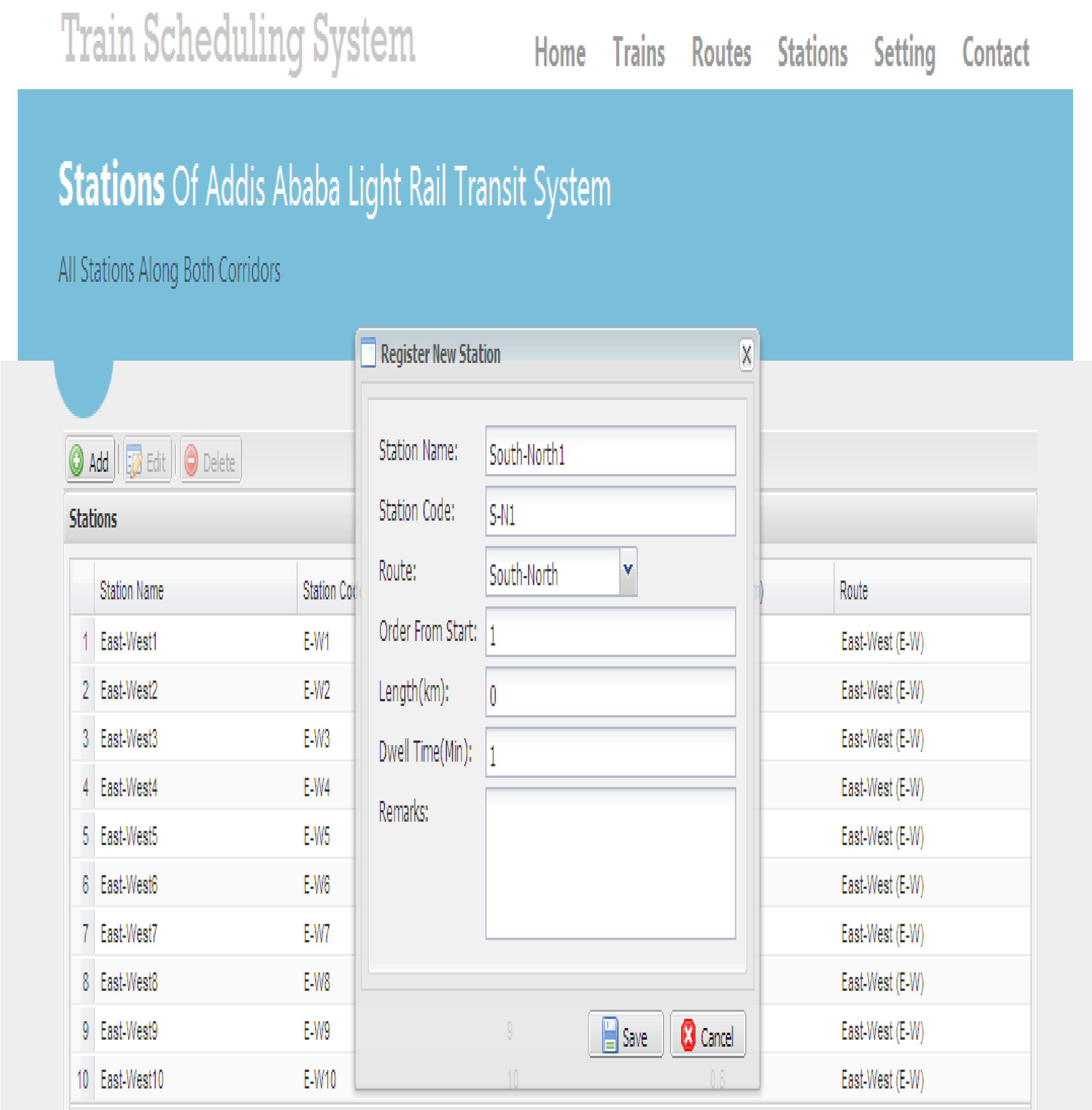


For stations along North-South route:

Table 7.10: N-S routestation parameter Setting

Stations along South-Nourth route:

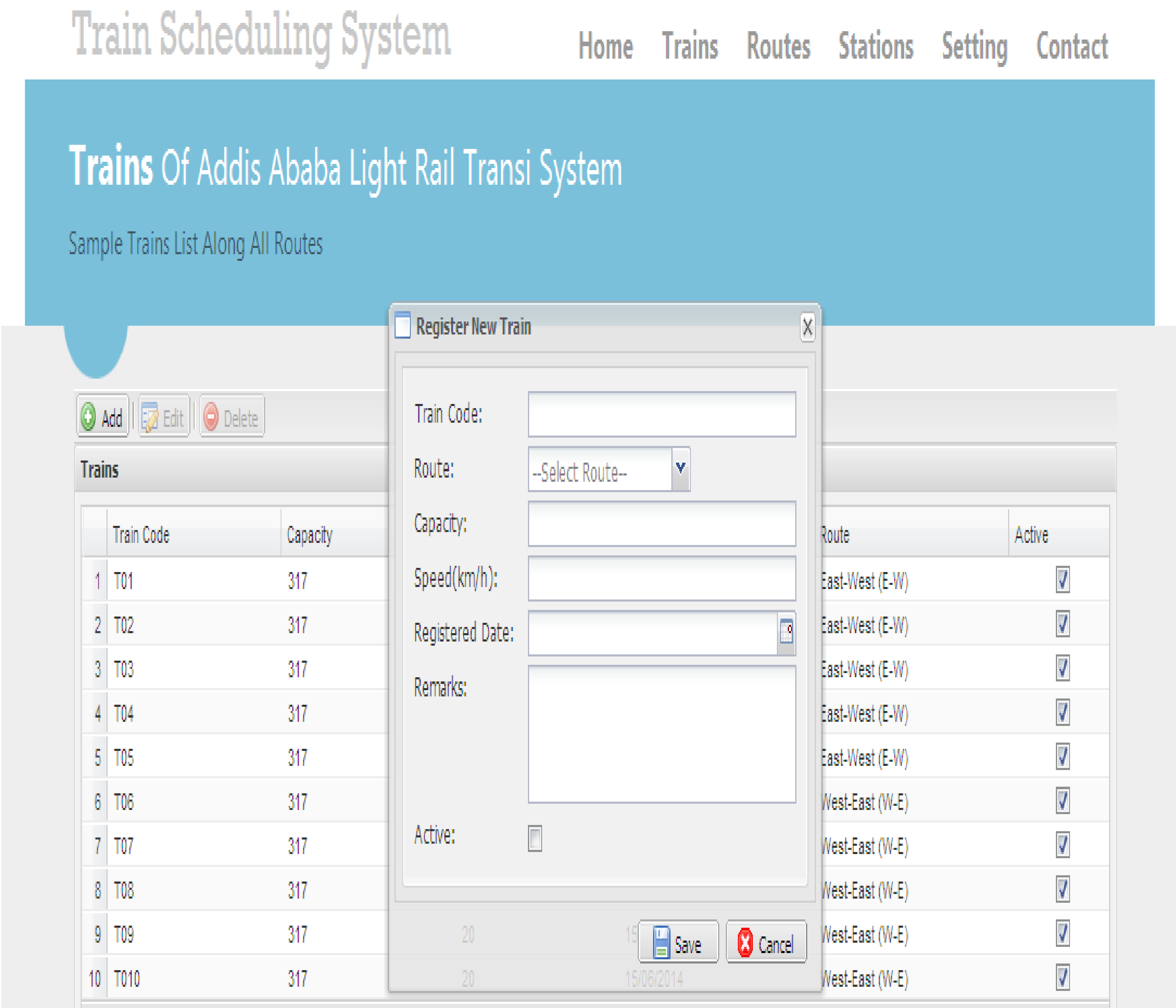
Table 7.11: S-N routestation parameter Setting



7.1.4.Train allocation along four routes of both corridors:

Trains are vehicles on which passengers travel from place to place. Passengers alight and board at stations after trains have stopped along specified route. According to this case there are 40 trains along four routes on both corridors of East-West and North-South at peak hours and 32 at off peak hours and specified with their descriptive parameters like train code, route, capacity, speed and registration date seem like below.

Table 7.12: Trains setting



Trains allocated along East-West route

Table 7.13: Ttrains setting along E-W route

Trains allocated along West-East route:

Table 7.14: Trains setting along W-E route

Trains allocated along North-South route:

Table 7.15: Trains setting along N-S route

Trains allocated along South-North route:

Table 7.16: Trains setting along S-N route

8. RESULTS AND DISCUSSION

An efficient train scheduling developed and simulated using the following inputs and resulted accordingly. The Dwell time is less than 1min and running time is of 3-4min on average which is good. Head on time is 7.22min which is less than 7.5min that is supposed to be implemented by contractor that decrease the passenger time. Number of trains is supposed to allocated is 40 and 32 at peak and off peak hours respectively along all routes of the AALRT system that can satisfy the passenger demand. As it decreases the number of trains from 40 to 32 to save the operating cost of 8 trains as off peak hours is large period of the day. Ethiopian railway corporation is supposed to allocate 41 trains for both corridors and is not being clarified the number of trains that should be assigned at off peak hours. So, making decrease the number of trains from 41 to 40 is a being deal.

The sample scheduling being displayed at sample stations of E-W2, W-E1, N-S1 and S-N5 on appendixes D, E, F and G shows that: The trains supposed to be allocated along each route, the arrival and departure time being at any station as expected even it is not being got similar schedules that was done before. Thus, it is supposed to be implemented to Ethiopia for the first time. The tables below show the settings of train scheduling parameters after being feed their attributes.

The developed system is being checked by feeding the specification modeled/selected test data which consists of the descriptive parameters of setting of the schedule, route, station and train that are used for train scheduling. The outputs of the simulation shows of system setting, routes, stations and trains with their descriptive parameters along four routes on both corridors as expected and the final deserved output of designed train scheduling of all trains supposed to be allocated on specified route being at any station along that route with their arrival and departure times for the whole day by using 5 trains for each route instead of 10 trains resulted on the calculation, because the program can’t be executed on the computer is being used due to capacity problem. And the time gap between successive trains being allocated on each route is more than 20min as shown on the sample schedules on the sample stations being displayed, this is because it is being used 5-trains on each route instead of 10-trains which is less than demand capacity. But since the program is dynamic it can be reprogrammed.

8.1. Setting

Table 8.1: Scheduling setting output

	Start Time	End Time	Dwell Time(Min)	Train Speed(Km/Hr)	Start Time Interval(Min)
1	05:00:00	23:00:00	1	20	7

8.2. Routes

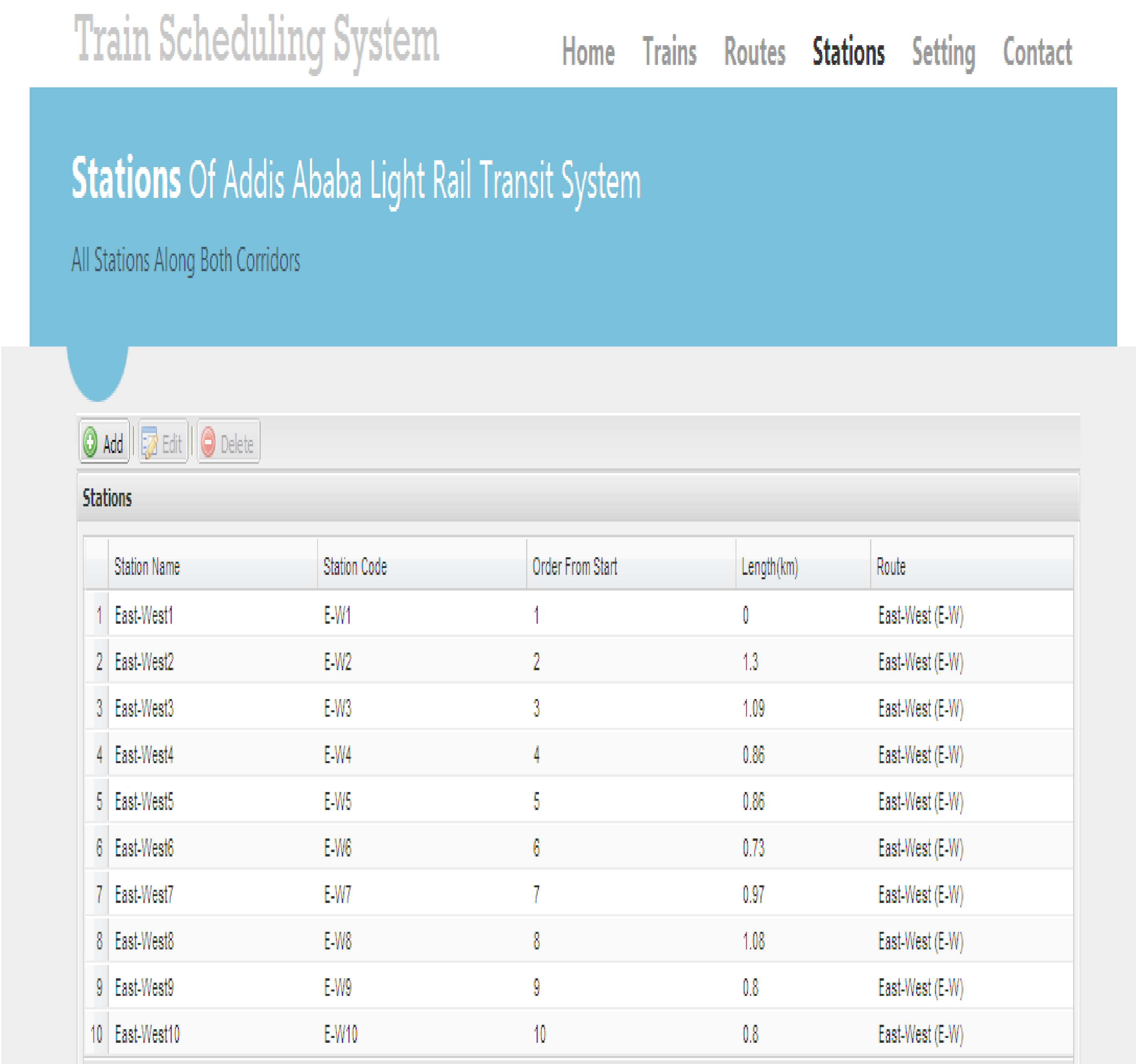
Table 8.2 Route setting out put

	Route Name	Route Code	Start From	End To	No. Of Stations
1	East-West	E-W	EW-1	EW-22	22
2	West-East	W-E	WE-1	WE-22	22
3	North-South	N-S	NS-1	NS-22	22
4	South-North	S-N	SN-1	SN-22	22

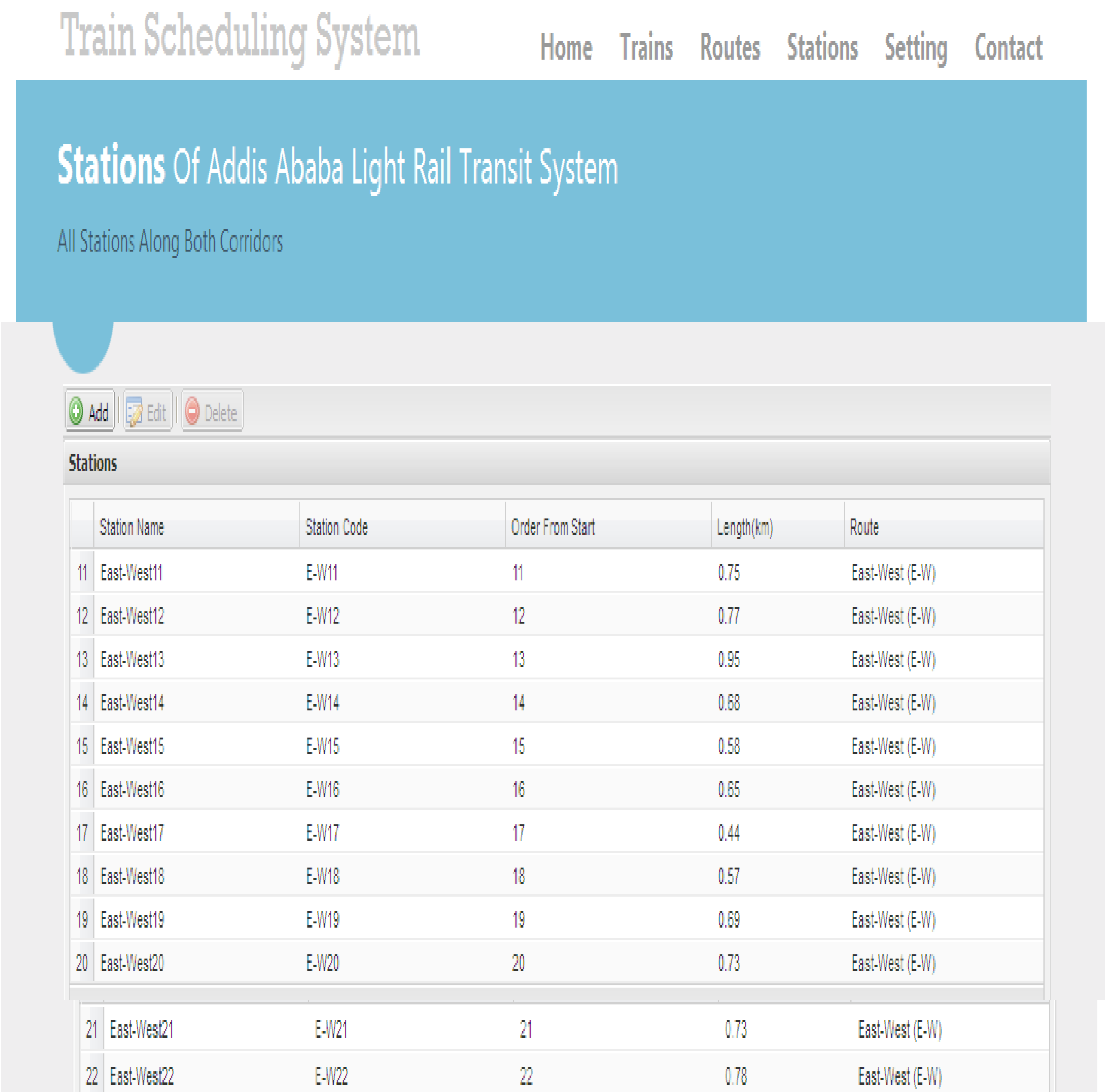
8.3. Stations

Stations along East-West route

Table 8.3: Station setting out put along E-W route



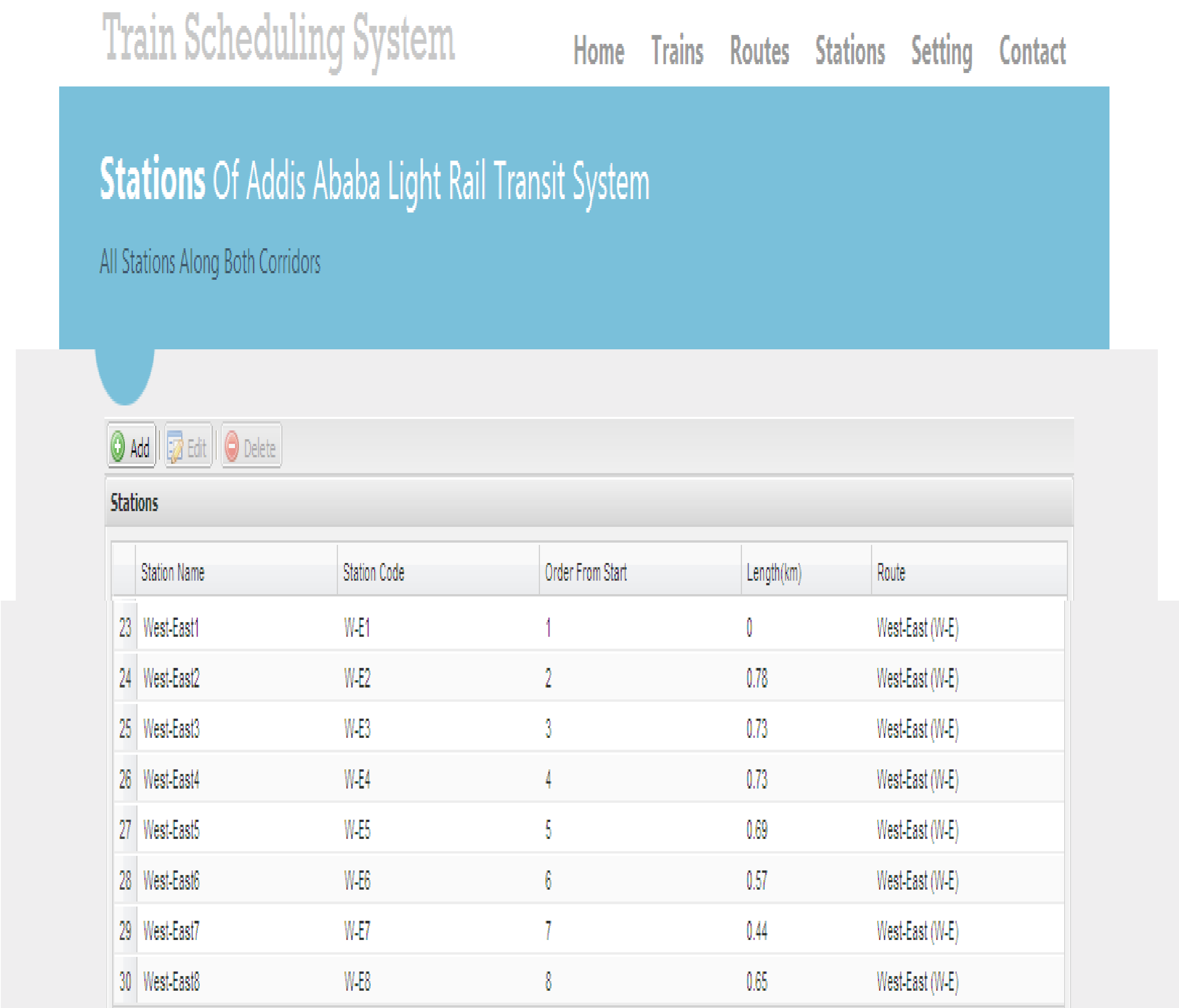
	Station Name	Station Code	Order From Start	Length(km)	Route
1	East-West1	E-W1	1	0	East-West (E-W)
2	East-West2	E-W2	2	1.3	East-West (E-W)
3	East-West3	E-W3	3	1.09	East-West (E-W)
4	East-West4	E-W4	4	0.86	East-West (E-W)
5	East-West5	E-W5	5	0.86	East-West (E-W)
6	East-West6	E-W6	6	0.73	East-West (E-W)
7	East-West7	E-W7	7	0.97	East-West (E-W)
8	East-West8	E-W8	8	1.08	East-West (E-W)
9	East-West9	E-W9	9	0.8	East-West (E-W)
10	East-West10	E-W10	10	0.8	East-West (E-W)



	Station Name	Station Code	Order From Start	Length(km)	Route
11	East-West11	E-W11	11	0.75	East-West (E-W)
12	East-West12	E-W12	12	0.77	East-West (E-W)
13	East-West13	E-W13	13	0.95	East-West (E-W)
14	East-West14	E-W14	14	0.68	East-West (E-W)
15	East-West15	E-W15	15	0.58	East-West (E-W)
16	East-West16	E-W16	16	0.65	East-West (E-W)
17	East-West17	E-W17	17	0.44	East-West (E-W)
18	East-West18	E-W18	18	0.57	East-West (E-W)
19	East-West19	E-W19	19	0.69	East-West (E-W)
20	East-West20	E-W20	20	0.73	East-West (E-W)
21	East-West21	E-W21	21	0.73	East-West (E-W)
22	East-West22	E-W22	22	0.78	East-West (E-W)

Stations along West-West route:

Table 8.4: Station setting out put along W-E route

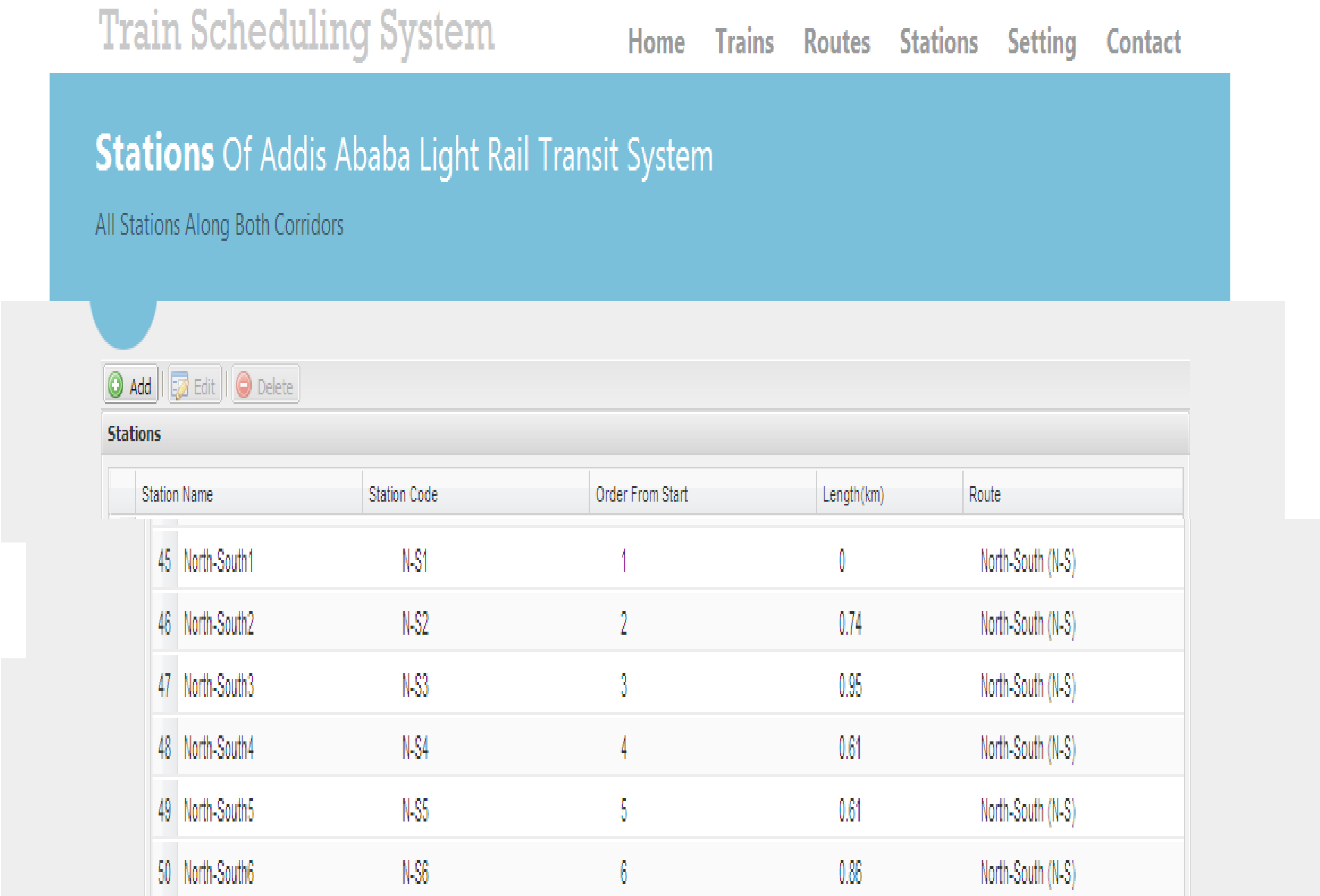


	Station Name	Station Code	Order From Start	Length(km)	Route
23	West-East1	W-E1	1	0	West-East (W-E)
24	West-East2	W-E2	2	0.78	West-East (W-E)
25	West-East3	W-E3	3	0.73	West-East (W-E)
26	West-East4	W-E4	4	0.73	West-East (W-E)
27	West-East5	W-E5	5	0.69	West-East (W-E)
28	West-East6	W-E6	6	0.57	West-East (W-E)
29	West-East7	W-E7	7	0.44	West-East (W-E)
30	West-East8	W-E8	8	0.65	West-East (W-E)

31	West-East9	W-E9	9	0.58	West-East (W-E)
32	West-East10	W-E10	10	0.68	West-East (W-E)
33	West-East11	W-E11	11	0.95	West-East (W-E)
34	West-East12	W-E12	12	0.77	West-East (W-E)
35	West-East13	W-E13	13	0.75	West-East (W-E)
36	West-East14	W-E14	14	0.8	West-East (W-E)
37	West-East15	W-E15	15	0.8	West-East (W-E)
38	West-East16	W-E16	16	1.08	West-East (W-E)
39	West-East17	W-E17	17	0.97	West-East (W-E)
40	West-East18	W-E18	18	0.73	West-East (W-E)
41	West-East19	W-E19	19	0.86	West-East (W-E)
42	West-East20	W-E20	20	0.86	West-East (W-E)
43	West-East21	W-E21	21	1.09	West-East (W-E)
44	West-East22	W-E22	22	1.3	West-East (W-E)

Stations along North-South route:

Table 8.5: Station setting out put along N-S route

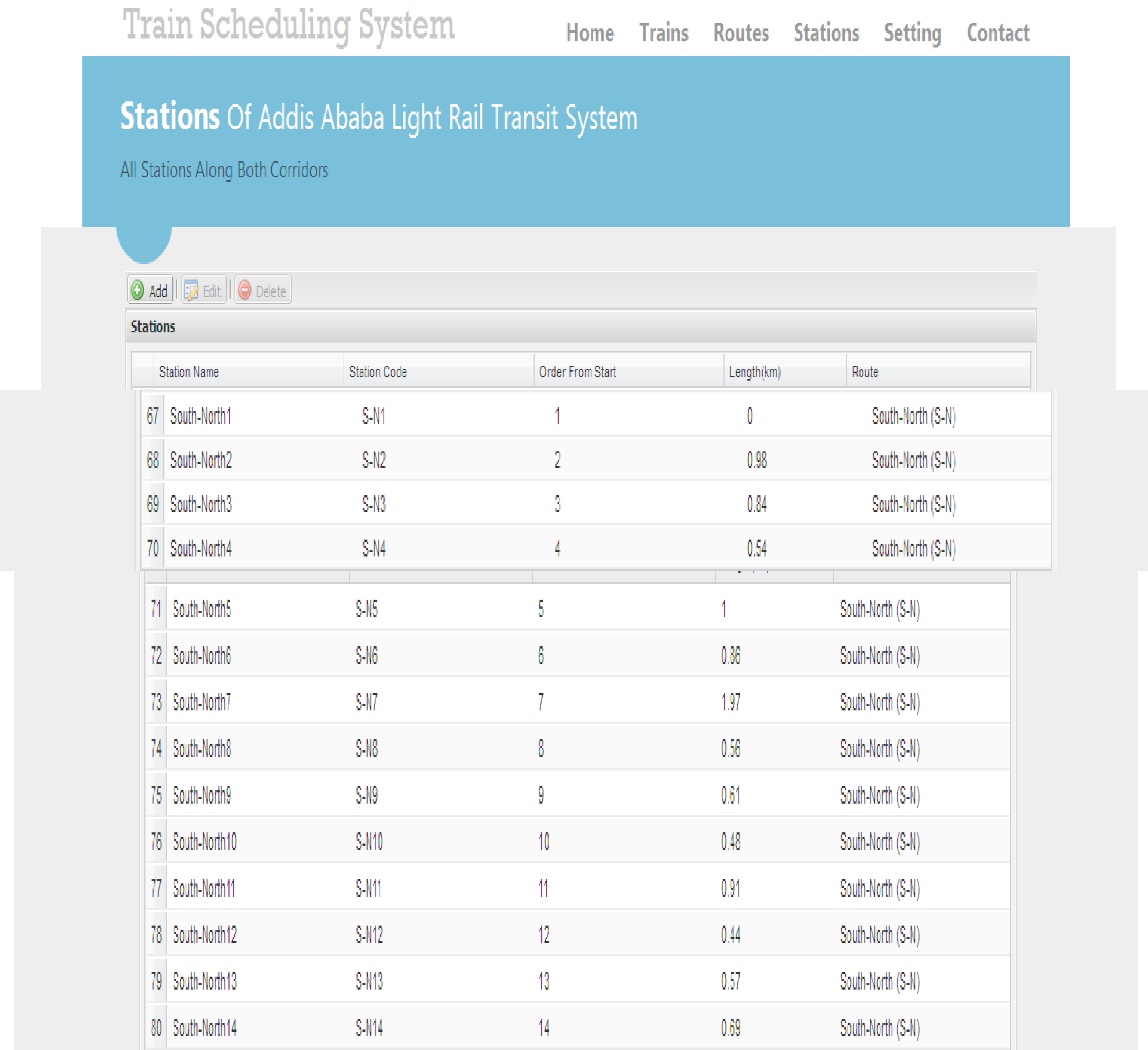


	Station Name	Station Code	Order From Start	Length(km)	Route
45	North-South1	N-S1	1	0	North-South (N-S)
46	North-South2	N-S2	2	0.74	North-South (N-S)
47	North-South3	N-S3	3	0.95	North-South (N-S)
48	North-South4	N-S4	4	0.61	North-South (N-S)
49	North-South5	N-S5	5	0.61	North-South (N-S)
50	North-South6	N-S6	6	0.86	North-South (N-S)

51	North-South7	N-S7	7	0.74	North-South (N-S)
52	North-South8	N-S8	8	0.59	North-South (N-S)
53	North-South9	N-S9	9	0.73	North-South (N-S)
54	North-South10	N-S10	10	0.69	North-South (N-S)
55	North-South11	N-S11	11	0.57	North-South (N-S)
56	North-South12	N-S12	12	0.44	North-South (N-S)
57	North-South13	N-S13	13	0.91	North-South (N-S)
58	North-South14	N-S14	14	0.48	North-South (N-S)
59	North-South15	N-S15	15	0.61	North-South (N-S)
60	North-South16	N-S16	16	0.56	North-South (N-S)
61	North-South17	N-S17	17	1.97	North-South (N-S)
62	North-South18	N-S18	18	0.86	North-South (N-S)
63	North-South19	N-S19	19	1	North-South (N-S)
64	North-South20	N-S20	20	0.54	North-South (N-S)
65	North-South21	N-S21	21	0.84	North-South (N-S)
66	North-South22	N-S22	22	0.98	North-South (N-S)

Stations along South-Nourth route:

Table 8.6: Station setting out put along S-N route



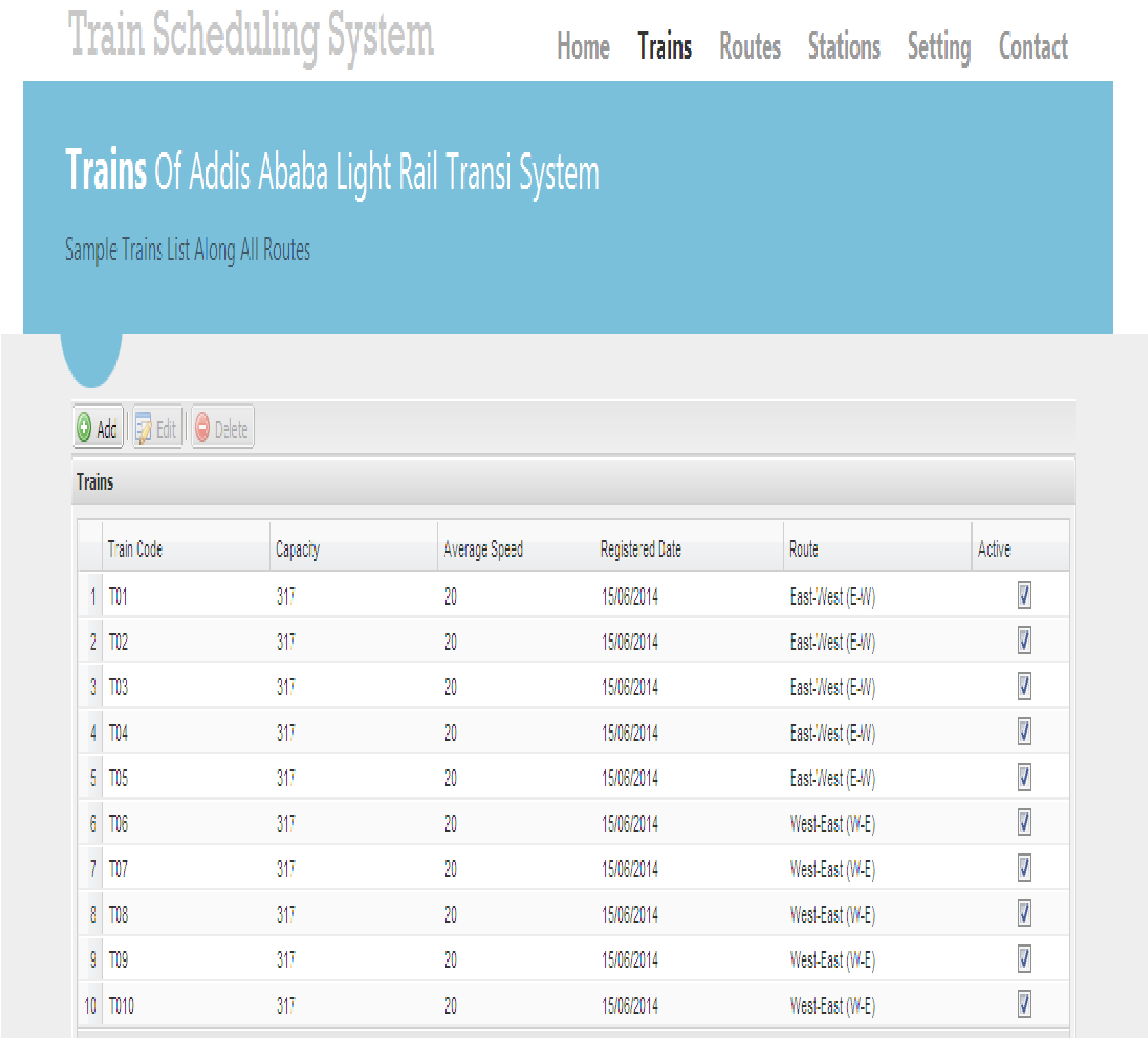
	Station Name	Station Code	Order From Start	Length(km)	Route
67	South-North1	S-N1	1	0	South-North (S-N)
68	South-North2	S-N2	2	0.98	South-North (S-N)
69	South-North3	S-N3	3	0.84	South-North (S-N)
70	South-North4	S-N4	4	0.54	South-North (S-N)
71	South-North5	S-N5	5	1	South-North (S-N)
72	South-North6	S-N6	6	0.86	South-North (S-N)
73	South-North7	S-N7	7	1.97	South-North (S-N)
74	South-North8	S-N8	8	0.56	South-North (S-N)
75	South-North9	S-N9	9	0.61	South-North (S-N)
76	South-North10	S-N10	10	0.48	South-North (S-N)
77	South-North11	S-N11	11	0.91	South-North (S-N)
78	South-North12	S-N12	12	0.44	South-North (S-N)
79	South-North13	S-N13	13	0.57	South-North (S-N)
80	South-North14	S-N14	14	0.69	South-North (S-N)

81	South-North15	S-N15	15	0.73	South-North (S-N)
82	South-North16	S-N16	16	0.59	South-North (S-N)
83	South-North17	S-N17	17	0.74	South-North (S-N)
84	South-North18	S-N18	18	0.86	South-North (S-N)
85	South-North19	S-N19	19	0.61	South-North (S-N)
86	South-North20	S-N20	20	0.61	South-North (S-N)
87	South-North21	S-N21	21	0.95	South-North (S-N)
88	South-North22	S-N22	22	0.74	South-North (S-N)

8.4. Trains

Trains allocated along East-West route:

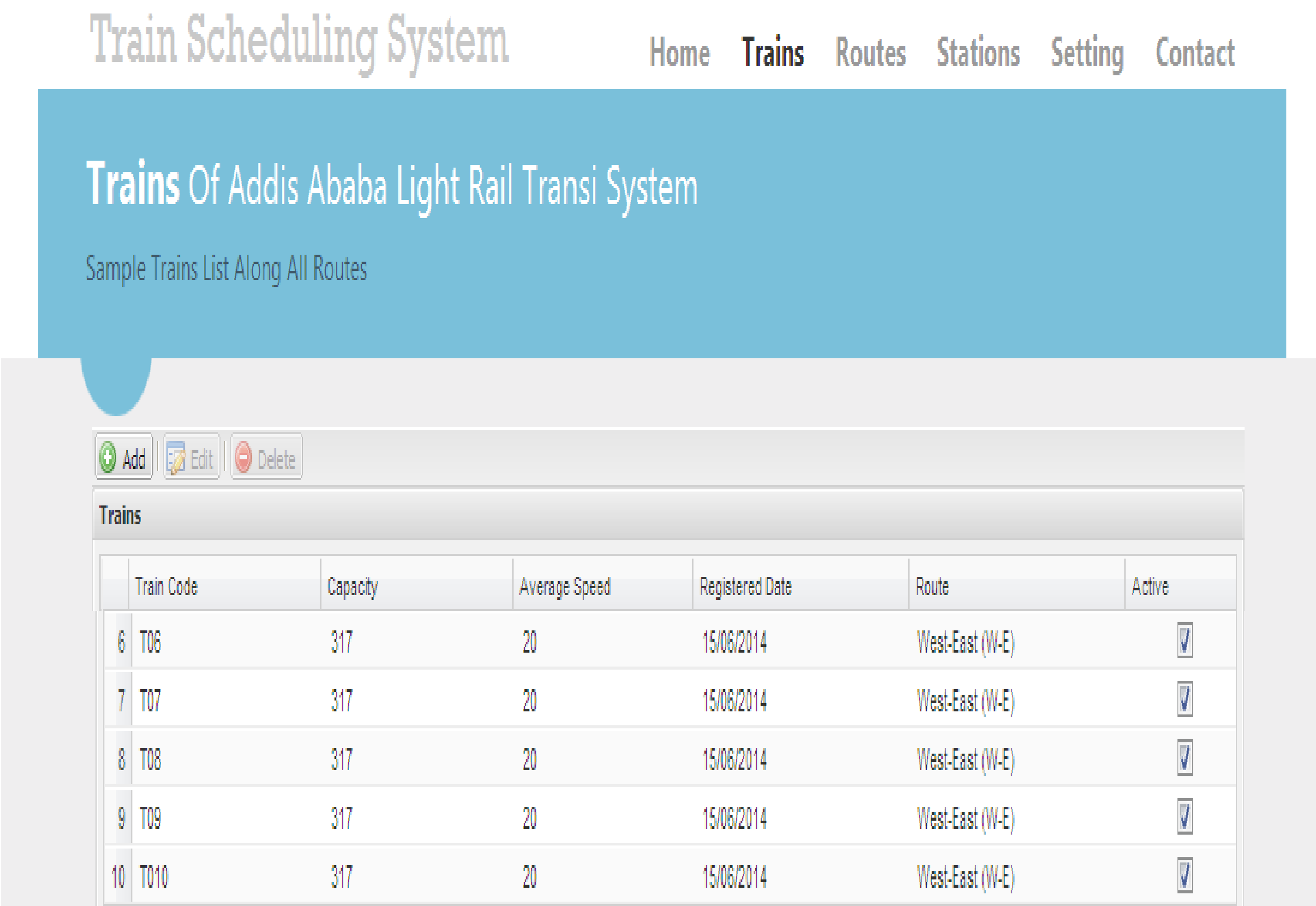
Table 8.7: Train output along E-W route



	Train Code	Capacity	Average Speed	Registered Date	Route	Active
1	T01	317	20	15/06/2014	East-West (E-W)	☑
2	T02	317	20	15/06/2014	East-West (E-W)	☑
3	T03	317	20	15/06/2014	East-West (E-W)	☑
4	T04	317	20	15/06/2014	East-West (E-W)	☑
5	T05	317	20	15/06/2014	East-West (E-W)	☑
6	T06	317	20	15/06/2014	West-East (W-E)	☑
7	T07	317	20	15/06/2014	West-East (W-E)	☑
8	T08	317	20	15/06/2014	West-East (W-E)	☑
9	T09	317	20	15/06/2014	West-East (W-E)	☑
10	T010	317	20	15/06/2014	West-East (W-E)	☑

Trains allocated along West-east route:

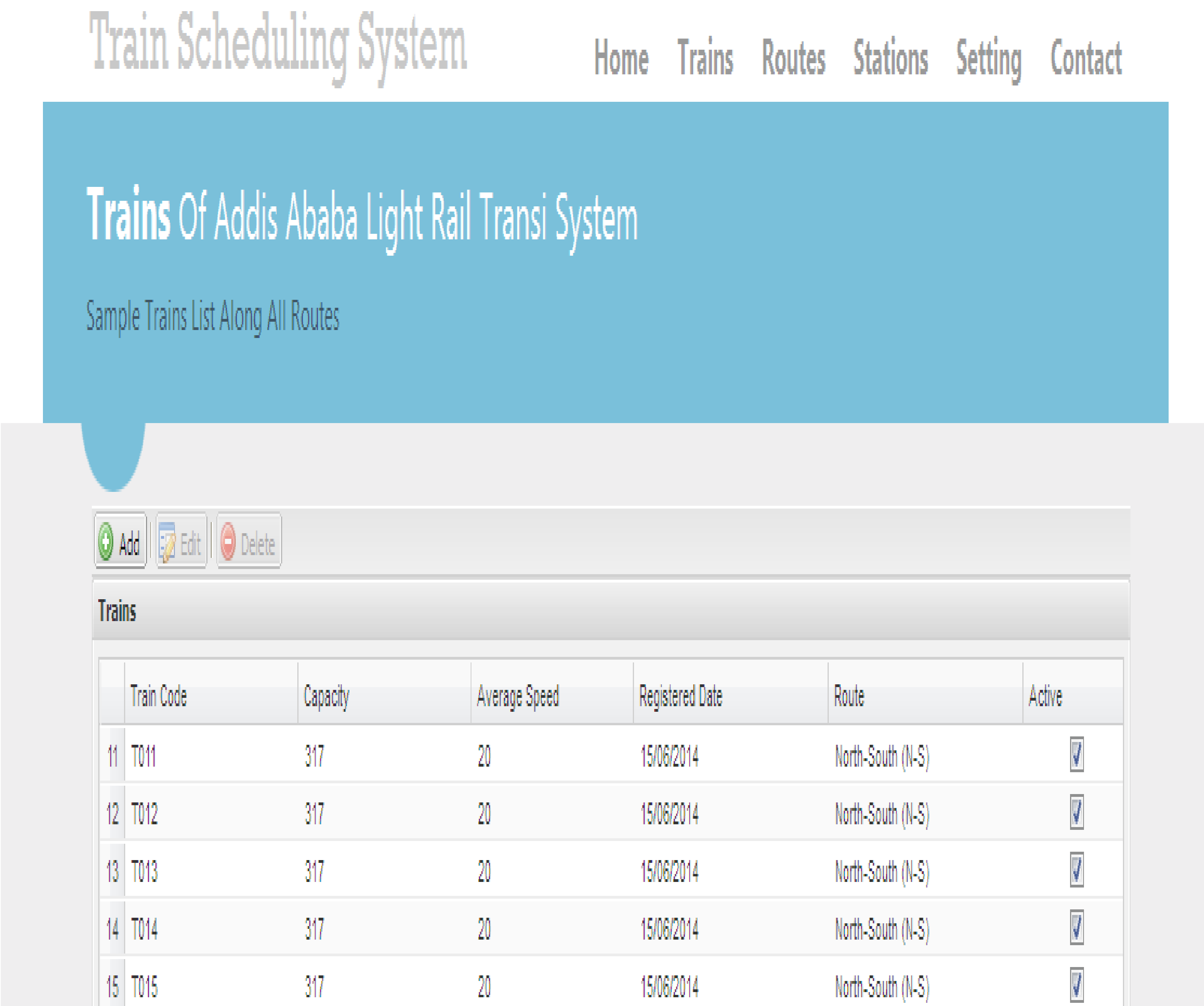
Table 8.8: Train output along W-E route



	Train Code	Capacity	Average Speed	Registered Date	Route	Active
6	T06	317	20	15/06/2014	West-East (W-E)	☑
7	T07	317	20	15/06/2014	West-East (W-E)	☑
8	T08	317	20	15/06/2014	West-East (W-E)	☑
9	T09	317	20	15/06/2014	West-East (W-E)	☑
10	T010	317	20	15/06/2014	West-East (W-E)	☑

Trains allocated along North-south route:

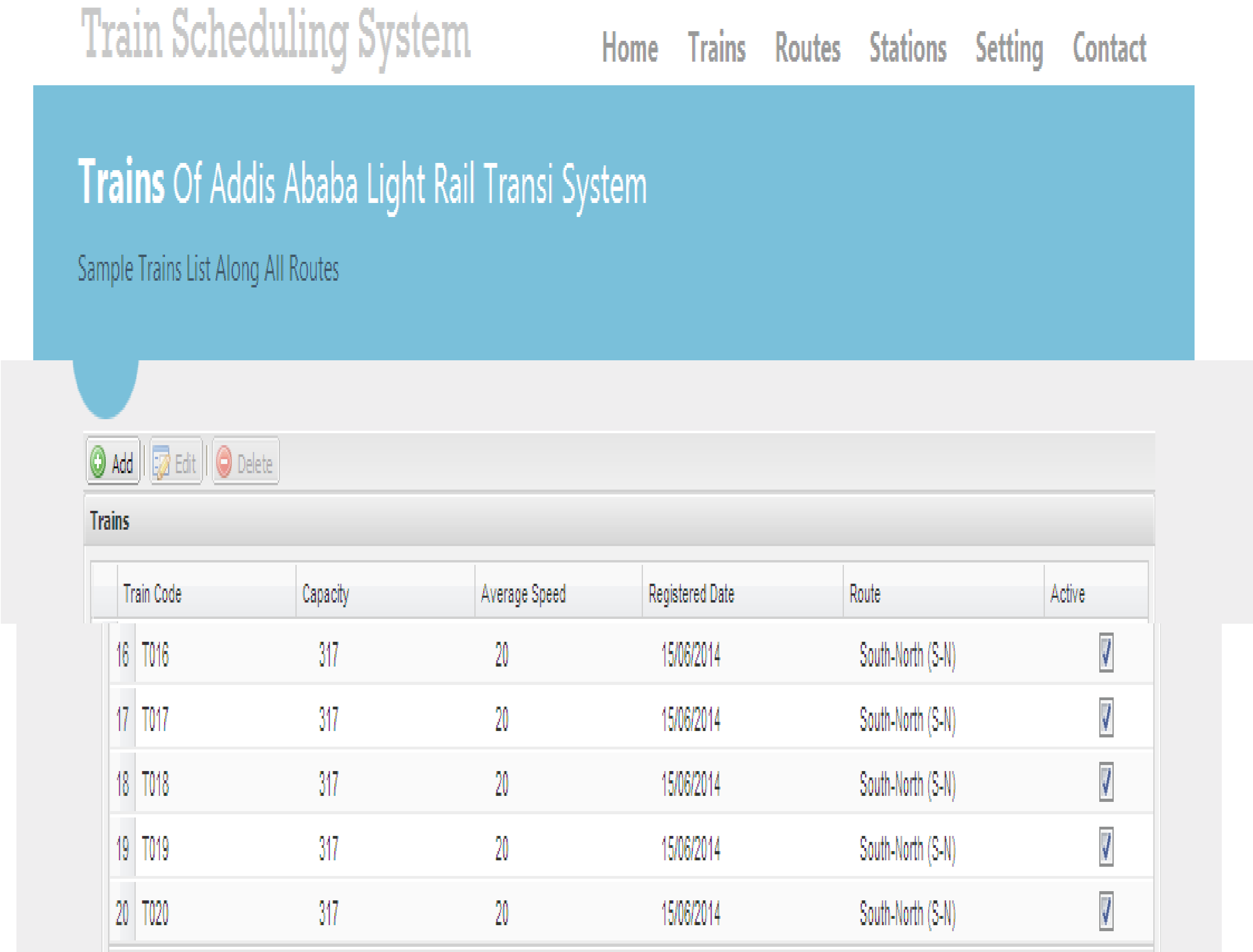
Table 8.9: Train output along N-S route



	Train Code	Capacity	Average Speed	Registered Date	Route	Active
11	T011	317	20	15/06/2014	North-South (N-S)	☑
12	T012	317	20	15/06/2014	North-South (N-S)	☑
13	T013	317	20	15/06/2014	North-South (N-S)	☑
14	T014	317	20	15/06/2014	North-South (N-S)	☑
15	T015	317	20	15/06/2014	North-South (N-S)	☑

Trains allocated along South-North route:

Table8.10: Train output along S-N route



	Train Code	Capacity	Average Speed	Registered Date	Route	Active
16	T016	317	20	15/06/2014	South-North (S-N)	√
17	T017	317	20	15/06/2014	South-North (S-N)	√
18	T018	317	20	15/06/2014	South-North (S-N)	√
19	T019	317	20	15/06/2014	South-North (S-N)	√
20	T020	317	20	15/06/2014	South-North (S-N)	√

9. CONCLUSION AND RECOMMENDATION

As it has being seen on the result, it can be concluded that the object of the thesis has attained, because this paper tried to show the developed train scheduling model, solved the model, validating the model via simulation and verifying the results which shows an efficient train running time, passenger waiting time, dwell time, head on time , departure time and arrival time being at any station to satisfy customers' demand and number of trains along all routes that saves operating cost even it is being used only sample 5 trains along each route.

It is recommended that the optimization or minimization cost function of train scheduling which reflects operating cost of trains (operator cost) and waiting time cost, in-vehicle time cost of passengers (user cost) subject to load factor constraint, waiting time constraint and the dwell time cost (which influences both the operator and user cost) accommodating on a single objective function even they are conflicting each other should be done.

REFERENCES

[1] Abbas-Turki, A.A., Grunder, O. and El-Moudni, A., 2003, “Periodic event scheduling based on controlled stochastic Petri net”, Proceedings of the 35th Southeastern Symposium, pp. 386-391.

[2] Isaai, M.Y. and Singh, M.G., 2001, “Hybrid applications of constraint satisfaction and meta-heuristics to railway timetabling: a comparative study”,IEEE Transactions on systems, man and cybernetics-part c: Applications and reviews, Vol. 31(1), pp. 87-95.

[3] Semet, Y. and Schoenauer, M., 2005, “An Efficient Memetic, Permutation-based Evolutionary Algorithm for Real-World Train Timetabling”, IEEE, Vol. 3, pp. 2752-2759.

[4] Verma, A., Dhingra, S.L., 2006. Developing integrated schedules for urban rail and feeder bus operation. Journal of Urban Planning and Development, ASCE 132 (3), 138–146.

[5] Burke, E.K, Eliman and Petrovic, S., 2002, “Recent research directions in automated timetabling”, European Journal of Operational Research, Vol. 140, pp. 266-280.

[6] Chu, S.C.K and Chan E.C.H., 1998, “Crew Scheduling of Light Rail Transit in Hong Kong: From Modeling to Implementation”, Computers Operations Research, Vol. 25(11), pp. 887-894.

[7] Carey and Malachy Ex ante heuristic measures of schedule reliability, Transportation Research Part B 33(7), pp. 473-494, 1999.

[8] Mattsson Train service reliability A survey of methods for deriving relationships for train delays Unpublished, http://users.du.se/ jen/Seminarieuppsatser/Forsening-tag-Mattsson.pdf, 2004.

[9] Middelkoop and Bouwman SIMONE: Large scale train network simulations, Proceedings of the 2001 Winter Simulation Conference pp. 1042-1047, Institute of Electrical and Electronic Engineering, Piscataway, New Jersey, 2001.

[10] Sandblad et al. T9 – Simulator system inomt°agtrafikstyring,enkundskabsdokumentation, UpsalaUniversitet, 26-05-2003.

[11] Vroman, Dekker and Kroon Reliability and heterogeneity of railway services, ERIM Research Report ERS-2003-090-LIS, Erasmus University Rotterdam, 2003.

[12] Kikuchi, S., 1985. Relationship between the number of stops and headway for a fixed-route transit system. Transportation Research A 19A (1), 65–71.

[13] Jovanonic, D., Harker, P., 1991. Tactical scheduling of rail operations: the SCAN I system. Transportation Science 25, 46–64.

[14] Salzborn, E.J.M., 1970. The minimum fleet size for a suburban railway system. Transportation Science 4, 383–402.

[15] Assad, A.A., 1982. A class of train-scheduling problems. Transportation Science 16 (3), 281–310.

[16] Cowling, P., Kendall, G. and Han, L., 2002, ‘’An Investigation of a Hyper heuristic Genetic Algorithm Applied to a Trainer Scheduling Problem’’, Proceedings of the Evolutionary Computation, Vol. 2, pp.1185-1190.

[17] Vansteenwegen, P. and Oudheusden, D., 2006, ‘’Developing railway timetables which guarantee a better service’’, European Journal of Operations Research, Vol. 173, pp. 337-350.

[18] Yakoob S.M and Sherali, H.D, 2007, “Mixed-integer programming models for an employee scheduling problem with multiple shifts and work locations”, Annals of Operations Research, Vol. 155 (1), pp.119-142.

[19] M. A. Salido, F. Barber, and L. Ingolotti, “Robustness in railway transportation scheduling,” in Proceedings of the 7th World Congress on Intelligent Control and Automation (WCICA ’08), pp. 2833–2837, IEEE Press, Chongqing, China, June 2008.

[20] M. Abril, F. Barber, L. Ingolotti, M. A. Salido, P. Tormos, and A. Lova, “An assessment of railwaycapacity,” Transportation Research Part E, vol. 44, no. 5, pp. 774–806, 2008.

[21] Moorthy, N.V.R., 1997. Planning of integrated transit network for bus and LRT. Journal of Advanced Transportation 31 (3), 283–309.

[22] Furth, P. G. and Wilson, N. M. H. (1981). Setting frequencies on Bus Routes: Theory and Practice,Transportation Research Record 818, Transportation research Board, Washington, D. C., pp 1 – 7.

APPENDIX A:

Passenger demand along E-W and N-S corridors at peak and off peak hours

Daily passenger Boarding/Alighting Volumes on E-W Line in Initial Stage

Passenger boarding Volume (1->22)	Passenger Alighting Volume (1->22)	E-W Cross-section Flow	Station	Passenger Boarding Volume (22->1)	Passenger Alighting Volume (22->1)	W-E Cross-section Flow
7253		7253	EW1		7244	
6149	29	13373	EW2	29	6185	7244
4094	89	17378	EW3	89	4139	13400
4071	245	21204	EW4	245	4044	17450
3181	406	23979	EW5	406	3190	21249
2017	392	25604	EW6	392	1999	24033
1860	547	26917	EW7	547	1842	25640
1423	572	27769	EW8	572	1423	26935
3452	2763	28458	EW9	2763	3416	27787
6315	7818	26955	EW10	7818	6333	28440
6204	5900	27259	EW11	5900	6177	26955
3125	2322	28062	EW12	2331	3143	27232
3438	2170	29330	EW13	2170	3438	28044
2271	1995	29607	EW14	1995	2271	29312
2119	2615	29111	EW15	2642	2119	29589
1841	3942	27010	EW16	3933	1841	29066
1170	4792	23388	EW17	4801	1170	26974
433	4082	19739	EW18	4046	433	23343
223	4505	15456	EW19	4514	223	19730
89	4036	11509	EW20	4000	89	15438
32	4917	6624	EW21	4953	32	11527
	6624		EW22	6606		6606
60760	60560		Total	60751	60751	

Passenger Boarding & Alighting Volumes during Morning Rush-Hour on E-W

Line in Initial Stage

Passenger boarding Volume (1->22)	Passenger Alighting Volume (1->22)	E-W Cross-section Flow	Station	Passenger Boarding Volume (22->1)	Passenger Alighting Volume (22->1)	W-E Cross-section Flow
656		656	EW1		648	
556	3	1210	EW2	3	553	648
370	8	1573	EW3	8	370	1198
368	22	1919	EW4	22	362	1560
288	37	2170	EW5	36	285	1900
183	35	2317	EW6	35	179	2149
168	49	2436	EW7	49	165	2292
129	52	2513	EW8	51	127	2408
312	250	2575	EW9	247	305	2408
572	708	2439	EW10	699	566	2484
561	534	2567	EW11	527	552	2543
283	210	2540	EW12	208	281	2410
311	196	2654	EW13	194	307	2435
206	181	2679	EW14	178	203	2507
192	237	2635	EW15	236	189	2621
167	357	2444	EW16	352	165	2645
106	434	2117	EW17	429	105	2598
39	369	1786	EW18	362	39	2411
20	408	1399	EW19	404	20	2087
8	365	1042	EW20	358	8	1764
3	445	599	EW21	443	3	1380
	599		EW22	591		1031
5499	5499		Total	5431	5431	591

Passenger Boarding & Alighting Volumes during Evening Rush-Hour on E-W

Line in Initial Stage

Passenger boarding Volume (1->22)	Passenger Alighting Volume (1->22)	E-W Cross-section Flow	Station	Passenger Boarding Volume (22->1)	Passenger Alighting Volume (22->1)	W-E Cross-section Flow
545		545	EW1		537	
462	2	1004	EW2	2	458	537
307	7	1305	EW3	7	307	993
306	18	1592	EW4	18	300	1293
239	30	1801	EW5	30	236	1575
151	29	1923	EW6	29	148	1781
140	41	2021	EW7	41	136	1900
107	43	2085	EW8	42	105	1996
259	207	2137	EW9	205	253	2059
474	587	2024	EW10	579	469	2107
466	443	2047	EW11	437	458	1997
235	174	2107	EW12	173	233	2018
258	163	2203	EW13	161	255	2078
171	150	2223	EW14	148	168	2172
159	196	2186	EW15	196	157	2193
138	296	2028	EW16	291	136	2154
88	360	1756	EW17	356	87	1999
33	307	1482	EW18	300	32	1730
17	338	1161	EW19	335	16	1462
7	303	864	EW20	296	7	1144
2	369	497	EW21	367	2	854
	497		EW22	490		490
4563	4563		Total	4502	4502	

Daily Passenger Boarding/Alighting on N-S Line in Initial Stage

Passenger boarding Volume (6->27)	Passenger Alighting Volume (6->27)	S-N Cross-section Flow	Station	Passenger Boarding Volume (27->6)	Passenger Alighting Volume (27->6)	N-S Cross-section Flow
5033		5033	NS6		5024	
3286	13	8306	NS7	13	3322	5024
2873	46	11133	NS8	46	2918	8333
5666	287	16512	NS9	287	5639	11205
6588	720	22380	NS10	720	6597	16557
4791	945	26225	NS11	945	4773	22434
3685	1370	28539	NS12	1370	3667	26261
2561	1578	29523	NS13	1578	2561	28557
2358	2322	29560	NS14	2322	2322	29541
1810	1902	29467	NS15	1902	1828	29542
4549	4492	29525	NS16	4492	4522	29467
4862	5063	29324	NS17	5072	4880	29498
4279	4388	29215	NS18	4388	4279	29306
3257	4329	28143	NS19	4329	3257	29197
2191	3495	26839	NS20	3522	2191	28125
848	2147	25540	NS21	2138	848	26794
639	2359	23820	NS22	2368	639	25504
362	2448	21734	NS23	2412	362	23775
460	5371	16822	NS24	5380	460	21725
152	5433	11542	NS25	5397	152	16804
33	5057	6518	NS26	5093	33	11560
	6518		NS27	6500		6500
60283	60283		Total	60274	60274	

Passenger Boarding and Alighting Volume during Morning Rush-Hour on N-S

Line in Initial Stage

Passenger boarding Volume (6->27)	Passenger Alighting Volume (6->27)	S-N Cross-section Flow	Station	Passenger Boarding Volume (27->6)	Passenger Alighting Volume (27->6)	N-S Cross-section Flow
455		455	NS6		452	
297	1	752	NS7	1	299	452
260	4	1008	NS8	4	262	749
513	26	1494	NS9	26	507	1007
596	65	2025	NS10	65	593	1488
434	86	2373	NS11	85	429	2017
333	124	2583	NS12	123	330	2361
232	143	2672	NS13	142	230	2567
213	210	2675	NS14	209	209	2656
164	172	2667	NS15	171	164	2656
412	406	2672	NS16	404	407	2649
440	458	2654	NS17	456	439	2652
387	397	2644	NS18	394	385	2635
295	392	2547	NS19	389	293	2625
198	316	2429	NS20	317	197	2528
77	194	2311	NS21	192	76	2409
58	213	2156	NS22	213	57	2293
33	222	1967	NS23	217	33	2137
42	486	1522	NS24	484	41	1953
14	492	1045	NS25	485	14	1511
3	458	590	NS26	458	3	1039
	590		NS27	584		584
5456	5456		Total	5419	5419	

Passenger Boarding and Alighting Volume during Evening Rush-Hour on N-S

Line in Initial Stage

Passenger boarding Volume (6->27)	Passenger Alighting Volume (6->27)	S-N Cross-section Flow	Station	Passenger Boarding Volume (27->6)	Passenger Alighting Volume (27->6)	N-S Cross-section Flow
378		378	NS6		374	
247	1	624	NS7	1	248	374
216	3	836	NS8	3	217	621
426	22	1240	NS9	21	420	835
495	54	1681	NS10	54	491	1233
360	71	1970	NS11	70	356	1671
277	103	2143	NS12	102	273	1956
192	118	2217	NS13	118	191	2128
177	174	2220	NS14	173	173	2201
136	143	2213	NS15	142	136	2201
342	337	2217	NS16	335	337	2195
365	380	2202	NS17	378	364	2198
321	330	2194	NS18	327	319	2183
245	325	2114	NS19	323	243	2175
165	262	2016	NS20	262	163	2095
64	161	1918	NS21	159	63	1996
48	177	1789	NS22	176	48	1900
27	184	1632	NS23	180	27	1771
35	403	1263	NS24	401	34	1618
11	408	867	NS25	402	11	1252
2	380	489	NS26	379	2	861
	489		NS27	484		484
4527	4527		Total	4490	4490	

APPENDIX B:

Webpage design using HTML and ASP.net controller languages for setting of Routes, Stations and Train

```
<%@PageTitle="Settings"Language="C#"MasterPageFile="~/Site.Master"Auto
EventWireup="true"CodeBehind="Setting.aspx.cs"Inherits="TrainScheduler
.Public.Setting"%>
<%@RegisterTagPrefix="ext"Namespace="Coolite.Ext.Web"Assembly="Coolite
.Ext.Web, Version=0.8.1.2802, Culture=neutral,
PublicKeyToken=f58c952e9aa5b80a"%>

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er">
</asp:Content>
<asp:ContentID="Content2"ContentPlaceHolderID="FeaturedContent"runat="
server">
<sectionclass="featured">
<divclass="content-wrapper">
<hgroupclass="title">
<h1><%: Title %></h1>
<h2>Of The Train Scheduling</h2>
</hgroup>
<p>
                General parameter settings of attributes of
Routes,Stations& Trains
</p>
</div>
</section>
</asp:Content>
<asp:ContentID="Content3"ContentPlaceHolderID="MainContent"runat="serv
er">
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</ext:ScriptManager>
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lSettings"
TypeName="TrainScheduler.Business.Setting"></asp:ObjectDataSource>

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<Fields>
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<ext:RecordFieldName="EndTime"/>
<ext:RecordFieldName="DwellTime"/>
```

```
<ext:RecordFieldName="TrainSpeed"/>
<ext:RecordFieldName="StartTimeInterval"/>
</Fields>
</ext:JsonReader>
</Reader>
</ext:Store>
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<Items>
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e"Text="Add">
<Listeners>
<ClickHandler="#{newWindow}.show();"/>
</Listeners>
<ToolTips>
<ext:ToolTipID="ToolTip1"runat="server"Html="Add New Setting"/>
</ToolTips>
</ext:ToolbarButton>
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dit"StandOut="true"
Text="Edit"Enabled="false">
<Listeners>
<ClickHandler="#{editWindow}.show();"/>
</Listeners>
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<ext:ToolTipID="ToolTip2"runat="server"Html="Update Selected
Setting"/>
</ToolTips>
</ext:ToolbarButton>
<ext:ToolbarSeparatorID="ToolbarSeparator2"runat="server"/>
<ext:ToolbarButtonID="DeleteToolBar"runat="server"Icon="Delete"StandOu
t="true"
Text="Delete"Enabled="false">
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<ClickHandler="CyberMDP.DoConfirm()"/>
</Listeners>
</ext:ToolbarButton>
</Items>
</ext:Toolbar>
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"StripeRows="True"
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<ext:ColumnDataIndex="DwellTime"Header="Dwell Time(Min)"Width="200"/>
<ext:ColumnDataIndex="TrainSpeed"Header="Train
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<ext:ColumnDataIndex="StartTimeInterval"Header="Start Time
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</View>
<SelectionModel>
<ext:RowSelectionModelID="RowSelectionModel1"runat="server"SingleSelec
t="true">
<Listeners>
<%--<RowSelect
Handler="#{FormPanel2}.getForm().loadRecord(record);#{EditToolBar}.ena
ble();#{DeleteToolBar}.enable();" />--%>
</Listeners>
</ext:RowSelectionModel>
</SelectionModel>
<BottomBar>
<ext:PagingToolbarID="PagingToolBar1"runat="server"StoreID="storeSetti
ngs"
PageSize="10"DisplayInfo="true"DisplayMsg="Displaying Setting {0} -
{1} of {2}"/>
</BottomBar>
</ext:GridPanel>
<ext:WindowID="newWindow"runat="server"Collapsible="false"Icon="Applic
ation"
Title="Register New
Setting"ShowOnLoad="false"AutoHeight="true"AutoScroll="true"
BodyStyle="padding:6px;"PageX="20"PageY="100"Width="400"ButtonAlign="R
ight"
Resizable="false">
<Body>
<ext:FormPanelID="FormPanel1"runat="server"BodyStyle="padding:5px;"But
tonAlign="Right"
```

```
Frame="true"AutoHeight="true"Title=""AutoWidth="true">
<Body>
<ext:FormLayoutID="FormLayout2"runat="server">
<ext:AnchorHorizontal="100%">
<ext:TimeFieldID="txtStartTime"runat="server"FieldLabel="Start 
Time"AllowBlank="false"Format="H:mm"MinTime="5:00"MaxTime="7:00"
BlankText="Start Time is required.">
</ext:TimeField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:TimeFieldID="txtEndTime"runat="server"FieldLabel="End 
Time"AllowBlank="false"Format="H:mm"MinTime="18:00"MaxTime="23:00"
BlankText="End Time is required.">
</ext:TimeField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:NumberFieldID="txtDwellTime"MinValue="0"AllowDecimals="False"runa
t="server"FieldLabel="Dwell Time(min)"AllowBlank="false"
BlankText="Dwell Time is required.">
</ext:NumberField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:NumberFieldID="txtTrainSpeed"MinValue="0"AllowDecimals="False"run
at="server"FieldLabel="Train Speed(km/hr)"AllowBlank="false"
BlankText="Train Speed is required.">
</ext:NumberField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:NumberFieldID="txtStartTimeInterval"MinValue="0"AllowDecimals="Fa
lse"runat="server"FieldLabel="Start-Time 
Interval(min)"AllowBlank="false"
BlankText="Start-Time Interval is required.">
</ext:NumberField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:TimeFieldID="txtMorFrom"runat="server"FieldLabel="Peak Hr 
From(Morn)"AllowBlank="false"Format="H:mm"MinTime="05:00"MaxTime="10:0
0"
BlankText="Peak Hr From(Morn) is required.">
</ext:TimeField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:TimeFieldID="txtMorTo"runat="server"FieldLabel="Peak Hr 
To(Morn)"AllowBlank="false"Format="H:mm"MinTime="06:00"MaxTime="11:00"
BlankText="Peak Hr To(Morn) is required.">
</ext:TimeField>
```

```
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:TimeFieldID="txtEveFrom"runat="server"FieldLabel="Peak Hr 
From(Even)"AllowBlank="false"Format="H:mm"MinTime="15:00"MaxTime="18:0
0"
BlankText="Peak Hr From(Even) is required.">
</ext:TimeField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:TimeFieldID="txtEveTo"runat="server"FieldLabel="Peak Hr 
To(Even)"AllowBlank="false"Format="H:mm"MinTime="16:00"MaxTime="19:00"
BlankText="Peak Hr To(Even) is required.">
</ext:TimeField>
</ext:Anchor>
</ext:FormLayout>
</Body>
</ext:FormPanel>
</Body>
<Buttons>
<ext:ButtonID="btnSettingSave"runat="server"Text="Save"Icon="Disk">
<AjaxEvents>
<ClickOnEvent="btnSettingSave_Click"Success="Ext.Msg.alert ('Train 
Scheduling System', 'Setting is Successfully 
Saved!!');#{GridPanel1}.reload();">
</Click>
</AjaxEvents>
<Listeners>
<ClickHandler="#{newWindow}.hide();"/>
</Listeners>
</ext:Button>
<ext:ButtonID="btnCancel"runat="server"Text="Cancel"Icon="Cancel">
<Listeners>
<ClickHandler="#{newWindow}.hide();"/>
</Listeners>
</ext:Button>
</Buttons>
</ext:Window>
</asp:Content>
```

Webpage design using HTML and ASP.net controller languages for Routes:

```
<%@PageTitle="Routes"Language="C#"MasterPageFile="~/Site.Master"AutoEv
entWireup="true"CodeBehind="Route.aspx.cs"Inherits="TrainScheduler.Pub
lic.Route"%>
<%@RegisterAssembly="Coolite.Ext.Web"Namespace="Coolite.Ext.Web"TagPre
fix="ext"%>
```

```
<asp:ContentID="Content1"ContentPlaceHolderID="HeadContent"runat="serv
er">
</asp:Content>
<asp:ContentID="Content2"ContentPlaceHolderID="FeaturedContent"runat="
server">
<sectionclass="featured">
<divclass="content-wrapper">
<hgroupclass="title">
<h1><%: Title %></h1>
<h2>Of Addia Ababa Light Rail Transit System</h2>
</hgroup>
<p>
                Four routes along both corridors
</p>
</div>
</section>
</asp:Content>
<asp:ContentID="Content3"ContentPlaceHolderID="MainContent"runat="serv
er">
<ext:ScriptManagerID="ScriptManager1"runat="server “Theme="Gray">
</ext:ScriptManager>
<asp:ObjectDataSourceID="objRoutes"runat="server"SelectMethod="GetAllR
outes"
TypeName="TrainScheduler.Business.Route"></asp:ObjectDataSource>
<ext:StoreID="storeRoutes"runat="server"DataSourceID="objRoutes">
<Reader>
<ext:JsonReaderReaderID="Id">
<Fields>
<ext:RecordFieldName="Id"/>
<ext:RecordFieldName="RouteName"/>
<ext:RecordFieldName="RouteCode"/>
<ext:RecordFieldName="Start"/>
<ext:RecordFieldName="EndPlace"/>
<ext:RecordFieldName="NumberOfStations"/>
<ext:RecordFieldName="Remarks"/>
</Fields>
</ext:JsonReader>
</Reader>
</ext:Store>
<ext:ToolbarID="Toolbar1"runat="server">
<Items>
<ext:ToolbarButtonID="AddToolBar"runat="server"Icon="Add"StandOut="tru
e"Text="Add">
<Listeners>
<ClickHandler="#{newWindow}.show();"/>
</Listeners>
```

```
<ToolTips>
<ext:ToolTipID="ToolTip1"runat="server"Html="Add New Route"/>
</ToolTips>
</ext:ToolbarButton>
<ext:ToolbarSeparatorID="ToolbarSeparator1"runat="server"/>
<ext:ToolbarButtonID="EditToolBar"runat="server"Icon="ApplicationFormE
dit"StandOut="true"
Text="Edit"Enabled="false">
<Listeners>
<ClickHandler="#{editWindow}.show();"/>
</Listeners>
<ToolTips>
<ext:ToolTipID="ToolTip2"runat="server"Html="Update Selected Route"/>
</ToolTips>
</ext:ToolbarButton>
<ext:ToolbarSeparatorID="ToolbarSeparator2"runat="server"/>
<ext:ToolbarButtonID="DeleteToolBar"runat="server"Icon="Delete"StandOu
t="true"
Text="Delete"Enabled="false">
<ToolTips>
<ext:ToolTipID="ToolTip3"runat="server"Html="Delete Selected Route"/>
</ToolTips>
<Listeners>
<ClickHandler="CyberMDP.DoConfirm()"/>
</Listeners>
</ext:ToolbarButton>
</Items>
</ext:Toolbar>
<ext:GridPanelID="GridPanel1"runat="server"Title="Routes"Frame="true"S
tripeRows="True"
StoreID="storeRoutes"AutoHeight="true"Width="960"TrackMouseOver="true"
>
<LoadMaskShowMask="true"/>
<ColumnModelID="ColumnModel1"runat="server">
<Columns>
<ext:RowNumbererColumnWidth="30"/>
<ext:ColumnDataIndex="RouteName"Header="Route Name"Width="200"/>
<ext:ColumnDataIndex="RouteCode"Header="Route Code"Width="200"/>
<ext:ColumnDataIndex="Start"Header="Start From"Width="200"/>
<ext:ColumnDataIndex="EndPlace"Header="End To"Width="200"/>
<ext:ColumnDataIndex="NumberOfStations"Header="No. Of
Stations"Width="130"/>
</Columns>
</ColumnModel>
<View>
<ext:GridViewID="GridView1"runat="server"EnableRowBody="true">
```

```
</ext:GridView>
</View>
<SelectionModel>
<ext:RowSelectionModelID="RowSelectionModel1"runat="server"SingleSelec
t="true">
<Listeners>
<%--<RowSelect
Handler="#{FormPanel2}.getForm().loadRecord(record);#{EditToolBar}.ena
ble();#{DeleteToolBar}.enable();" />--%>
</Listeners>
</ext:RowSelectionModel>
</SelectionModel>
<BottomBar>
<ext:PagingToolbarID="PagingToolBar1"runat="server"StoreID="storeRoute
s"
PageSize="10"DisplayInfo="true"DisplayMsg="Displaying Routes {0} - {1}
of {2}"/>
</BottomBar>
</ext:GridPanel>
<ext:WindowID="newWindow"runat="server"Collapsible="false"Icon="Applic
ation"
Title="Register New
Route"ShowOnLoad="false"AutoHeight="true"AutoScroll="true"
BodyStyle="padding:6px;"PageX="20"PageY="100"Width="400"ButtonAlign="R
ight"
Resizable="false">
<Body>
<ext:FormPanelID="FormPanel1"runat="server"BodyStyle="padding:5px;"But
tonAlign="Right"
Frame="true"AutoHeight="true"Title=""AutoWidth="true">
<Body>
<ext:FormLayoutID="FormLayout2"runat="server">
<ext:AnchorHorizontal="100%">
<ext:TextFieldID="txtRouteName"runat="server"FieldLabel="Route
Name"AllowBlank="false"
BlankText="Route Name is required.">
</ext:TextField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:TextFieldID="txtRouteCode"runat="server"FieldLabel="Route
Code"AllowBlank="false"
BlankText="Route Code is required.">
</ext:TextField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
```

```
<ext:TextFieldID="txtStart"runat="server"FieldLabel="Start
From"AllowBlank="false"
BlankText="Start From is required.">
</ext:TextField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:TextFieldID="txtEndPlace"runat="server"FieldLabel="End
To"AllowBlank="false"
BlankText="End Place is required.">
</ext:TextField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:NumberFieldID="txtNumberOfStations"MinValue="1"AllowDecimals="Fal
se"runat="server"FieldLabel="No. Of Stations"AllowBlank="false"
BlankText="No. Of Stations is required.">
</ext:NumberField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:TextAreaID="txtRemark"runat="server"FieldLabel="Remarks">
</ext:TextArea>
</ext:Anchor>
</ext:FormLayout>
</Body>
</ext:FormPanel>
</Body>
<Buttons>
<ext:ButtonID="btnRouteSave"runat="server"Text="Save"Icon="Disk">
<AjaxEvents>
<ClickOnEvent="btnRouteSave_Click"Success="Ext.Msg.alert('Train
Scheduling System', 'Route is Successfully
Saved!!');#{GridPanel1}.reload();">
</Click>
</AjaxEvents>
<Listeners>
<ClickHandler="#{newWindow}.hide();"/>
</Listeners>
</ext:Button>
<ext:ButtonID="btnCancel"runat="server"Text="Cancel"Icon="Cancel">
<Listeners>
<ClickHandler="#{newWindow}.hide();"/>
</Listeners>
</ext:Button>
</Buttons>
</ext:Window>
</asp:Content>
```

Webpage design using HTML and ASP.net controller languages for Stations:

```
<%@PageTitle="Stations"Language="C#"MasterPageFile="~/Site.Master"Auto
EventWireup="true"CodeBehind="Station.aspx.cs"Inherits="TrainScheduler
.Public.Station"%>

<%@RegisterTagPrefix="ext"Namespace="Coolite.Ext.Web"Assembly="Coolite
.Ext.Web, Version=0.8.1.2802, Culture=neutral,
PublicKeyToken=f58c952e9aa5b80a"%>
<asp:ContentID="Content1"ContentPlaceHolderID="HeadContent"runat="serv
er">
</asp:Content>
<asp:ContentID="Content2"ContentPlaceHolderID="FeaturedContent"runat="
server">
<sectionclass="featured">
<divclass="content-wrapper">
<hgroupclass="title">
<h1><%: Title %></h1>
<h2>Of Addis Ababa Light Rail Transit System</h2>
</hgroup>
<p>
                All Stations Along Both Corridors
</p>
</div>
</section>
</asp:Content>
<asp:ContentID="Content3"ContentPlaceHolderID="MainContent"runat="serv
er">

<ext:ScriptManagerID="ScriptManager1"runat="server"Theme="Gray">
</ext:ScriptManager>
<asp:ObjectDataSourceID="objStations"runat="server"SelectMethod="GetAl
lStations"
TypeName="TrainScheduler.Business.Station"></asp:ObjectDataSource>
<asp:ObjectDataSourceID="objRoutes"runat="server"SelectMethod="GetAllR
outes"
TypeName="TrainScheduler.Business.Route"></asp:ObjectDataSource>
<ext:StoreID="storeStations"runat="server"DataSourceID="objStations">
<Reader>
<ext:JsonReaderReaderID="Id">
<Fields>
<ext:RecordFieldName="Id"/>
<ext:RecordFieldName="StationName"/>
<ext:RecordFieldName="StationCode"/>
<ext:RecordFieldName="OrderFromStart"/>
<ext:RecordFieldName="Length"/>
```

```
<ext:RecordFieldName="Route"/>
<ext:RecordFieldName="Remarks"/>
</Fields>
</ext:JsonReader>
</Reader>
</ext:Store>
<ext:StoreID="storeRoutes"runat="server"DataSourceID="objRoutes">
<Reader>
<ext:JsonReaderReaderID="Id">
<Fields>
<ext:RecordFieldName="Id"/>
<ext:RecordFieldName="RouteName"/>
<ext:RecordFieldName="RouteCode"/>
</Fields>
</ext:JsonReader>
</Reader>
</ext:Store>
<ext:ToolbarID="Toolbar1"runat="server">
<Items>
<ext:ToolbarButtonID="AddToolBar"runat="server"Icon="Add"StandOut="tru
e"Text="Add">
<Listeners>
<ClickHandler="#{newWindow}.show();"/>
</Listeners>
<ToolTips>
<ext:ToolTipID="ToolTip1"runat="server"Html="Add New Station"/>
</ToolTips>
</ext:ToolbarButton>
<ext:ToolbarSeparatorID="ToolbarSeparator1"runat="server"/>
<ext:ToolbarButtonID="EditToolBar"runat="server"Icon="ApplicationFormE
dit"StandOut="true"
Text="Edit"Enabled="false">
<Listeners>
<ClickHandler="#{editWindow}.show();"/>
</Listeners>
<ToolTips>
<ext:ToolTipID="ToolTip2"runat="server"Html="Update Selected
Station"/>
</ToolTips>
</ext:ToolbarButton>
<ext:ToolbarSeparatorID="ToolbarSeparator2"runat="server"/>
<ext:ToolbarButtonID="DeleteToolBar"runat="server"Icon="Delete"StandOu
t="true"
Text="Delete"Enabled="false">
<ToolTips>
```

```
<ext:ToolTipID="ToolTip3"runat="server"Html="Delete Selected
Station"/>
</ToolTips>
<Listeners>
<ClickHandler="CyberMDP.DoConfirm()"/>
</Listeners>
</ext:ToolbarButton>
</Items>
</ext:Toolbar>
<ext:GridPanelID="GridPanel1"runat="server"Title="Stations"Frame="true
"StripeRows="True"
StoreID="storeStations"AutoHeight="true"Width="960"TrackMouseOver="tru
e">
<LoadMaskShowMask="true"/>
<ColumnModelID="ColumnModel1"runat="server">
<Columns>
<ext:RowNumbererColumnWidth="30"/>
<ext:ColumnDataIndex="StationName"Header="Station Name"Width="200"/>
<ext:ColumnDataIndex="StationCode"Header="Station Code"Width="200"/>
<ext:ColumnDataIndex="OrderFromStart"Header="Order From
Start"Width="200"/>
<ext:ColumnDataIndex="Length"Header="Length(km)"Width="130"/>
<ext:ColumnDataIndex="Route"Header="Route"Width="200"/>
</Columns>
</ColumnModel>
<View>
<ext:GridViewID="GridView1"runat="server"EnableRowBody="true">
</ext:GridView>
</View>
<SelectionModel>
<ext:RowSelectionModelID="RowSelectionModel1"runat="server"SingleSelec
t="true">
<Listeners>
<%--<RowSelect
Handler="#{FormPanel2}.getForm().loadRecord(record);#{EditToolBar}.ena
ble();#{DeleteToolBar}.enable();" />--%>
</Listeners>
</ext:RowSelectionModel>
</SelectionModel>
<BottomBar>
<ext:PagingToolbarID="PagingToolBar1"runat="server"StoreID="storeStati
ons"
PageSize="10"DisplayInfo="true"DisplayMsg="Displaying Stations {0} -
{1} of {2}"/>
</BottomBar>
</ext:GridPanel>
```

```
<ext:WindowID="newWindow"runat="server"Collapsible="false"Icon="Applic
ation"
Title="Register New
Station"ShowOnLoad="false"AutoHeight="true"AutoScroll="true"
BodyStyle="padding:6px;"PageX="20"PageY="100"Width="400"ButtonAlign="R
ight"
Resizable="false">
<Body>
<ext:FormPanelID="FormPanel1"runat="server"BodyStyle="padding:5px;"But
tonAlign="Right"
Frame="true"AutoHeight="true"Title=""AutoWidth="true">
<Body>
<ext:FormLayoutID="FormLayout2"runat="server">
<ext:AnchorHorizontal="100%">
<ext:TextFieldID="txtStationName"runat="server"FieldLabel="Station
Name"AllowBlank="false"
BlankText="Station Name is required.">
</ext:TextField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:TextFieldID="txtStationCode"runat="server"FieldLabel="Station
Code"AllowBlank="false"
BlankText="Station Code is required.">
</ext:TextField>
</ext:Anchor>
<ext:Anchor>
<ext:ComboBoxID="ddlRoutes"runat="server"StoreID="storeRoutes"FieldLab
el="Route"
TypeAhead="true"Mode="Local"ForceSelection="true"TriggerAction="All"Di
splayField="RouteName"
Width="150"ValueField="Id"EmptyText="--Select Route--">
</ext:ComboBox>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:NumberFieldID="txtOrderFromStart"MinValue="1"AllowDecimals="False
"runat="server"FieldLabel="Order From Start"AllowBlank="false"
BlankText="Order From Start is required.">
</ext:NumberField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:NumberFieldID="txtLength"MinValue="0"AllowDecimals="True"runat="s
erver"FieldLabel="Length(km)"AllowBlank="false"
BlankText="Length is required.">
</ext:NumberField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
```

```
<ext:NumberFieldID="txtDwellTime"MinValue="1"AllowDecimals="False"runa
t="server"FieldLabel="Dwell Time(Min)"AllowBlank="false"
BlankText="Dwell Time is required.">
</ext:NumberField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:TextAreaID="txtRemark"runat="server"FieldLabel="Remarks">
</ext:TextArea>
</ext:Anchor>
</ext:FormLayout>
</Body>
</ext:FormPanel>
</Body>
<Buttons>
<ext:ButtonID="btnStationSave"runat="server"Text="Save"Icon="Disk">
<AjaxEvents>
<ClickOnEvent="btnStationSave_Click"Success="Ext.Msg.alert('Train
Scheduling System', 'Station is Successfully
Saved!!');#{GridPanel1}.reload();">
</Click>
</AjaxEvents>
<Listeners>
<ClickHandler="#{newWindow}.hide();"/>
</Listeners>
</ext:Button>
<ext:ButtonID="btnCancel"runat="server"Text="Cancel"Icon="Cancel">
<Listeners>
<ClickHandler="#{newWindow}.hide();"/>
</Listeners>
</ext:Button>
</Buttons>
</ext:Window>
</asp:Content>
```

Webpage design using HTML and ASP.net controller languages for Trains:

```
<%@PageTitle="Trains"Language="C#"MasterPageFile="~/Site.Master"AutoEv
entWireup="true"CodeBehind="Train.aspx.cs"Inherits="TrainScheduler.Pub
lic.Train"%>
<%@RegisterAssembly="Coolite.Ext.Web"Namespace="Coolite.Ext.Web"TagPre
fix="ext"%>
<asp:ContentID="Content1"ContentPlaceHolderID="HeadContent"runat="serv
er">

</asp:Content>
```

```
<asp:ContentID="Content2"ContentPlaceHolderID="FeaturedContent"runat="
server">
<sectionclass="featured">
<divclass="content-wrapper">
<hgroupclass="title">
<h1><%: Title %></h1>
<h2>Of Addis Ababa Light Rail Transit System</h2>
</hgroup>
<p>
            Sample Trains List Along All Routes
</p>
</div>
</section>
</asp:Content>
<asp:ContentID="Content3"ContentPlaceHolderID="MainContent"runat="serv
er">
<ext:ScriptManagerID="ScriptManager1"runat="server"Theme="Gray">
</ext:ScriptManager>
<asp:ObjectDataSourceID="objTrains"runat="server"SelectMethod="GetAllT
rains"
TypeName="TrainScheduler.Business.Train"></asp:ObjectDataSource>
<asp:ObjectDataSourceID="objRoutes"runat="server"SelectMethod="GetAllR
outes"
TypeName="TrainScheduler.Business.Route"></asp:ObjectDataSource>
<ext:StoreID="storeTrains"runat="server"DataSourceID="objTrains">
<Reader>
<ext:JsonReaderReaderID="Id">
<Fields>
<ext:RecordFieldName="Id"/>
<ext:RecordFieldName="TrainCode"/>
<ext:RecordFieldName="Capacity"/>
<ext:RecordFieldName="Speed"/>
<ext:RecordFieldName="Remark"/>
<ext:RecordFieldName="Active"/>
<ext:RecordFieldName="RegisteredDate"Type="Date"/>
<ext:RecordFieldName="Remarks"/>
<ext:RecordFieldName="Route"/>
</Fields>
</ext:JsonReader>
</Reader>
</ext:Store>
<ext:StoreID="storeRoutes"runat="server"DataSourceID="objRoutes">
<Reader>
<ext:JsonReaderReaderID="Id">
<Fields>
<ext:RecordFieldName="Id"/>
```

```
<ext:RecordFieldName="RouteName"/>
<ext:RecordFieldName="RouteCode"/>
</Fields>
</ext:JsonReader>
</Reader>
</ext:Store>
<ext:ToolbarID="Toolbar1"runat="server">
<Items>
<ext:ToolbarButtonID="AddToolBar"runat="server"Icon="Add"StandOut="tru
e"Text="Add">
<Listeners>
<ClickHandler="#{newWindow}.show();"/>
</Listeners>
<ToolTips>
<ext:ToolTipID="ToolTip1"runat="server"Html="Add New Train"/>
</ToolTips>
</ext:ToolbarButton>
<ext:ToolbarSeparatorID="ToolbarSeparator1"runat="server"/>
<ext:ToolbarButtonID="EditToolBar"runat="server"Icon="ApplicationFormE
dit"StandOut="true"
Text="Edit"Enabled="false">
<Listeners>
<ClickHandler="#{editWindow}.show();"/>
</Listeners>
<ToolTips>
<ext:ToolTipID="ToolTip2"runat="server"Html="Update Selected Train"/>
</ToolTips>
</ext:ToolbarButton>
<ext:ToolbarSeparatorID="ToolbarSeparator2"runat="server"/>
<ext:ToolbarButtonID="DeleteToolBar"runat="server"Icon="Delete"StandOu
t="true"
Text="Delete"Enabled="false">
<ToolTips>
<ext:ToolTipID="ToolTip3"runat="server"Html="Delete Selected Train"/>
</ToolTips>
<Listeners>
<ClickHandler="CyberMDP.DoConfirm()"/>
</Listeners>
</ext:ToolbarButton>
</Items>
</ext:Toolbar>
<ext:GridPanelID="GridPanel1"runat="server"Title="Trains"Frame="true"S
tripeRows="True"
StoreID="storeTrains"AutoHeight="true"Width="960"TrackMouseOver="true"
>
<LoadMaskShowMask="true"/>
```

```
<ColumnModelID="ColumnModel1"runat="server">
<Columns>
<ext:RowNumbererColumnWidth="30"/>
<ext:ColumnDataIndex="TrainCode"Header="Train Code"Width="160"/>
<ext:ColumnDataIndex="Capacity"Header="Capacity"Width="160"/>
<ext:ColumnDataIndex="Speed"Header="Average Speed"Width="150"/>
<ext:ColumnDataIndex="RegisteredDate"Header="Registered
Date"Width="180">
<RendererFn="Ext.util.Format.dateRenderer('d/m/Y')"/>
</ext:Column>
<ext:ColumnDataIndex="Route"Header="Route"Width="180"/>
<ext:CheckColumnDataIndex="Active"Header="Active"Width="100"/>
</Columns>
</ColumnModel>
<View>
<ext:GridViewID="GridView1"runat="server"EnableRowBody="true">
</ext:GridView>
</View>
<SelectionModel>
<ext:RowSelectionModelID="RowSelectionModel1"runat="server"SingleSelec
t="true">
<Listeners>
<%--<RowSelect
Handler="#{FormPanel2}.getForm().loadRecord(record);#{EditToolBar}.ena
ble();#{DeleteToolBar}.enable();" />--%>
</Listeners>
</ext:RowSelectionModel>
</SelectionModel>
<BottomBar>
<ext:PagingToolbarID="PagingToolBar1"runat="server"StoreID="storeTrain
s"
PageSize="10"DisplayInfo="true"DisplayMsg="Displaying Trains {0} - {1}
of {2}"/>
</BottomBar>
</ext:GridPanel>
<ext:WindowID="newWindow"runat="server"Collapsible="false"Icon="Applic
ation"
Title="Register New
Train"ShowOnLoad="false"AutoHeight="true"AutoScroll="true"
BodyStyle="padding:6px;"PageX="20"PageY="100"Width="400"ButtonAlign="R
ight"
Resizable="false">
<Body>
<ext:FormPanelID="FormPanel1"runat="server"BodyStyle="padding:5px;"But
tonAlign="Right"
Frame="true"AutoHeight="true"Title=""AutoWidth="true">
```

```
<Body>
<ext:FormLayoutID="FormLayout2"runat="server">
<ext:AnchorHorizontal="100%">
<ext:TextFieldID="txtTrainCode"runat="server"FieldLabel="Train
Code"AllowBlank="false"
BlankText="Train Code is required.">
</ext:TextField>
</ext:Anchor>
<ext:Anchor>
<ext:ComboBoxID="ddlRoutes"runat="server"StoreID="storeRoutes"FieldLab
el="Route"
TypeAhead="true"Mode="Local"ForceSelection="true"TriggerAction="All"Di
splayField="RouteName"
Width="150"ValueField="Id"EmptyText="--Select Route--">
</ext:ComboBox>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:NumberFieldID="txtCapacity"MinValue="1"AllowDecimals="False"runat
="server"FieldLabel="Capacity"AllowBlank="false"
BlankText="Capacity is required.">
</ext:NumberField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:NumberFieldID="txtSpeed"runat="server"MinValue="1"AllowDecimals="
False"FieldLabel="Speed(km/h)"AllowBlank="false"
BlankText="Speed is required.">
</ext:NumberField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:DateFieldID="txtRegisteredDate"runat="server"FieldLabel="Register
ed Date"AllowBlank="false"
BlankText="Registered Date is required.">
</ext:DateField>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:TextAreaID="txtRemark"runat="server"FieldLabel="Remarks">
</ext:TextArea>
</ext:Anchor>
<ext:AnchorHorizontal="100%">
<ext:CheckboxID="txtActive"runat="server"FieldLabel="Active">
</ext:Checkbox>
</ext:Anchor>
</ext:FormLayout>
</Body>
</ext:FormPanel>
</Body>
```

```
<Buttons>
<ext:ButtonID="btnTrainSave"runat="server"Text="Save"Icon="Disk">
<AjaxEvents>
<ClickOnEvent="btnTrainSave_Click"Success="Ext.Msg.alert('Train
Scheduling System', 'Train is Successfully
Saved!!');#{GridPanel1}.reload();">
</Click>
</AjaxEvents>
<Listeners>
<ClickHandler="#{newWindow}.hide();"/>
</Listeners>
</ext:Button>
<ext:ButtonID="btnCancel"runat="server"Text="Cancel"Icon="Cancel">
<Listeners>
<ClickHandler="#{newWindow}.hide();"/>
</Listeners>
</ext:Button>
</Buttons>
</ext:Window>
</asp:Content>
```

Webpage design using HTML and ASP.net controller languages for Contact address

```
PageTitle="Contact"Language="C#"MasterPageFile="~/Site.Master"AutoEven
tWireup="true"CodeBehind="Contact.aspx.cs"Inherits="TrainScheduler.Con
tact"%>

<asp:Contentrunat="server"ID="BodyContent"ContentPlaceHolderID="MainCo
ntent">
<hgroupclass="title">
<h1><%: Title %></h1>
<h2>Address</h2>
</hgroup>

<sectionclass="contact">
<header>
<h3>Name: G/Aftse G/Michael</h3>
</header>
<p>
<spanclass="label">Mobile Phone: +251923412178/+251913775906</span>
<span>.</span>
</p>

</section>
```

```
<sectionclass="contact">
<p>
<spanclass="label">Email: g_square1@yahoo.com/
gebrisherc@gmail.com</span>
<span>.</span>
</p>

</section>

<sectionclass="contact">
<header>
<h3>Address:</h3>
</header>
<p>
            Addis Ababa,<br/>
            Ethiopia
</p>
</section>
</asp:Content>
```

APPENDEX C:

Full train scheduling code using C# programming language:

```
using System;
usingSystem.Collections.Generic;
usingSystem.ComponentModel.DataAnnotations;
usingSystem.Linq;
usingSystem.Text;
usingSystem.Threading.Tasks;

namespaceTrainScheduler.Business
{
publicclassSchedule
    {
Business.Train _train = newTrain();
Business.Station _station = newStation();
Business.Setting _setting = newSetting();
privatestringtrainCode = string.Empty;
privatestringstationName = string.Empty;
privateTimeSpanfromTime;
privateTimeSpantoTime;
privatestring way = string.Empty;
privateintstartTimeInterval;
privatestaticTimeSpanstartTime;

public Schedule()
        {
StationId = 0;
        }

publicintStationId { get; set; }

publicstringStationName
        {
get { returnstationName; }
set { stationName = value; }
        }

publicTimeSpanArrivalTime
        {
get { returnfromTime; }
set { fromTime = value; }
        }

publicTimeSpanDepartureTime
        {
```

```
get { returntoTime; }
set { toTime = value; }
        }

publicstringTodayDate { get; set; }

publicstringTrainCode
        {
get { returntrainCode; }
set { trainCode = value; }
        }

publicstring Way
        {
get { return way; }
set { way = value; }
        }

publicList<Schedule>GetTodaySchedulesForAStation(intstationId, string route)
        {
List<Schedule>allSchedules = GetTodaySchedules();
TimeSpancurrentTime = DateTime.Now.TimeOfDay;
var selected = from p inallSchedules
wherep.StationId.Equals(stationId) &&p.Way.Equals(route) &&p.ArrivalTime>currentTime
select p;
returnnewList<Schedule>(selected.ToList().OrderBy(p =>p.ArrivalTime));
        }

publicList<Schedule>GetTodaySchedules()
        {
List<Schedule> schedules = newList<Schedule>();
//Get All Active Trains
varallTrains = _train.GetAllActiveTrains();

TimeSpanendTime = _setting.GetAllSettings().First().EndTime;

//Iterate through all Trains
for (int index = 0; index <allTrains.Count; index++)
            {
if (index == 0)
                {
//set starting time interval for the first train
startTimeInterval = 0;
                }
else
                {
```

```
//set the starting time interval for the rest of the trains
startTimeInterval += int.Parse(_setting.GetAllSettings().First().StartTimeInterval);
                }
//set the starting time of the train at a station
startTime =
_setting.GetAllSettings().First().StartTime.Add(newTimeSpan(0,startTimeInterval,0));
//do the scheduling until the end time is reached
while (endTime.Hours>startTime.Hours)
                {

//get all stations at the selected route
varallStations =
                        _station.GetAllStationsByRoute(allTrains[index].RouteId)
                            .OrderBy(p =>p.OrderFromStart)
                            .ToList();
//iterate through all the stations
for (intindexStation = 0; indexStation<allStations.Count(); indexStation++)
                    {
//set the Arrival time of the train at the first station
if (indexStation == 0)
                        {

startTime =
startTime.Add(newTimeSpan(0,
int.Parse(allStations[indexStation].TimeNeed) , 0));
                        }
//set the Arrival time of the train for the rest of the stations
else
                        {
startTime =
schedules[schedules.Count - 1].DepartureTime.Add(newTimeSpan(0,
int.Parse(allStations[indexStation].TimeNeed) , 0));
                        }



varnewSchedule = newSchedule
                        {
TrainCode = allTrains[index].TrainCode,
ArrivalTime = startTime,
StationId = allStations[indexStation].Id,
StationName = allStations[indexStation].StationName,
DepartureTime = startTime.Add(newTimeSpan(0, allStations[indexStation].DwellTime, 0)),
TodayDate = DateTime.Now.ToShortDateString(),
                            Way = "Front"
                        };
```

```
schedules.Add(newSchedule);

                        }


//get all stations for the return route
varallStationsBack =
                            _station.GetAllStationsByRoute(allTrains[index].RouteId)
                                .OrderByDescending(p =>p.OrderFromStart)
                                .ToList();
//Iterate through all the stations
for (intindexBack = 0; indexBack<allStationsBack.Count; indexBack++)
                        {

if (indexBack == 0)
                            {
startTime = startTime.Add(newTimeSpan(0, startTimeInterval, 0));
                            }
else
                            {
startTime =
schedules[schedules.Count - 1].DepartureTime.Add(newTimeSpan(0,
int.Parse(allStationsBack[indexBack].TimeNeed) , 0));
                            }

varnewSchedule = newSchedule
                            {
TrainCode = allTrains[index].TrainCode,
ArrivalTime = startTime,
StationId = allStationsBack[indexBack].Id,
StationName = allStationsBack[indexBack].StationName,
DepartureTime = startTime.Add(newTimeSpan(0, allStationsBack[indexBack].DwellTime, 0)),
TodayDate = DateTime.Now.ToShortDateString(),
                                Way = "Back"
                            };

schedules.Add(newSchedule);
                        }

                    }

                }
```

```
return schedules;
        }
    }
}
```

Function/Class for Setting:

```
using System;
usingSystem.Collections.Generic;
usingSystem.Linq;
usingSystem.Text;
usingSystem.Threading.Tasks;
usingTrainScheduler.DataAccess;

namespaceTrainScheduler.Business
{
publicclassSetting
    {
TrainSchedulerDataContext _context = newTrainSchedulerDataContext();
publicvoidSaveSetting(DataAccess.Setting setting)
        {
            _context.Settings.InsertOnSubmit(setting);
            _context.SubmitChanges();
        }

publicList<DataAccess.Setting>GetAllSettings()
        {
var selected = from p in _context.Settings
select p;
returnselected.ToList();
        }
    }
}
```

Function/Class for Route:

```
using System;
usingSystem.Collections.Generic;
usingSystem.Linq;
usingSystem.Text;
usingSystem.Threading.Tasks;
usingTrainScheduler.DataAccess;

namespaceTrainScheduler.Business
{
publicclassRoute
    {
```

```
TrainSchedulerDataContext _context = newTrainSchedulerDataContext();

publicvoidSaveRoute(DataAccess.Route route)
        {
            _context.Routes.InsertOnSubmit(route);
            _context.SubmitChanges();
        }

publicList<DataAccess.Route>GetAllRoutes()
        {
var selected = from p in _context.Routes
select p;
returnselected.ToList();
        }
    }
}
```

Function/Class for Station:

```
using System;
usingSystem.Collections.Generic;
usingSystem.Linq;
usingSystem.Text;
usingSystem.Threading.Tasks;
usingTrainScheduler.DataAccess;

namespaceTrainScheduler.Business
{
publicclassStation
    {
TrainSchedulerDataContext _context = newTrainSchedulerDataContext();
publicvoidSaveStation(DataAccess.Station station)
        {
            _context.Stations.InsertOnSubmit(station);
            _context.SubmitChanges();
        }

publicList<DataAccess.vwRouteStation>GetAllStations()
        {
var selected = from p in _context.vwRouteStations
select p;
returnselected.ToList();
        }

publicList<DataAccess.vwRouteStation>GetAllStationsByRoute(introuteId)
        {
var selected = from p in _context.vwRouteStations
```

```
wherep.RouteId.Equals(routeId)
select p;
returnselected.ToList();
        }

    }
}
```

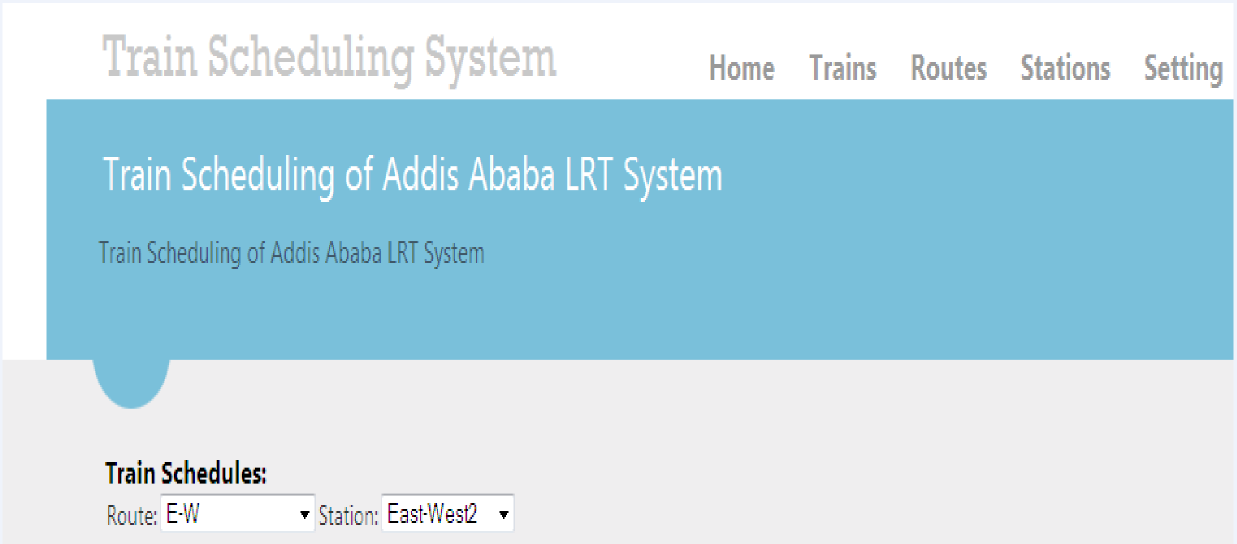
Function /Class for Train**:**

```
using System;
usingSystem.Collections.Generic;
usingSystem.Linq;
usingSystem.Text;
usingSystem.Threading.Tasks;
usingTrainScheduler.DataAccess;

namespaceTrainScheduler.Business
{
publicclassTrain
    {
TrainSchedulerDataContext _context = newTrainSchedulerDataContext();
Business.Setting _setting = newSetting();

publicvoidSaveTrain(DataAccess.Train train)
        {
            _context.Trains.InsertOnSubmit(train);
            _context.SubmitChanges();
        }

publicList<DataAccess.vwTrainRoute>GetAllTrains()
        {
var selected = from p in _context.vwTrainRoutes
select p;
returnselected.ToList();
        }

publicList<DataAccess.vwTrainRoute>GetAllActiveTrains()
        {
TimeSpanpeakHourMorFrom = _setting.GetAllSettings().First().MorningPeakFrom;
TimeSpanpeakHourMorTo = _setting.GetAllSettings().First().MorningPeakTo;
TimeSpanpeakHourEveFrom = _setting.GetAllSettings().First().EveningPeakFrom;
TimeSpanpeakHourEveTo = _setting.GetAllSettings().First().EveningPeakTo;
boolisPeakHour = false;
TimeSpancurrentTime = DateTime.Now.TimeOfDay;
```

```
if ((peakHourMorFrom<= currentTime&&currentTime<= peakHourMorTo) ||
(peakHourEveFrom<= currentTime&&currentTime<= peakHourEveTo))
            {
isPeakHour = true;
            }
var selected = from p in _context.vwTrainRoutes
wherep.Active.Equals(true)
select p;
if (isPeakHour)
returnselected.ToList();
if (selected.Count() <=40)
returnselected.ToList();
//To do some logic here
returnselected.ToList();
        }

publicintGetTrainSpeed()
        {
var selected = from p in _context.Settings
select p;
returnConvert.ToInt32(selected.First().TrainSpeed);
        }
    }
}
```

APPENDEX D:

Sample schedule at station E-W2 of East-West route



The Next Train Will Arrive in 32 Minutes

Train Code	Arrival Time	Departure Time
T03	17:07	17:08
T04	17:42	17:43
T05	18:17	18:18
T01	18:40	18:41
T02	19:22	19:23
T03	20:04	20:05
T04	20:46	20:47
T01	21:23	21:24
T05	21:28	21:29
T02	22:12	22:13
T03	23:01	23:02
T01	00:06	00:07
T05	00:39	00:40
T02	01:02	01:03
T03	01:58	01:59
T01	02:49	02:50

T05	03:50	03:51
T02	03:52	03:53
T03	04:55	04:56
T01	05:32	05:33
T02	06:42	06:43
T05	07:01	07:02
T03	07:52	07:53
T01	08:15	08:16
T02	09:32	09:33
T05	10:12	10:13
T03	10:49	10:50
T01	10:58	10:59
T02	12:22	12:23
T05	13:23	13:24
T01	13:41	13:42
T03	13:46	13:47
T02	15:12	15:13
T01	16:24	16:25
T05	16:34	16:35
T03	16:43	16:44
T02	18:02	18:03
T01	19:07	19:08
T03	19:40	19:41
T05	19:45	19:46
T02	20:52	20:53
T01	21:50	21:51
T03	22:37	22:38
T05	22:56	22:57
T01	00:33	00:34
T03	01:34	01:35
T05	02:07	02:08
T01	03:16	03:17

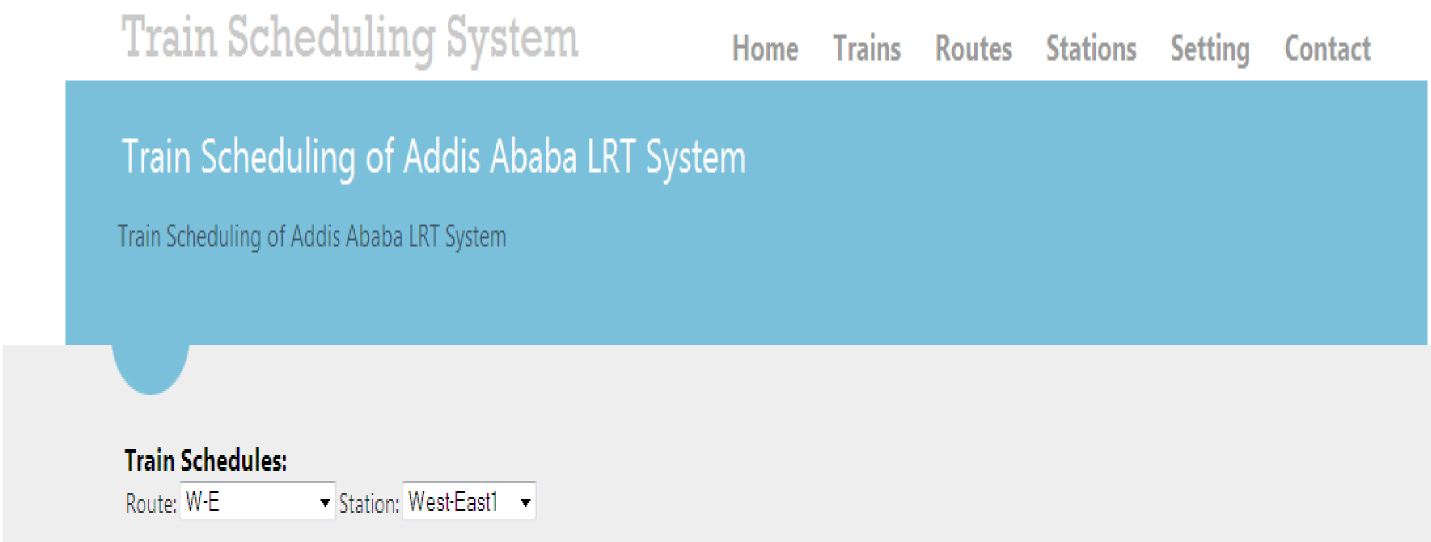
T03	04:31	04:32
T05	05:18	05:19
T01	05:59	06:00
T03	07:28	07:29
T05	08:29	08:30
T01	08:42	08:43
T03	10:25	10:26
T01	11:25	11:26
T05	11:40	11:41
T03	13:22	13:23
T01	14:08	14:09
T05	14:51	14:52
T03	16:19	16:20
T01	16:51	16:52
T05	18:02	18:03
T03	19:16	19:17
T01	19:34	19:35
T05	21:13	21:14
T03	22:13	22:14
T01	22:17	22:18
T05	00:24	00:25
T01	01:00	01:01
T03	01:10	01:11
T05	03:35	03:36
T01	03:43	03:44
T03	04:07	04:08
T01	06:26	06:27
T05	06:46	06:47
T03	07:04	07:05
T01	09:09	09:10
T05	09:57	09:58
T03	10:01	10:02

T01	11:52	11:53
T03	12:58	12:59
T05	13:08	13:09
T01	14:35	14:36
T03	15:55	15:56
T05	16:19	16:20
T01	17:18	17:19
T03	18:52	18:53
T05	19:30	19:31
T01	20:01	20:02
T03	21:49	21:50
T05	22:41	22:42
T01	22:44	22:45
T03	00:46	00:47
T01	01:27	01:28
T05	01:52	01:53
T03	03:43	03:44
T01	04:10	04:11
T05	05:03	05:04
T03	06:40	06:41
T01	06:53	06:54
T05	08:14	08:15
T01	09:36	09:37
T03	09:37	09:38
T05	11:25	11:26
T01	12:19	12:20
T03	12:34	12:35
T05	14:36	14:37
T01	15:02	15:03
T03	15:31	15:32
T01	17:45	17:46
T05	17:47	17:48

T03	18:28	18:29
T01	20:28	20:29
T05	20:58	20:59
T03	21:25	21:26
T05	00:09	00:10
T03	00:22	00:23
T03	03:19	03:20
T05	03:20	03:21
T03	06:16	06:17
T05	06:31	06:32
T03	09:13	09:14
T05	09:42	09:43
T03	12:10	12:11
T05	12:53	12:54
T03	15:07	15:08
T05	16:04	16:05
T03	18:04	18:05
T05	19:15	19:16
T03	21:01	21:02
T05	22:26	22:27
T05	01:37	01:38
T05	04:48	04:49
T05	07:59	08:00
T05	11:10	11:11
T05	14:21	14:22
T05	17:32	17:33
T05	20:43	20:44

APPENDEX E:

Sample schedule at station W-E1 of West-East route



The Next Train Will Arrive in 10 Minutes

Train Code	Arrival Time	Departure Time
T09	16:50	16:51
T010	17:18	17:19
T06	18:43	18:44
T07	19:18	19:19
T08	19:53	19:54
T09	20:28	20:29
T010	21:03	21:04
T06	22:00	22:01
T07	22:42	22:43
T08	23:24	23:25
T09	00:06	00:07
T010	00:48	00:49
T06	01:17	01:18
T07	02:06	02:07
T09	03:44	03:45
T010	04:33	04:34

T06	04:34	04:35
T07	05:30	05:31
T09	07:22	07:23
T06	07:51	07:52
T010	08:18	08:19
T07	08:54	08:55
T09	11:00	11:01
T06	11:08	11:09
T010	12:03	12:04
T07	12:18	12:19
T06	14:25	14:26
T09	14:38	14:39
T07	15:42	15:43
T010	15:48	15:49
T06	17:42	17:43
T09	18:16	18:17
T07	19:06	19:07
T010	19:33	19:34
T06	20:59	21:00
T09	21:54	21:55
T07	22:30	22:31
T010	23:18	23:19
T06	00:16	00:17
T09	01:32	01:33
T07	01:54	01:55
T06	03:33	03:34
T09	05:10	05:11
T07	05:18	05:19
T06	06:50	06:51
T07	08:42	08:43
T09	08:48	08:49
T06	10:07	10:08

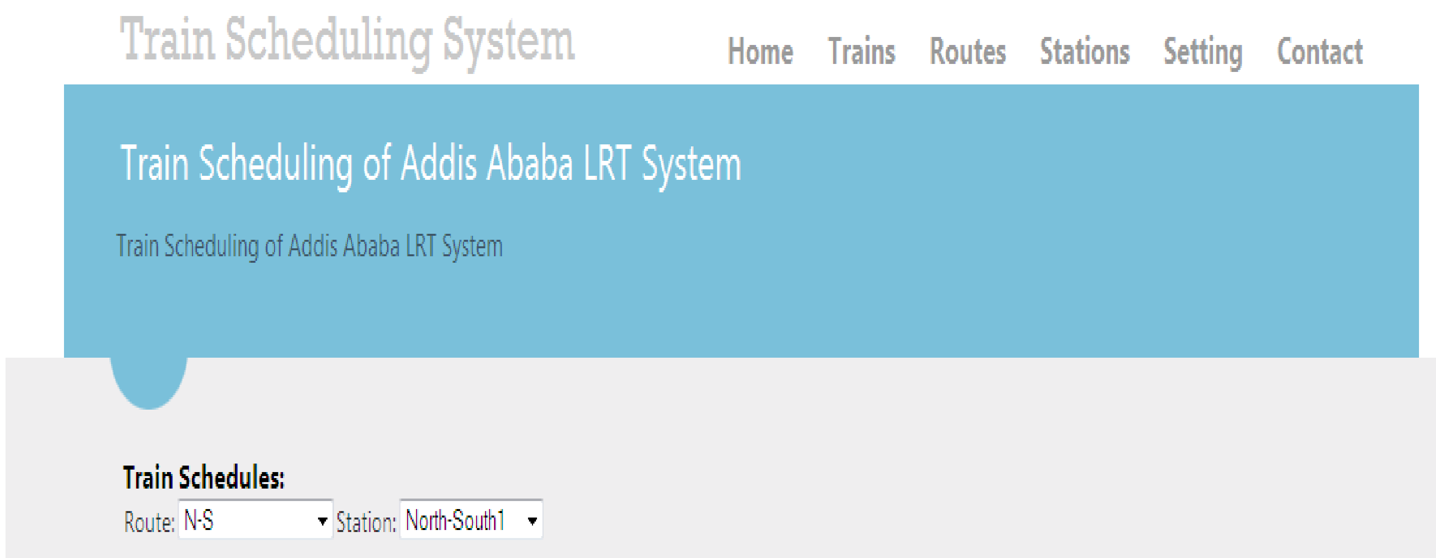
T07	12:06	12:07
T09	12:26	12:27
T06	13:24	13:25
T07	15:30	15:31
T09	16:04	16:05
T06	16:41	16:42
T07	18:54	18:55
T09	19:42	19:43
T06	19:58	19:59
T07	22:18	22:19
T06	23:15	23:16
T09	23:20	23:21
T07	01:42	01:43
T07	05:06	05:07
T07	08:30	08:31
T07	11:54	11:55
T07	15:18	15:19
T07	18:42	18:43
T07	22:06	22:07
T07	01:30	01:31
T07	04:54	04:55
T07	08:18	08:19
T07	11:42	11:43
T07	15:06	15:07
T07	18:30	18:31
T07	21:54	21:55
T07	01:18	01:19
T07	04:42	04:43
T07	08:06	08:07
T07	11:30	11:31
T07	14:54	14:55
T07	18:18	18:19

T07	21:42	21:43
T07	01:06	01:07
T07	04:30	04:31
T07	07:54	07:55
T07	11:18	11:19
T07	14:42	14:43
T07	18:06	18:07
T07	21:30	21:31
T07	00:54	00:55
T07	04:18	04:19
T07	07:42	07:43
T07	11:06	11:07
T07	14:30	14:31
T07	17:54	17:55
T07	21:18	21:19
T07	00:42	00:43
T07	04:06	04:07
T07	07:30	07:31
T07	10:54	10:55
T07	14:18	14:19
T07	17:42	17:43
T07	21:06	21:07
T07	00:30	00:31
T07	03:54	03:55
T07	07:18	07:19
T07	10:42	10:43
T07	14:06	14:07
T07	17:30	17:31
T07	20:54	20:55
T07	00:18	00:19
T07	03:42	03:43
T07	07:06	07:07

T07	10:30	10:31
T07	13:54	13:55
T07	17:18	17:19
T07	20:42	20:43
T07	00:06	00:07
T07	03:30	03:31
T07	06:54	06:55
T07	10:18	10:19
T07	13:42	13:43
T07	17:06	17:07
T07	20:30	20:31
T07	23:54	23:55

APPENDIX F:

Sample schedule at station N-S1 of North -South route



The Next Train Will Arrive in 36 Minutes

Train Code	Arrival Time	Departure Time
T011	17:19	17:20
T012	17:47	17:48
T013	18:15	18:16
T014	18:43	18:44
T015	19:11	19:12
T011	21:02	21:03
T012	21:37	21:38
T013	22:12	22:13
T014	22:47	22:48
T015	23:22	23:23
T011	00:45	00:46
T012	01:27	01:28
T013	02:09	02:10
T014	02:51	02:52
T011	04:28	04:29
T012	05:17	05:18

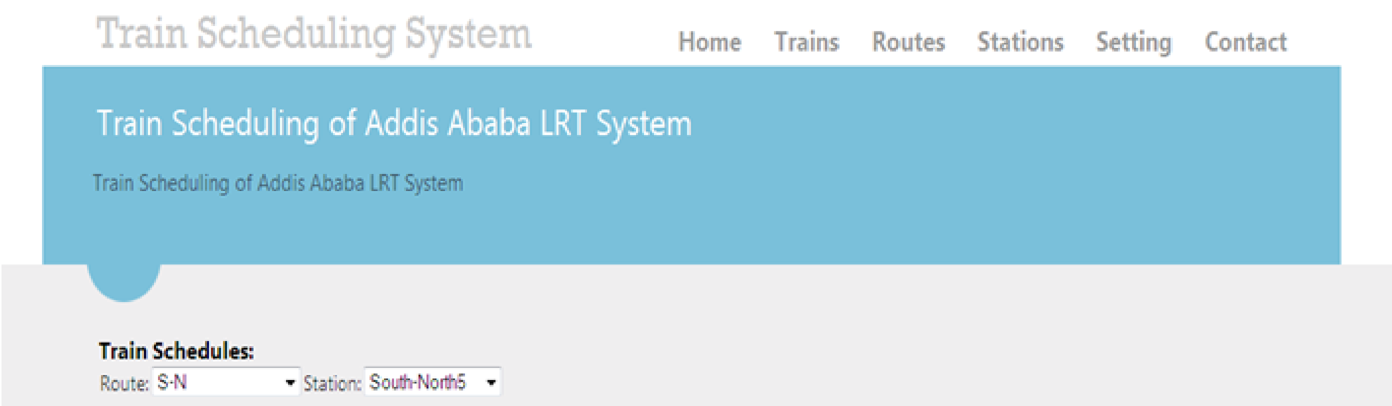
T013	06:06	06:07
T014	06:55	06:56
T011	08:11	08:12
T012	09:07	09:08
T013	10:03	10:04
T014	10:59	11:00
T011	11:54	11:55
T012	12:57	12:58
T013	14:00	14:01
T014	15:03	15:04
T011	15:37	15:38
T012	16:47	16:48
T013	17:57	17:58
T014	19:07	19:08
T011	19:20	19:21
T012	20:37	20:38
T013	21:54	21:55
T011	23:03	23:04
T014	23:11	23:12
T012	00:27	00:28
T013	01:51	01:52
T012	04:17	04:18
T013	05:48	05:49
T012	08:07	08:08
T013	09:45	09:46
T012	11:57	11:58
T013	13:42	13:43
T012	15:47	15:48
T013	17:39	17:40
T012	19:37	19:38
T013	21:36	21:37
T012	23:27	23:28

T013	01:33	01:34
T013	05:30	05:31
T013	09:27	09:28
T013	13:24	13:25
T013	17:21	17:22
T013	21:18	21:19
T013	01:15	01:16
T013	05:12	05:13
T013	09:09	09:10
T013	13:06	13:07
T013	17:03	17:04
T013	21:00	21:01
T013	00:57	00:58
T013	04:54	04:55
T013	08:51	08:52
T013	12:48	12:49
T013	16:45	16:46
T013	20:42	20:43
T013	00:39	00:40
T013	04:36	04:37
T013	08:33	08:34
T013	12:30	12:31
T013	16:27	16:28
T013	20:24	20:25
T013	00:21	00:22
T013	04:18	04:19
T013	08:15	08:16
T013	12:12	12:13
T013	16:09	16:10
T013	20:06	20:07
T013	00:03	00:04
T013	04:00	04:01

T013	07:57	07:58
T013	11:54	11:55
T013	15:51	15:52
T013	19:48	19:49
T013	23:45	23:46

APPENDIX G:

Sample schedule at station S-N5 of South-North route



The Next Train Will Arrive in 35 Minutes

Train Code	Arrival Time	Departure Time
T016	19:23	19:24
T017	19:51	19:52
T018	20:19	20:20
T019	20:47	20:48
T020	21:15	21:16
T016	23:41	23:42
T017	00:16	00:17
T018	00:51	00:52
T019	01:26	01:27
T020	02:01	02:02
T017	04:41	04:42
T018	05:23	05:24
T019	06:05	06:06
T020	06:47	06:48
T017	09:06	09:07
T018	09:55	09:56
T019	10:44	10:45
T020	11:33	11:34
T017	13:31	13:32

T018	14:27	14:28
T019	15:23	15:24
T020	16:19	16:20
T017	17:56	17:57
T018	18:59	19:00
T019	20:02	20:03
T020	21:05	21:06
T017	22:21	22:22
T018	23:31	23:32
T019	00:41	00:42
T020	01:51	01:52
T017	02:46	02:47
T019	05:20	05:21
T020	06:37	06:38
T017	07:11	07:12
T019	09:59	10:00
T020	11:23	11:24
T017	11:36	11:37
T019	14:38	14:39
T017	16:01	16:02
T020	16:09	16:10
T019	19:17	19:18
T017	20:26	20:27
T020	20:55	20:56
T019	23:56	23:57
T017	00:51	00:52
T020	01:41	01:42
T019	04:35	04:36
T017	05:16	05:17
T020	06:27	06:28
T019	09:14	09:15
T017	09:41	09:42

T020	11:13	11:14
T019	13:53	13:54
T017	14:06	14:07
T020	15:59	16:00
T017	18:31	18:32
T019	18:32	18:33
T020	20:45	20:46
T017	22:56	22:57
T019	23:11	23:12
T020	01:31	01:32
T020	06:17	06:18
T020	11:03	11:04
T020	15:49	15:50
T020	20:35	20:36
T020	01:21	01:22
T020	06:07	06:08
T020	10:53	10:54
T020	15:39	15:40
T020	20:25	20:26
T020	01:11	01:12
T020	05:57	05:58
T020	10:43	10:44
T020	15:29	15:30
T020	20:15	20:16
T020	01:01	01:02
T020	05:47	05:48
T020	10:33	10:34
T020	15:19	15:20
T020	20:05	20:06
T020	00:51	00:52
T020	05:37	05:38
T020	10:23	10:24

T020	15:09	15:10
T020	19:55	19:56
T020	00:41	00:42
T020	05:27	05:28
T020	10:13	10:14
T020	14:59	15:00
T020	19:45	19:46
T020	00:31	00:32
T020	05:17	05:18
T020	10:03	10:04
T020	14:49	14:50
T020	19:35	19:36
T020	00:21	00:22
T020	05:07	05:08
T020	09:53	09:54
T020	14:39	14:40
T020	19:25	19:26
T020	00:11	00:12
T020	04:57	04:58
T020	09:43	09:44
T020	14:29	14:30
T020	19:15	19:16
T020	00:01	00:02
T020	04:47	04:48
T020	09:33	09:34
T020	14:19	14:20
T020	19:05	19:06
T020	23:51	23:52
T020	04:37	04:38
T020	09:23	09:24
T020	14:09	14:10
T020	18:55	18:56