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MODELLING AND SIMULATING TRAIN SCHEDULE SYSTEM: CASE OF RIFT VALLEY RAILWAYS

BY

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Declaration

This Research is my own work carried out at the University of Nairobi in the Academic Year 2012/2013 and has not been presented for award for any other degree.

Signature……………………………………

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Abbreviations

RVR	Rift Valley Railways
OCC	Operation Control Centre
FOFI	First Out first in (If train priorities are the same First Train to get out of a station is the one that First got In)
DSS	Decision Support System
GPS	Geographical Positioning System
GIS	Geographical Information System
SPSS	Statistical Package for Social Sciences
KPI	Key Performance Indicator

Definition of terms

System	Collection of entities or set of related entities sometimes called components or elements. This has variables necessary to describe the system at a particular time.
Meetpoint	Location where two trains may cross or pass each other.
Track Segment	Part of a railway line that is bounded by two distinct end points, in this case the meetpoints
Block Section	Section of the railway line delimited by signals
Running lines	Active Railway lines.
Siding	Customer service line
Train Conflict	When two trains approach each other on a single line track travelling in opposite directions

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ABSTRACT

The use of ICT systems as a business enabler has introduced strong business competitiveness worldwide. Survival of businesses from small scale to high scale increasingly depends on implementation and usage of relevant business ICT systems to survive. Most firms that are still manual or semi-automated in carrying out their business processes have lost competence, relevance and no matter how strategic the business is with relevance to economic growth of a country, they have lost business leadership opportunities.

The main aim of this research was to develop and simulate a train scheduling system by implementing algorithms that use prioritization factors to achieve a schedule that reflects business requirements and ensure safe train crossing. This was achieved by developing conceptual and system models based on requirements obtained from studying the existing processes and systems at Rift Valley Railways in Kenya. The developed system is capable of capturing the lengths of trains in a particular schedule, and gives priority to longer trains to pass while shorter ones wait at a station during crossing. The system also gives priority to passenger trains over cargo trains. Long distance passenger trains get top priority followed by commuter train and finally cargo trains. Cargo trains are prioritized in terms of nature of load, categorized as high, medium and low. If 2 trains are of the same type and have the same priority, the system uses First out first in option where the train given priority to pass is the one that arrived the crossing station first while the other waits.

The main conclusions from the research indicate that train scheduling can be done better at RVR through use of technology to achieve safety. Use of technology will also achieve better prioritization with reduced human intervention/decision in train operation. Another conclusion is that formality needs to be introduced in prioritization using heuristic algorithm that has set prioritization factors. Simplicity of system is a key success factor in places like RVR where use of technological tools is limited. Further work is recommended on this research and includes uploading scheduled track maintenance to the system to enable variable section time be taken into consideration by the algorithm. Real time schedule update as actual trains move to enable automatic schedule update with actual train dispatch and receipt as well as on Board train computers to relay messages to train drivers from Control/stations was recommended by users.

CHAPTER ONE

INTRODUCTION

1.0 Background of the Study

There is a growing interest in the Railway sector in the East Africa Region owing to the fact that the Railway is a key factor in reducing the cost of doing business regionally. This is more so for Kenya that largely serves landlocked countries like Uganda, Rwanda, Burundi and the new territory of Sudan. The government realizes that the Railway is one of the enabling factors to improve Kenya's regional business competitiveness. This notwithstanding, major stakeholders also have the surging need to increase the efficiency of Railway transportation.

After independence in the early 1960s, Railway and Port operations in Kenya, Uganda and Tanzania were administered by a single body: the East African Railways and Harbours. The breakup of the East African Community in 1977 marked the beginning of the end for the region's railway system. Each of the three East African countries took up running its own system. In Kenya, railway and port operations were split between two state-owned corporations: Kenya Railways and Kenya Ports Authority. The railway became starved of investment funds and in Kenya, although the railway is the second most important provider of transport services after roads, it is currently in desperate need for investment and modernization. The railway freight throughput has decreased from about 4.8 million tonnes per annum in the early 1980's to the level of 2.3 million tonnes per annum in 2005/6. [Kenya Railways website – June 2012]

However, owing to limited financial resources from the Government, little investment to increase freight throughput, deliver improved quality of service, introduce new and innovative technology and improve the working conditions of its employees was unattainable. In order to improve the performance of the railways, the Government decided to concession Kenya Railways to a private investor for 25 years on Freight business from 1st November, 2006. Under this arrangement, the Government was to continue owning the railway infrastructure and facilities but the concessionaire would operate trains, maintain the infrastructure and pay utility fees to Government. Recognizing the historical links between Kenya Railways and Uganda Railways, who operate a similar gauge track, the mutual dependency of the railways on each other and the potential benefits to be derived by concessioning the railways jointly, in June 2003, the

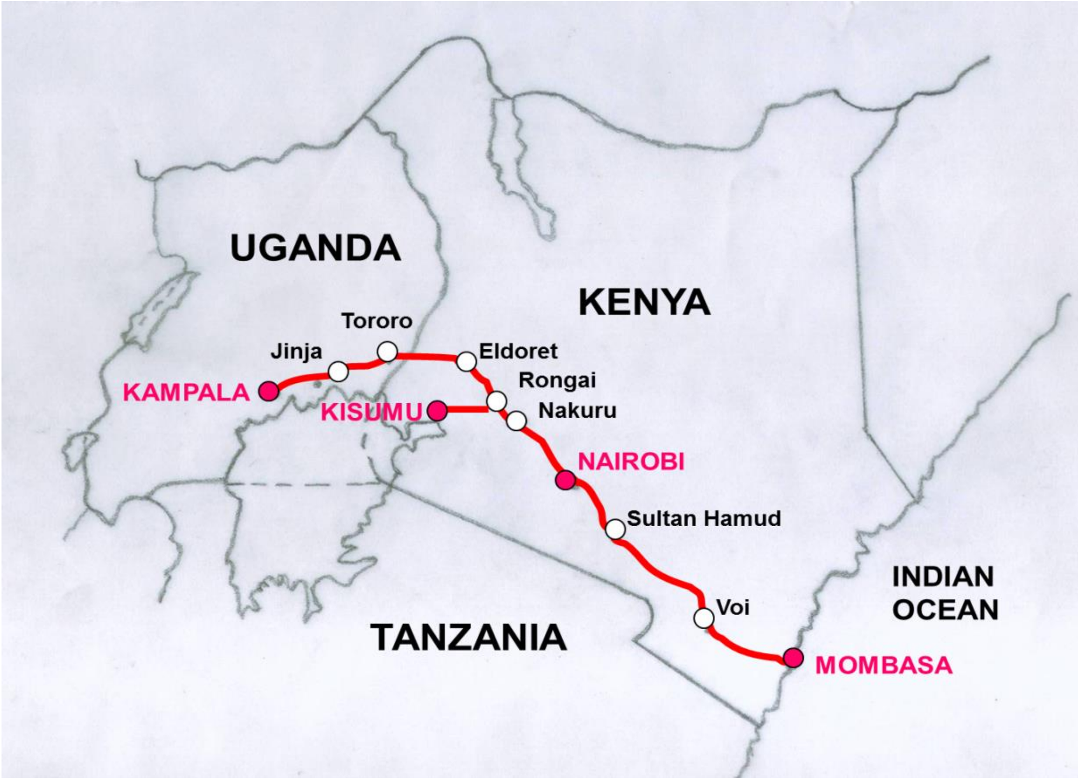
Governments of the two countries made a strategic decision that Kenya Railways (KR) and Uganda Railways (UR) should be concessioned jointly.

Notably however, since concession in 2006, Rift Valley Railways has continued on a downward business trend with the volumes decreasing on an annual basis. The business performance of Rift Valley Railways in the year 2005/2006 was 1,958,138 tonnages with a revenue of USD 62,203,600. In 2006/2007 the tonnages was 1,746,788 with revenue of USD 54,740,418. In 2007/2008 the tonnages was 1,765,700 with revenue of USD 51,861,752. [Kenya Railways, 2006, 2007, 2008]

Currently, Rift Valley Railways holds the sole train operator mandate through a concession license and is therefore responsible for passenger services within Kenya and freight in Kenya and Uganda. At RVR, train scheduling, dispatching, running and reception is currently performed manually by human operators who have adopted elementary tools in their practice and in so doing solve conflicts in very slow rates. RVR has one Operation Control Centre (OCC) centrally placed in Nairobi that does all the trains planning and operations with a regional control centre in Kampala that implements the plans from OCC in the Uganda region as well as report incidents and disruptions to OCC for re-planning. The OCC controls train operation of 1,333km between Mombasa and Kampala, 286km between Nakuru and Butere, 65Km between Leseru and Kitale and 265km between Nairobi and Nanyuki. [Kenya Railways, 1985]. In total this is 1949 km of track most of which is a single track, except at the Railway stations and between Nakuru station and Nakuru junction station, where we have more than one track and trains can run in parallel.

The current RVR railway network is illustrated in figure one (1). The figure shows the mainline without sidings and branch lines described above. This is the main cargo freight corridor for the RVR network.

Figure 1: Main Railway line in Kenya and Uganda



Source : NTTC Conference, 2009

At the OCC, the entire system is divided into 3 segments, each having a control desk manned by a desk controller as detailed below;

1. Mombasa to Mtito Andei
2. Mtito Andei to Nairobi including Nanyuki Branch line
3. Nairobi to Kampala including Kisumu Branch line (upto Butere)

On a weekly basis, the business plan is availed to OCC by Commercial department to plan and avial rolling stock resources. Depending on volume of traffic projected from the business plan, the number of trains (both up and down direction) per day is calulatable. Based on this, up and down trains are manually planned and prioritized through a train plan schedule, bearing in mind where the resources are required. The Train plan schedule has trains that are named depending on origin, destination,day of week, and order of movement to destinantion. Once this is done, the desk controllers must manually plot train movement and make decesions on priority of movement and crossings at stations, based on information received from stations regarding crossings. The manual chart determines reception/ dispatch of trains at stations and yards culmulatively determining train turnround.

While it is reasonable to note that the operation, dispatch/reception of trains in RVR is done manually by human operators using charts, it has a sluggish effect on train operation and turnaround, causing delays and operational inefficiencies. This research shows that by putting in place robust decision support systems (DSS) RVR can effectively manage the train operation, dispatch/reception and schedule operations effectively, where the system can use predefined algorithms to make apt decisions.

Many Railway systems around the world have adopted creation of flexible timetables with forecasting capability which adapt to disruptions of train operations, caused by technical failures or track incidents which affect the ultimate running time, stop over times and the departure times. It is worth noting that cumulatively the primary causes of delays at a given terminal will propagate into progressive terminals for incoming trains thus culminating into unnecessary disruptions for the entire train operation working. This in effect affects turnaround and in the long run freight volumes carried in a specific period. From the above RVR needs to adopt dispatch schedules embedded in manner to avoid unnecessary collisions and delays.

In Sweden the Railway operators have embraced the use of train traffic controllers which has proved to be a great success in monitoring the train movements and by automatic and manual functions controlling the train routes. The manual functions undertaken by train traffic controllers intervene when conflicts or disturbances occur, which is called control by exception [Sandblad, et al,1997]. Further studies have shown that the only feasible way to boost this sector is to improve and optimize available train control standards and processes. This research demonstrates that it is feasible to solve train conflicts optimally or near optimally, in the most realistic amount of time using a model to simulate train operations for RVR network.

1.1 Problem statement

Currently, the rail network at RVR allows for having only one train in any block section or siding. This network is in form of track segments between stations, which make the connection between all the meetpoints. In this context, meetpoints include not just stations, but also any location where two trains may cross simultaneously. This necessitates that trains only meet or overtake at meetpoints, using a manually generated paper line clear, while liaising with the OCC desk controller for that particular section. The controller has a focus on his/her section only with no big picture of the entire network.

This research used simulation techniques to show how scheduling algorithm can be used to improve operational efficiency through an Information System that will be used to address global schedule visibility, while optimizing train paths based on business critical factors.

1.2 Objectives of the study

The key objective of the Research was to use simulation techniques to show how scheduling algorithms can be used to improve operational efficiency at RVR by optimizing the train movement planning process.

Additionally this research sort to achieve the following objectives:

I. Understudy and document existing train movement planning system at RVR in order to identify challenges and opportunities within the system.
II. Develop conceptual and system models for train operation system
III. Simulate the model for train operation system
IV. Recommend optimal train operation system based on existing resources.

1.3 Research questions

The following research questions were generated to study the current system at RVR and also to identify a model to be used to improve train operation at RVR.

I. What is the current scheduling technique used at RVR?
II. What model will help to counter the limitations, assumptions, input in current trains control process and hence determine the optimal train control process?
III. How will the proposed system improve quality of service in the train control process?
IV. How will the proposed system detect and solve schedule conflicts?

1.4 Significance of the study

By implementing automated train movement planning system several stakeholders will benefit as detailed below

a. RVR business and management will gain the following;

    I. Best cycle time of the assets – The best train paths will be used through formal prioritization factors hence getting the best cycle time for each train depending on business requirement.

    II. Reduce scheduling errors currently attributed to manual processes

    III. Increase operational safety and reduce accident risks – Current position of each desk controller handling a section of the rail track and not knowing what the schedules are in other track sections will be eliminated, with a global picture of the days train schedule in place to be followed by each desk controller. The desk controllers will report any deviations to the Chief controller to enable re-scheduling. The system will ensure conflict resolution and hence ensure safety by ensuring that no two trains meet to cause an accident in a single track section.

    IV. Reduce operational costs – Fuel consumption is currently the highest cost factor in RVR business. Increase in fuel consumption by locomotives is attributed to a number of factors including speed and idling at stations awaiting crossings. It has been proved that slowing down of train speed increases the consumption of fuel and thus the stoppage at stations to enable train crossing is a contributing factor to fuel usage increase. The system will ensure optimal paths with no conflict hence enable minimal idling or stoppage at stations to enable crossing. The overtime claim by the train guards will also decrease due to reduced stoppage and better transit times hence less man hours, this will reduce operational costs.

b. RVR staff will have better tools to carry out their day to day functions, this as outlined in (a) above will improve the business and result in better revenue that can be translated to bonuses. These tools will make set KPI's be more realistic to staff as opposed to the past where KPI's were set and tools to enable you meet these KPI's were missing.

c. Kenya Ports Authority – Over the years there has been congestion at the port owing to Railway destined cargo pile up. As pointed out in (a) above the system will reduce the cycle time of the assets and improve cargo off take from the port.
d. Kenya Government - Axle load on roads is 8 tonnes, all containers heavier than this should go by rail but owing to rail inefficiencies this has been going by road hence deteriorating the roads at a high rate. The system will ensure improved business efficiency and thus reduce road usage. This will translate to reduced road maintenance budget in the country. These funds can be channeled to other development projects that will benefit the country.

1.5 Purpose of the study

Currently RVR is using manual systems for trains operations. This study looked at the current train operation system in use at RVR and reviewed an automated trains operation model and how this can improve scheduling of trains hence improve decision making with regards to train operation translating to improved business performance.

1.6 Assumptions of the study

a) The infrastructure and rolling stock are in optimally working condition
b) Each section along the track has pre-defined running time by trains.
c) It is assumed that there are no line blocks along the line
d) GPS is available to track the position of trains this is enhanced by all locomotives having radio installation to enable communication with other locos, stations and OCC.
e) All information for undertaking the project will be readily available.

1.7 Limitations of the study

1. There exists only one line; there currently exists a single track apart from stations where we have multiple lines. Scheduling results with crossings in either direction may only be got for stations only where trains can pass each other.
2. Unforeseen scheduling interruptions caused by natural causes e.g washaways that cause the line to be closed.
3. Unforeseen schedule interruptions caused by loco failures and accidents

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

David Nalo the then Permanent Secretary in the Ministry of Trade and Industry presented a paper titled “Place of ICT in Growth of Business” in September 2007, where he narrated how ICT makes it possible to convert information into business opportunities [David Nalo- 2007]. This is indeed true for the Rail Transport business and a number of systems have been modeled around this fact.

Train scheduling is one of the most challenging and difficult problems in Railway planning. Over the years this has been done manually in Kenya. Many studies have been conducted worldwide, with a view of getting more efficient scheduling methods as illustrated below.

One of the earliest works on optimum solution to the train scheduling challenges was carried out by Morlok and Peterson whose objective was to minimize the sum of fixed costs of trains, variable cost of transportation, handling and storage of freight and opportunity costs of using rail equipment, while providing on-time deliveries of time-sensitive goods [Morlok & Peterson – 1970].

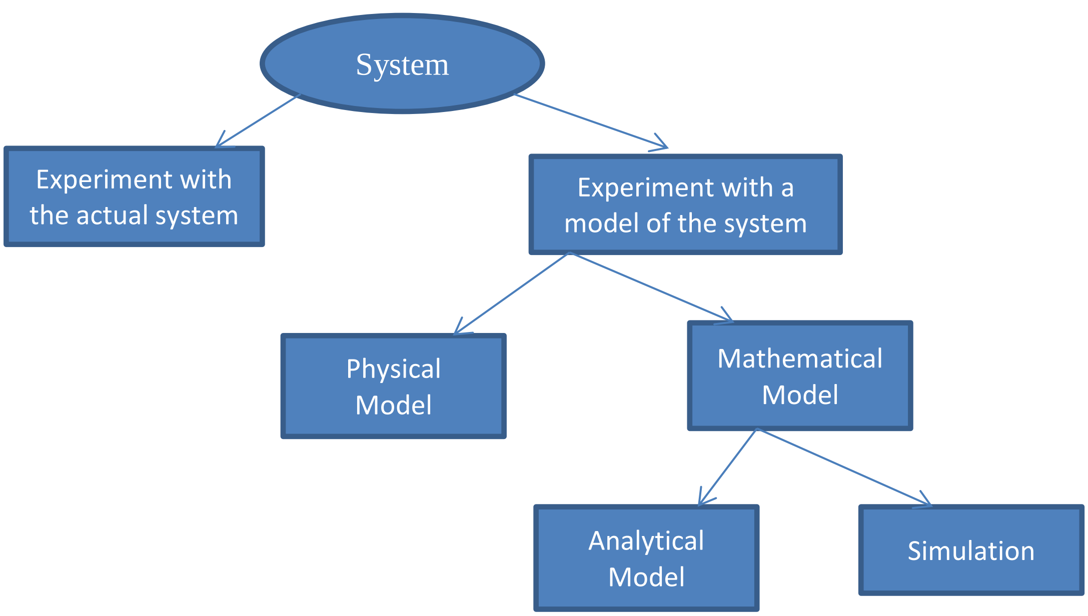
Many models have been developed after Morlok & Peterson model, each taking into consideration different parameters to meet desired outcomes. Jovanovic and Harker in 1991 developed the SCAN-I model to construct timetable and pass plans with the focus on robustness against travel and randomness. They employed a branch-and-bound variant called process-interaction to access whether a timetable is feasible under deterministic assumptions. In 1995 Carey and Lockwood presented a timetabling problem on a single rail line assuming a constant velocity for each train. They constructed the timetable and schedule to minimize total weighted delay subject to maximizing train velocity and siding length. A multi-objective model for passenger train service planning was developed by Chang et al in the year 2000. They determined the optimal allocation of passenger train services on an inter-city high-speed rail line without branches by specifying subset of stations at which the train must stop. While still focusing on passenger trains, Ghoseiri et al in 2004 also developed a multi-objective model for the passenger train scheduling problem on a railroad network with the objective of minimizing fuel consumption cost and total passenger time subject to the train movement continuity constraint and trip time and dwell time constraints [Journal of Eastern Asia].

Models enable prediction concerning the behavior of a system under study. It is an abstraction of some real system that can be used to obtain predictions and formulate control strategies [Reuben Y. Rubinstien et al - 1998].

Computer simulation has long served as an important tool in a wide variety of disciplines. Simulation is a numerical technique for conducting experiments on a digital computer, which involves certain types of mathematical and logical models and describe the behavior of business or economic system (or some component thereof) over extended periods of real time [Naylor et al -1966].

Systems can be studied to try and gain some insight into the relationships among various components, or to predict performance under some new conditions being considered. Systems can be simulated in different ways as illustrated in figure 2 below.

Figure 2: Ways to simulate a system



Source: Simulation Modeling and Analysis - Averill Law (1982)

In most cases it is not possible to alter the system physically and let it operate under new conditions, for this reason, it is usually necessary to build a model as a representation of the system and study it as the surrogate for the actual system. Literature review further reveals that Mathematical model is often used representing a system in terms of logical and quantitative relationships that are then manipulated and changed to see how the model reacts, and thus how the system would react – if the mathematical model is a valid one [Averill – 1982].

Literature review further reveals that mathematical models are examined to see how they can answer the questions of interest about the system it is supposed to represent and if the model is simple enough it may be possible to work with its relationships and quantities to get an exact analytical solution. But some analytical solutions are complex precluding any possibility of an analytical solution and in this case the model is studied by means of simulation- numerically exercising the model for inputs in question to see how they affect the output measures of performance. Given that we have a mathematical model to be studied by means of simulation, hence referred as simulation model, particular tools must be used to achieve this.

The preparation of models is an integral part of the development of a computer simulation. There are many kinds of models: physical, flow-chart, mathematical and computer. In many cases a system may best be modeled by a combination of these types.

Most of the models found in literature present a common structure which is basically the structure of a typical decision support system. A Decision Support System (DSS) can be defined as a computer based interactive system that aids the process of decision making [Averill – 1982]. For trains operation, it can be called a real-time traffic management system with a short time horizon that aids dispatchers to control the train traffic. These systems have three main functions:

- Predict train movements
- Detect expected conflicts
- Propose a solution for the conflicts

However, these dispatching systems are not designed to replace dispatchers but to support them in taking the best possible decisions and executing the same.

Several approaches for re-scheduling railway traffic have been suggested since the early seventies. Still, it was only in the last decade, with the advances in technology, that the most relevant research was conducted. Train dispatching systems can be broadly divided into two categories:

- Fixed-speed models - Fixed-speed models assume that trains travel at their maximum speed whenever possible, and later an acceptable speed profile is determined.
- Variable-speed models - Variable-speed models consider velocity as a variable giving more realism to the model.

2.1 Existing Re-scheduling Models

The following section describes different re-scheduling and management approaches.

2.1.1 Inter-train conflict management

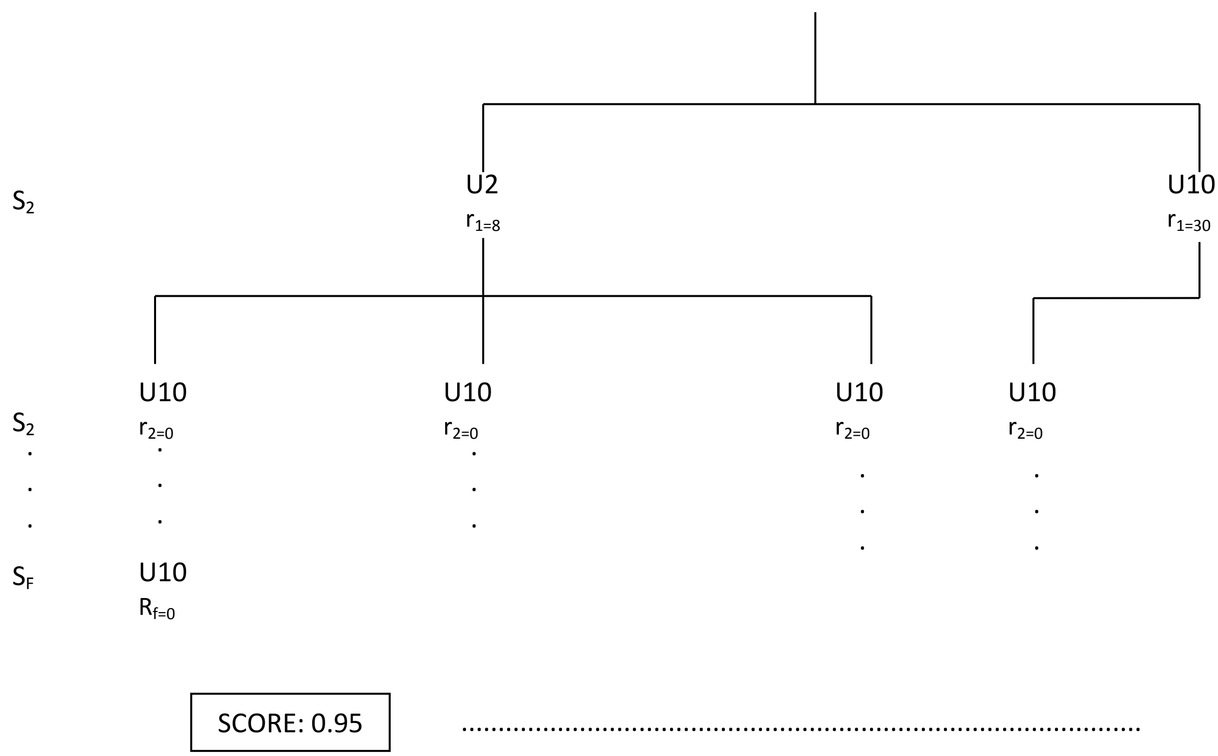
Ismail Sahin developed the Inter-train conflict model which is a fixed-speed model for rescheduling trains on a single-track railway**.** He developed an algorithm with the objective of obtaining better conflict solutions than train dispatchers, and optimal or near optimal solutions in a reasonable amount of time. He considered time horizon of a single day and assumed an initial conflict-free schedule**.** The algorithm he developed compares the scheduled arrival times with the actual arrival times in order to detect deviations from the initial schedule. Then, for set of disturbed trains, a discrete-event simulator verifies if there are any conflicts and which one will be the first to occur. The program then only solves this conflict, not taking into account the other following potential conflicts. It is assumed that there can be only two resolutions for conflict, which is stopping one train or the other, with this in mind the program simulates both alternatives. For each case, the algorithm calculates the expected time of arrival at scheduled points of every train in the problem, taking into consideration their future conflict delays. Based on outcome results, decision is taken choosing the alternative that causes the minimum total delay of the system. The algorithm then proceeds to detect and resolve immediate conflicts, consecutively, one at a time. Sahin obtained good results for computational experiments on small instances with 20 trains and 19 meet points. The optimal solution was found for 13 times over 26 problem instances. While comparing the heuristic algorithm with the dispatchers' solution, the savings in the total waiting times is 2.5 min per train. [Sahin – 1999]

This research has borrowed from Sahin in considering a day's horizon in scheduling; however his model only considered time as the priority factor, by looking at projected versus actual arrival times.

2.1.2 On-line timetable re-scheduling

In 1999 Adenso et al proposed a fixed-speed model for solving real-time timetable changes on a regional network. They did a research based on historical data that looked at possible incidents and their average duration. This research was modeled to be able to foresee the influence that an incident may have on timetables. The model used is a MIP (mixed integer program) where the objective function, to be maximized, is the number of passengers transported. As expected, this problem is very complex, with several constraints, hence a backtracking method is used to explore the solution space. The quality of each solution is calculated considering the number of passengers transported, the delays and the priority of each service.

Figure 3 An example of the backtracking tree in the process of exploring the solution space



SOURCE: Adenso-Diaz 1999

Each level of the tree represents a service S and nodes on any level represent trains that can operate the service. Based on train priority, number of passengers and delay, each node is assigned a cumulative score to reflect it attractiveness. A horizon of the next F services is considered in order to reduce the search tree, F being the number of levels of services to search through and this will determine the depth of search by the algorithm. A depth-first search with a branch-and-bound procedure is where all possible solutions are at the level F of the tree. The model then presents a specified number of the best possible solutions to the train dispatcher. The system was implemented in 1998 in Asturias, Spain, and offered a set of useful solutions in less than 5 min. [Adenso-Daiz 1999]. This research has borrowed the train priority factor used in this model and based on cumulative score on all set priorities, set the priority of a given train.

2.1.3 Greedy Travel-Advance Strategy

Greedy travel advance strategy, is a discrete-event model used to obtain time-efficient and energy-efficient suboptimal schedules where the discrete events consider the times when a train reaches a meetpoint [Medanic, 2002]. It assumes that the velocities of the trains for each section of the route are fixed, and that the times of origin of the trains are given, based on this the time for the next event is calculated. This algorithm is called greedy because it is locally optimal and depends on local information, where when a train reaches a meetpoint the algorithm only considers the trains in its vicinity. If the train can reach the next meetpoint safely, then the model proceeds to the next event, if not, the algorithm decides which nearby train has to be stopped at a meetpoint.

This model assumes that trains travel at their maximum velocities allowed in the sections of the line, based on this the schedule is converted into an efficient pacing schedule, where the optimal pacing of trains is established in order to save energy. To get the optimal velocities, an average is calculated over the velocities of the sections that the train will travel, in addition to ensuring that the times of arrival previously calculated will remain the same. This assumption of maximum velocities in the current RVR rail network is not possible as there are great challenges with dilapidated track, poor locomotive maintenance and no GIS system to track whereabouts of train while they enter sections.

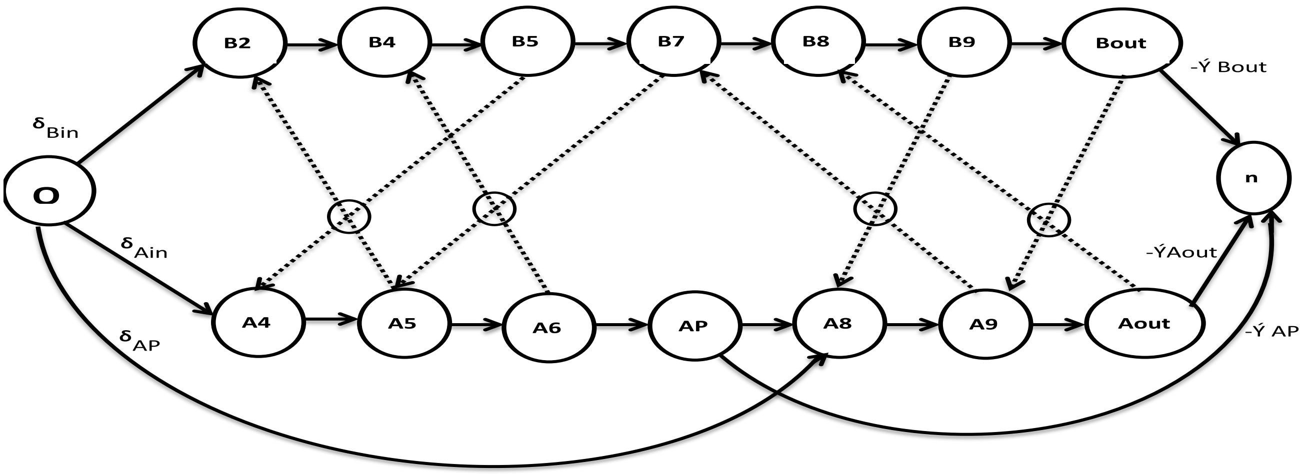
Computational experiments showed that this algorithm is very moderate in computational effort comparing with other programming formulations. This research has borrowed the concept of origin times of train from this model as a key input in the algorithm.

2.1.4 Re-scheduling with train speed coordination

Andrea D'Ariano *et al.* [D'Ariano, 2007] introduced a variable-speed dispatching system that controlled railway traffic where acceleration and deceleration times were modelled considering the constraints of the signalling system and the rolling stock characteristics.

The system contains three parts: data loading that collects data from the field; a conflict detection and resolution procedure which has fixed-speed profiles, and used to solve the train scheduling problem; and a variable speed model that iteratively checks if the train speed profiles are acceptable. In the conflict detection and resolution procedure, the train scheduling problem is formulated as a job-shop problem with blocking and no-wait constraints. This type of approach uses the alternative graph [Mascis, 2002] as the model structure. Each job (train) must pass through a prescribed sequence of machines (block sections). The passing of a train through a particular block section (an operation) is a node of the alternative graph. A fixed arc represents the running time of a train through the block section (solid arrows in Figure 4). Whenever two jobs require the same resource, there is a potential conflict. In this case, one of the pair of the alternative arcs (dashed arrows in Figure 4), representing the minimum time headway between the associated trains has to be selected. By the inspection of the alternative graph, one can detect conflicts very rapidly. If the selection of an alternative arc increases the starting time of the following operation, a conflict between the two considered trains has been detected. This research has borrowed the concept of fixed section speeds and the conflict detection and resolution to be used to solve train scheduling based on set priority factors.

Figure 4. The alternative graph for the example with two trains



Source: Mascis 2002

Julius Mwangi in his research “Designing a real time train control and monitoring system architecture” [J.Mwangi -2011] proposed a train control and monitoring system that would be used to control issuance of authority to occupy a section of the track by a train. The system would generate an electronic line clear on request by the driver, eliminating the need for human interface in signaling and line clear issuance. The position of the train would then be detected by a GPS system. This research has the limitation of having only one train in section despite knowing the GPS positions of all trains. This research builds on Mwangi’s work by optimizing scheduling , while his research will compliment this research by ensuring electronic signaling and line clear issuance for trains at stations hence enhancing crossing as well as ensuring train visibility at any one time through the GPS system.

The studies and results above were useful for this research in understanding input data that have been used in previous models as well as outputs that have been generated thus assisting to enhance on the same. They formed the foundation and guide of this research.

2.2 The current train Operation at RVR

Train movement within the entire network is planned by Control and Planning section of the Operations department. Based on the business plan for the day, the Chief Controller uses train plan schedule to book trains 24 hours ahead of expected trip. This plan has train names with optimal times when trains are supposed to run if all other variables are correct. The optimal times was arrived at using crossings, speed restrictions and path (using appropriate time to dispatch to avoid conflict). In a scenario where there is no best path or there is a delay from the next best paths the train controller can create a special schedule name. The train plan schedule is as illustrated in Appendix I.

This plan is given to each desk controller manning the different routes to execute accordingly. The desk controller uses the plan to chart the timetable on the train chart 2 hours before departure using section defined running times. This is drawn on the chart using light pencil colour and ensures that the controller plans crossings through priority of train and path ahead of the trains movement. The desk controller plots the actual train movement on the chart using dark pencil colour or correct colour pen depending on the running train. This helps the controller monitor the planned against the actual and re-plan accordingly.

There are 5 depots namely Changamwe, Nairobi, Eldoret, Tororo and Kampala where trains stop for DTRS. This is a minor service where there is minor repair, refueling, sanding, and normal checkups by the fitters. This process is given a maximum of 4 hours to complete. Crew change is also effected in these depots. In the event that there are changes to the plan due to whatever reason, the desk controller changes and uses the timetable to help him/her re-plan. He then must advice the depots concerned to adjust crew schedule accordingly.

The desk controllers communicate with station masters on the dispatch of trains to ensure that the planned schedule is followed. This is currently done using cellphones. Station masters also communicate to each other on dispatch and reception through cellphones or Radios in some areas.

2.2.1 Timetables

Train desk controllers have two main tools to supervise the network which are the timetable (train plan schedule) and the train control chart. The timetable is a schedule of trains on the railway infrastructure. It contains the arrival and departure times of the trains, not only from stations, but also from intermediate stations and sidings.

The train control chart, is a graphical timetable and is a representation of the timetable in a more perceptive way. It is basically a time distance graph where all the trains' routes are represented. The X axis represents time of day spaced into 20 minutes, the Y axis the sequence of stations in distance scale. Lines indicate the movement of trains, with the slope indicating direction and speed, horizontal meaning stand-still.

Usually, the outbound direction is defined upwards. In this example, the horizontal lines represent the meetpoints along the track. The advantage of this diagram is that it makes it much more simple and intuitive to read the timetable and to detect conflicts. Appendix II is an example of a train control chart.

2.2.2 Safety technologies

Currently at RVR there are stations with 2 or 3 running lines as well as section lines which are between 2 stations that have only one line. The fixed block technology is used with only one train allowed in section at any one time. This is controlled by Station masters using cellphones. The train controllers plan movement during charting by 2 hours ahead. This helps in anticipating crossing of trains. During crossing a train is stopped within the falling mark just to enable other trains to pass. Between each mark the station master manipulates points manually to prevent accidents and collisions. After crossing, a train is allowed only 15 minutes waiting time to enable the station master to return the lines to normalcy.

The combined management by the traffic controllers by planning 2 hours ahead and allowing 15 minutes during crossing, control the train traffic and impose safe distance headways. The dispatching rules also ensure safety of trains operations and are mainly based on priority especially for passenger trains. However, at RVR due to delays caused by different factors, trains are prioritized depending on where the resources being conveyed are most required. This has the drawback of being heavily reliable on human beings with probability of errors as occurred in the year 2009 when we had a head on collision at Menegai Junction where the 2 station masters were running trains away from the actual stations using cellphones, each making assumptions while away from the station.

2.2.4 CONCEPTUAL MODEL

Scheduling is one of the mission critical factors that determine rail business output. This must be done to achieve a conflict free schedule to ensure utmost safety of train operation especially in a single rail business where trains in both directions travel on one line.

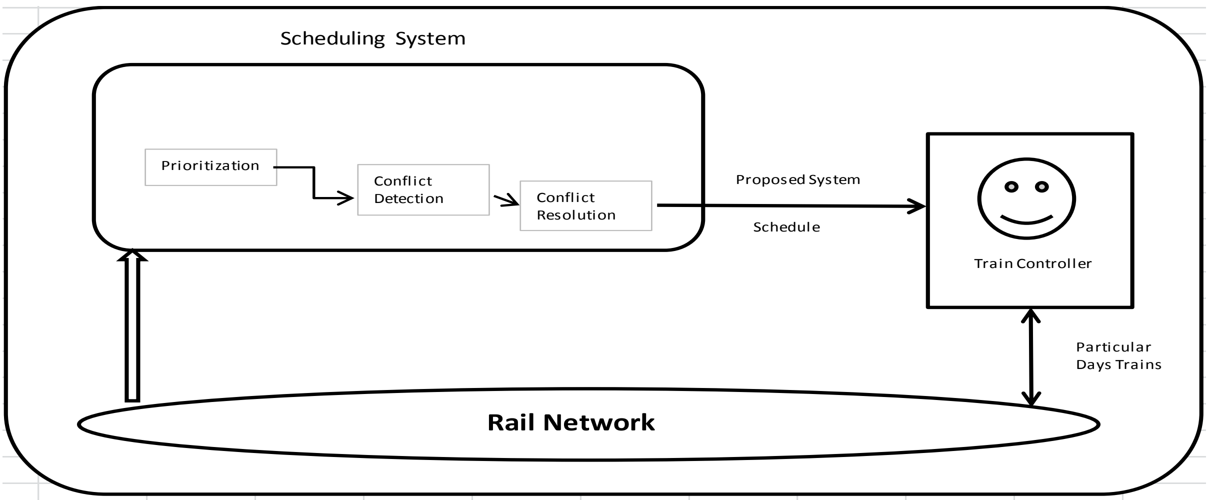
To come up with the conceptual model, the research borrowed from the body of knowledge of genetic algorithm. The form of genetic algorithms was described by Goldberg (Wesley, 1989). Genetic algorithm is a search mechanism based on mechanisms of natural selection and natural genetics, where there is an initial population, an initial set of random solutions which are represented by chromosomes. These chromosomes evolve through generations and in each generation, the solutions represented by the chromosomes of the population are evaluated using some measure of fitness. To create the next generation, new chromosomes are formed, with the chromosomes involved in the generation of new population being selected according to their fitness values. Fitter chromosomes have higher probabilities of being selected. After several generations, the algorithm converges to the best chromosome which represents the optimal solution to the problem. This research bases fitter chromosomes to priority as detailed below.
In comparison to the initial generation, all trains for a particular day are considered with their departure times and stations.

In terms of optimality, the Genetic Algorithm compares to scheduling model, where the generation evolves by putting an immediate neighbor of the best chromosome in the next generation, which guarantees improvement down the generations. Here the next best fit chromosome is chosen for next generation. In the same way in the scheduling model, trains are prioritized based on priority options illustrated below and the best fit will be given priority over the other to enable crossing at any station.

No	Train Type	Priority Factor	Priority	Remarks
1	Passenger	Train Type	One	Passenger Train are given priority over Cargo trains at any one time as they are as they carry humans train priority is based on safety, departure & arrival times as well as importance of satisfying customers
	Cargo		Two	
2	Long Distance	Type of Passenger Train	One	Long distance Passenger trains always have priority over commuter trains that have shorter travel distance compared to the long distance passenger trains.
	Commuter		Two	
3	Longer Cargo/Passenger	Length of Train	One	Train length is used to determine which train passes which during crossing at a station, where longer trains are given priority to pass over shorter. Safety aspect is taken into consideration during crossing of trains.
	Shorter Cargo/Passenger		Two	
4	Cargo High	Nature of Load	One	nature of load, total cost of goods to ferry and weight of load is considered. Safety is of importance e.g. train carrying highly flammable fuels is given higher priority, compensation was considered when it comes to total cost of goods being ferried e.g carrying CBK money is given higher priority. Weight of load is also considered, looking at total operational cost of running a train where running a heavier train is more expensive especially when it comes to fuel consumption hence heavier trains are given higher priority.
	Cargo Medium		Two	
	Cargo Low		Three	
5	Passenger and Cargo	FOFI		considers all the above and in the event that any two trains bear equal priorities with regards to priority and nature of load, it determines which train will pass the station as the other waits, where the first train to leave the station (first out) will be the one that first arrived the station (first in).

With above in mind, the system overview is presented in Figure 5 below showing three main functions: Prioritization, conflict detection and conflict resolution. The model is valid independent of how many trains are operational in a specific day.

Figure 5 Train schedule system overview



Source: Research

CHAPTER THREE
METHODOLOGY

3.0 INTRODUCTION

A system is a set of objects together with relationships between the objects and their attributes, where objects are the parts or components of a system and attributes are properties of the objects. System analysis is a structured technique for handling a problem leading to meeting well defined goals or objectives. To achieve this, sample of people were interviewed to ensure adequate information is collected to enable development of the scheduling system. The interviews enabled studying of the existing system with limitation and problems being identified.

3.1. ANALYSIS

The project looked at the information that would be processed and synthesized for the purposes of satisfying the research objectives and this was collected from a variety of primary and secondary research sources.

3.1.1 SAMPLING

A number of different people currently in their day to day function determine the final train scheduling process as well as the outcome of this scheduling. This research interviewed a sample of 100 critical respondents detailed below from a total population of 297 as detailed in Appendix IV. The sampling was purportive and not random having chosen to interview operation staff station between Mtito Andei and Nairobi. The reason being all Controllers are located in Nairobi and the section between Mtito Andei covers all trains from Mombasa destined for Nairobi and Uganda as well as all trains going back to Mombasa from Kampala and Nairobi.

- 1 General manager Control and Planning
- 1 Chief Controller
- 4 Senior Controllers
- 12 Desk Controllers
- 4 Loco Controllers
- 28 Station Masters
- 30 Train drivers

- 8 Guards
- 8 Loco Inspectors
- 4 Depot Superintendents

The respondent roles are detailed below:

- General Manager Control and Planning - Responsible for administration and operation of Control staff in both the OCC and planning sections. Analyses reports and makes necessary decisions to ensure overall business plan is met as per schedule plans. Has to liaise constantly with Commercial to get the overall freight available, source and destination.
- Chief Controller – Makes the overall train movement plan for OCC using the train schedule. Communicates the plans and co-ordinates execution of same along with related operations within RVR-K network. Also communicate daily trains plan to Regional Operating areas in the next 48 hours according to availability of traffic, path and crew. Analyze train movements and transit times for all trains as indicated in charts to ensure all crossings are properly planned as required and no unavoidable delays arise. Monitor positions of locomotives with a view to aligning same with availability of load and resources. Oversee the monitoring of movement of resources (empty wagons) to ensure expedited transit and deployment according to demand. Monitor closely dispatch of trains/traffic from yards and arrange for quick connections, turn round of locomotives and wagons to meet customers demand for improved efficiency. Maintain often liaison with key operational areas including RVR-U to realize seamless operations as envisaged in the Joint Concession.
- Senior Controller - Carry out the Plans and co-ordination of operations as laid out by the Planning & Control Manager and Chief Controller. Supervision of Control Office staff to ensure all tasks are carried out as required. Supervision of depot field operations staff to ensure instructions are carried out as required, and station staff and train crews in cases of serious irregularities to ensure safe, reliable and effective operations. Daily scheduling of trains, including allocation of locomotives, crew, according to availability of resources and liaise with the relevant Operating Officers accordingly.

- Desk Controllers (train controllers) – Plan and project train movements and make arrangements for train crossings to achieve maximum track capacity, punctuality and safety, and appropriate forward connections in order to achieve efficiency in their designated area of control. Advise Yard Masters, Assistant Yard Masters, Running Shift Foremen and Station Masters of booked trains and clearance of traffic from wayside stations and following up to ensure trains depart on time. Summarize and advise Yard Masters/Assistant Yard Masters and Station Masters of expected traffic (loaded/empty) for forward connection and/or retention. Rescheduling and adjustments of booked trains timings/dispatch yards to suit priorities and changing operational circumstances. Monitor position of stations to avoid overstay of traffic and clear same as appropriate. Report accidents/incidents and any other unusual occurrences to the relevant Regional authorities and co-ordinate resource mobilization and related activities at site until normal working is restored. Monitor punctuality of all trains and intervene in case of any deviations from the normal running times for remedial measures. Prepare stock reports summaries which give a clear picture on the position of stations and yards and make arrangements for placing inward loaded wagons to sidings as well as withdrawal of loaded/offloaded wagons.
- Loco Controller - Allocate locos on trains for load clearance in liaison with Chief Controller and/or Senior Controllers. Ensuring locomotives are availed to the Depots and/or Workshops for maintenance services to be carried out on schedule and promptly without compromising availability and performance. Liaise with the Depot Supervisors in all depots and/or Workshops to ensure locos under repair are released in good time. Advice train crew in cases of failures or abnormal situations en-route and best methods of dealing with same.
- Station Masters – Person in charge of trains working of the whole or a portion of the station. Responsible for ensuring signal equipment within his station are in good working condition, while being the custodian of all the related keys for signalling. Deals with trains expeditiously to ensure punctuality and reporting any failure of communication equipment. Record all trains that pass the station and their timings and transmitting the same to OCC. Give line clear to allow trains into sections.

- Train Drivers – In charge of any power propelled vehicle on the railway line. Must have copy of working timetable and appendixes for reference plus all notices to assist him carry out his work. Before putting train in motion to commence or he must satisfy himself that he has been given authority to proceed, it is the proper one for section concerned and where it's a paper line ticket, it is properly made out and contains no alterations.
- Train Guards – Is in charge of the train and carries all documentation concerning the cargo he is conveying. Must have copy of working timetable and appendixes for reference plus all notices to assist him carry out his work. This also include red and green flag, hand signal lamp and a whistle to assist him in emergencies or stoppages. He acts as the assistant train driver.
- Locomotive Inspectors – These are Senior drivers and are charged with checking the key competencies of the drivers.
- Depot Superintendent – He does the daily turn round service for Locomotives which involves fuelling, sanding, watering and minor services. This is done at major depots on completion of a train journey.

The above sample of people gave adequate relevant information as they are involved from the planning, dispatching and receiving, maintaining and moving process of the train from one destination to another.

3.1.2 DATA COLLECTION METHOD

Interviews with respondents detailed above was used as one of the data collection methods to ensure that all requirement information for the system is collected. This method was preferred as more information would be gathered through observation as well as reference to documents used by respondents at their work place. Detailed interview guide is as shown in Appendix III and was pre-tested by interviewing the Chief Controller, three Desk controllers, one General Manager Control & Planning as well as one Station Master. Cronbach alpha was used to measure the reliability and the questionnaire was found to be reliable.

In addition, Desk Review was also used to collect information and this looked at operational manuals currently being used. This included analysis of

- Traffic Manual

- General rules book
- Working timetable.
- Previous train plan schedules sheets
- Previous/existing timetables.

3.1.3 DATA ANAYSIS AND INTERPRETATION

The Data collected from the interviews was analysed using SPSS version 18 Software tool and statistical tools used to present data were:

- Graphical analysis
- Tabulation of data

The research sought to find out the education level of the respondents by gender. The results show that most of the respondents (92.4%) for the research were male while female respondents accounted for (7.6%) of the research. Of the respondents with Certificate education, only (7.5%) accounted for the female respondents while (87.0%) of the respondents with Diploma education were male. The research further established that all the respondents (100.0%) with Bachelors education and Higher Diploma were male. Male respondents therefore formed a majority of the respondents for the research. This is due to the fact that Male staff are more in the company especially in the operational field than women. This is mainly due to the labor intensive, 24 hour operation involved.

Table 1: Distribution of Gender and Education Level

	Sex		Total
Education level	Male	Female	
Certificate	92.5	7.5	100.0
Diploma	87.0	13.0	100.0
Higher Diploma	100.0	0.0	100.0
Bachelors	100.0	0.0	100.0
Total	92.4	7.6	100.0

Source: Research

Information on the job position of the respondents was obtained and assessed with regards to the education level. The research established that almost two thirds of the respondents had a certificate education while a fifth of the respondents had attained Diploma level education. Only

7.2 % and 5.4% of the respondents had attained a higher Diploma and Bachelors education respectively.

Further analysis shows that the senior controller position was held by respondents with Bachelors education whereas the position of Depot Superintendent was held by respondents with Diploma education. Similarly, over three quarters of the respondents with certificate education and around a fifth of the respondents with Diploma education held the train driver and train guard position respectively while only 5.6% of the respondents with Bachelors education held a position as train guard while at RVR. Equally, almost two thirds of the respondents with certificate education were station masters while only 23.3 and 10.0 % had higher diploma and diploma respectively. The same proportion of respondents (50.0%) with Certificate and Diploma education held the position of locomotive inspector. The implies that most operational staff have low education level, this therefore required the implementation of a simple system that is easy to learn and work with.

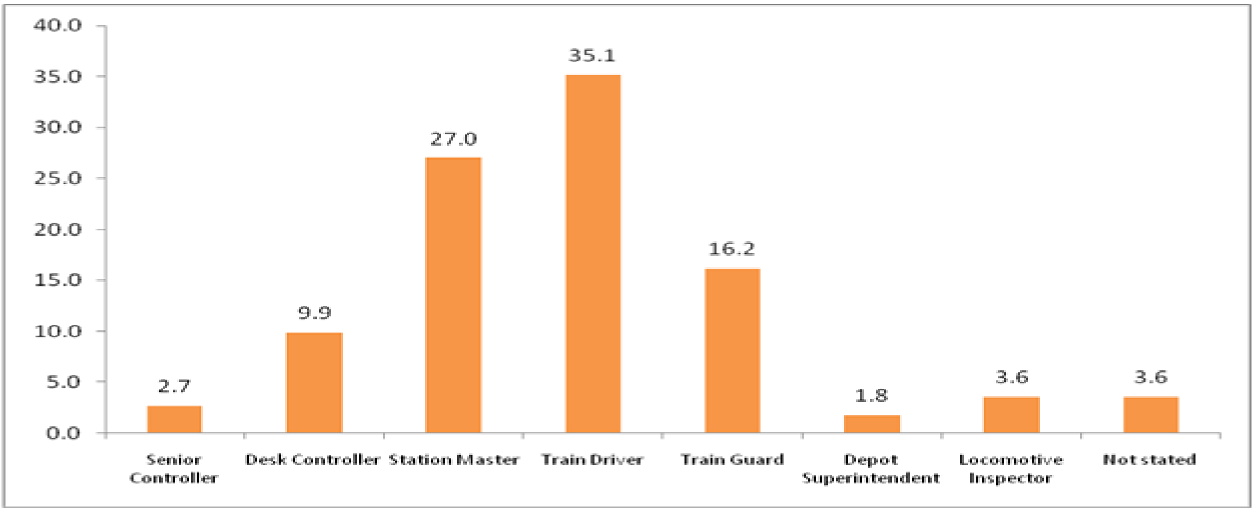
Table 2: Education level and Position at RVR

	Education Level				
Job Position	Certificate	Diploma	Higher Diploma	Bachelors	Total
Senior Controller	0.0	0.0	0.0	100.0	100.0
Desk Controller	45.5	27.3	9.1	18.2	100.0
Station Master	66.7	10.0	23.3	0.0	100.0
Train Driver	79.5	20.5	0.0	0.0	100.0
Train Guard	77.8	16.7	0.0	5.6	100.0
Depot Superintendent	0.0	100.0	0.0	0.0	100.0
Locomotive Inspector	50.0	50.0	0.0	0.0	100.0
Not stated	0.0	100.0	0.0	0.0	100.0
Total	64.9	22.5	7.2	5.4	100.0

Source: Research

Figure 6 shows that the train driver post stands out as the major position held by majority of the respondents at RVR which accounts for (35.1 %) of the respondents. This number is followed closely by the station master position which is held by (27.0%) of the respondents. Similarly, (16.2%) and (9.9%) of the respondents hold the train guard and desk controller position respectively at the RVR. Other positions held by respondents at RVR include locomotive inspector (3.6%), senior controller (2.7%) and depot superintendent (1.8%).

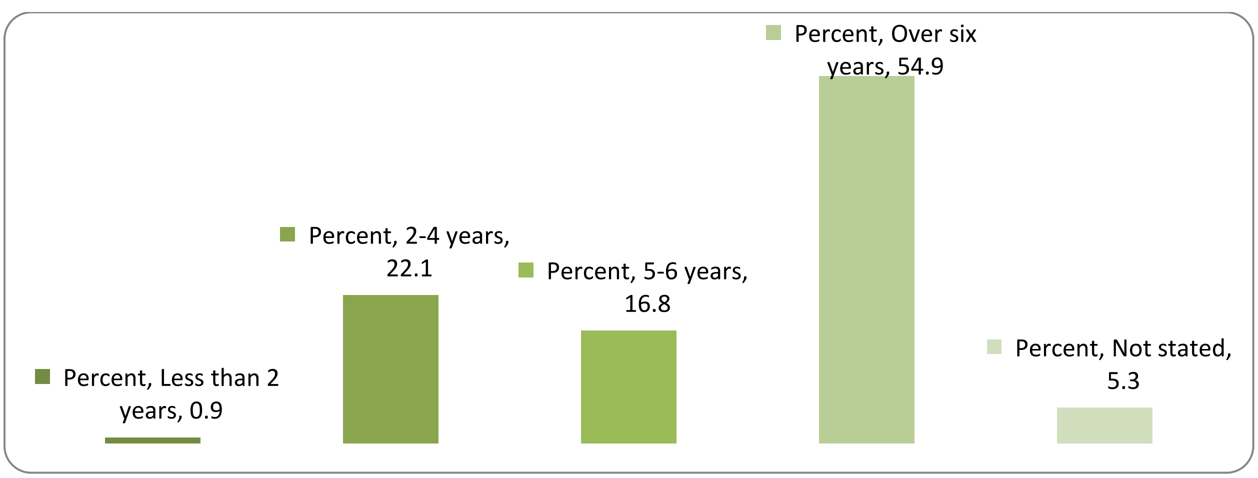
Figure 6: Distribution of respondents by Position



Source: Research

Survey respondents were asked about the period they had served in the current position while at RVR. Figure 7 below shows the length of time that respondents served in the current position. The result of the research shows that almost three fifths of the respondents had served in the current position for over six years. The number was followed by almost a fifth of the respondents who established that they had served in the current position for around 2-4 years and 16.8% of the respondents who asserted that they had served in the current position for around 5-6 years. A negligible percentage (0.9%) of the respondents had served in their current position for less than two years.

Figure 7: Period serves in the current position



Source: Research

The question assessing number of years that respondents have worked with RVR shows that a 44.0% have worked in RVR for over six years while 37.0% of the respondents have worked in RVR for around five to six years. The research also shows that respondents who have worked in RVR for around two to four years account for 18.5% of the respondents. The results of the research further revealed that almost all the respondents (99.1%) moved from Kenya Railways Corporation to Rift Valley Railways with 74.1% of the respondents having worked for KRC for over 15 years. This indicates the level of train operation experience of the respondents.

Table 3: Positions held at Kenya Railways

	Responses	Percent of Cases
station master/assistant	35	33.3
Clerk(booking clerk, train clerk, goods and coaching truck)	28	26.7
Point man	26	24.8
Fire man	25	23.8
shutter driver	23	21.9
Yards Foreman	13	12.4
Train guard	13	12.4
data controller	12	11.4
driver(locomotive driver/train driver/senior/junior driver)	12	11.4
Call man	11	10.5
locomotive controller	10	9.5
Gang man	6	5.7
locomotive inspector	4	3.8
desk controller	3	2.9
general fitter/truck maintainer	2	1.9
railtrack supervisor	2	1.9
senior controller	2	1.9

Source: Research

When asked to specify the positions that they have held while at Kenya Railways Corporation, respondents listed numerous posts. The respondents revealed that the station master/assistant station master position was the most prevalent position held as shown by 33.3% of the responses. Responses showing clerk position was represented by 26.7% of the responses. The research further showed that the various categories of clerk positions included train clerk, booking clerk and the good and coaching clerk. Of the responses given, the research also shows that (24.8 %) of the responses held the point man position while (23.8%) of the responses held the fire man position. Equally, the research established that (21.9%) of the responses held the shunter driver position while 12.4 % of the responses indicated that respondents held the yards foreman and train guard position respectively. Only 11.4% of the responses and 10.5% of the responses indicted that respondents held the driver and call man position respectively while at Kenya Railways Corporation. Other positions held by the responses as represented by 34.4% of the responses include the position of : gang man, catering stewardess, signal man, general fitter /track maintainer, locomotive controller, locomotive inspector, rail track supervisor, desk controller, senior controller, electrical fireman and travelling ticket examiner.

Analysis of Section B on Work Environment

With regards to the work environment, respondents were asked to specify the document or tools that they use to support their job functions. Respondents gave a wide variety of tools and documents used at their job. This information is represented in Table 4 below.

Table 4: Documents/Tools that support job function

	Responses
pipe range	83
stationary	24
token instruments	22
trolley permit books	17
computer	16
tool kit	12
charts(control chart/graphic chart)	10
safety wear	10
tie line	10
train register book	8
telephone	7
motive power manual/control manual book	7
derailer	5
mobile phones	4
working time table	3
private number sheets	3
general appendix and rules	2
dairy book	2
detonaters	2
signal cabin	2
point clamp	2
square key	1
PLC book	1
warning order books	1
red and green hand flags	1
hand signal lamps	1

Source:Research

The most common tools used by the respondents as revealed by the research is the pipe range with 83 responses. While the least used tools were square key, PLC Book, Warning order book, hand signal lamps and red and green hand flag having one respondent each.

Results of the research show that the use of stationery like books, pencils and note books, computers and tool kit were also tools that were used by the respondents to support their job function.

Other tools/documents such as mobile phones, telephones, charts (control chart and graphic chart), motive power manual/control manual book, general appendix and rules, working time table, dairy book, train register book, PLC book, warning order books, private number sheets, trolley permit books, token instruments, square key, tie line, derailer, detonators ,signal cabin and point clamp are among the tools that were listed by the respondents.

Respondents were further asked whether the tools were sufficient to enable them meet their KPIs. The results of the research show that only 18.7 % of the respondents were of the opinion that the tools were sufficient enough to enable them meet their KPIs. This implies that the tools available to the respondents are insufficient with only 16% indicating that computers support their day to day functions. Apart from the pipe range that is used by 83% of the respondents to support their job function, all the rest of the tools are at 30% indicating non availability of the said tools to support jobs. For computers this has translated to low computer literacy among operation staff.

The research established that there were two business seasons; high season and low season. This was affirmed by almost all (96.4%) the respondents in the survey. The results of the research further show that a fifth of the respondents were of the opinion that there was indeed a difference in work plan during the high business season and the low business season.

The research listed various causes of delay of train arrival and dispatching time. These included: rolling stock availability, Rolling stock condition, Crossing at station, Daily turn round service, communication between train and station, Scheduling and dispatching of trains. When asked about the causes of delay of train arrival/ dispatching time, over half of the responses (62.2%) affirmed that rolling stock condition was the cause of delay of train arrival/dispatching time while around half the number of responses (48.6%) showed that rolling stock availability was the cause of delay of train arrival /dispatching time. Daily turn round service was also a cause of delay of train arrival/dispatching time. The research findings show that (45.9%) of the responses were of the idea that daily turn round service causes delay of train arrival /dispatching time. Another cause of delay of train arrival /dispatching time is crossing at stations and this accounted for (36.9%) of the responses. Scheduling and dispatching of train and communication between train and station were also causes of train arrival/dispatching time which accounted for (33.3%) and (20.7%) of the responses respectively.

Table 5: Causes of delay of train arrival and dispatching time

	Responses	Percent of Cases
Rolling stock condition	69	62.2
Rolling stock availability	54	48.6
Daily turn round services	51	45.9
Crossing at station	41	36.9
Scheduling and dispatching of trains	37	33.3
Communication between train and station	23	20.7

Source: Research

The question assessing scheduling and dispatching of trains after delay shows that (44.5%) of the respondents were of the view that the scheduling and dispatching of train was reorganized after delay in travelling and dispatching time while 55.5% of the respondents were of the view that the scheduling and dispatching of trains was not re-organized after delay in arrival /dispatching time.

Respondents were also asked to specify how they manage train delays to meet timings close to the initial set schedule. Majority of the responses (32.3%) revealed that most of the respondents manage train delays to meet timings close to the initial set schedule by giving a delayed train a through run while a quarter of the responses indicated that respondents manage train delays by not shunting en-route. Similarly, maintaining speed section and maintaining running section time were strategies that respondents employed to manage train delays as indicated by (17.7%) and (13.5%) of the responses. This indicates that there is not set standard for managing delays and each individual uses what he perceives as the best way to manage delays. This is heavily dependent on human decision factor and not laid down rules.

Other strategies employed by the respondents to manage train delays to meet timings close to initial set schedule include: Not giving a delayed train so much crossing (tight crossing) (9.4%), Not crossing trains (5.2%), rescheduling trains (5.2%), Clear and open communication channels(2.1%), Advising crew by memo of any abnormal or speed restrictions(2.1%), personnel putting in extra personal efforts(2.1%), working extra hours(1.0%), avoid unauthorized stopping at stations (1.0%), and ensuring that crew report on time(1.0%).

Table 6: How train delays are managed

	Responses	Percent of Cases
giving a delayed train a run through	31	32.3
Not shunting en-route	25	26.0
maintaining speed section	17	17.7
maintaining running section time	13	13.5
not giving a delayed train so much crossing	9	9.4
follow train time tables strictly	6	6.3
not crossing trains	5	5.2
put in extra personal effort	2	2.1
advise crew by memo of any abnormal or speed restrictions	2	2.1
working extra hours	1	1
avoid unauthorized stoppage at stations	1	1

Source: Research

The research sought to find out the challenges that the respondents experience in trains. Poor locomotives (67.3%) and poor track conditions (62.7%) were among the major challenges faced by the respondents. These were followed closely by poor crossing which involved long crossing at sections and accidents which involved derailment and capsizing of wagons. These accounted for (16.4%) and (14.5%) of the responses. Equally, respondents were also of the opinion that poor communication (8.2%), lack of spare parts (6.4%) and demotivated staff (6.4%) were other challenges that they faced. Respondents cited low salaries as the cause of de-motivated staff.

The research also revealed that other challenges faced by respondents as indicted by (26.1%) of the responses include: Unavailability and poor maintained rolling stocks, competition by other transport networks, inadequate operational materials, under maintained signal frames, working without light at night due to low supply of paraffin, long working hours for train crew, vandalism of railway fitting, non-adherence to working time table and scheduling for trains by staff and lack of modern technology in train management.

Table 7: Challenges currently experienced

	Responses	Percent of Cases
Poor locomotive(wagon) conditions	74	67.3
poor track conditions	69	62.7
long crossing in section (poor crossing)	18	16.4
accidents	16	14.5
poor communication	9	8.2
lack spare parts	7	6.4
low salaries(de motivated staff)	7	6.4
speed restriction in sections	5	4.5
inadequate operational materials	5	4.5
unavailability and poorly maintained rolling stocks	3	2.7
rudimentary systems-lack of modern technology	3	2.7
under maintained signal frame	2	1.8
working without light at night due to low supply of parrafin	2	1.8
working materials not provided	2	1.8
vandalism of railway fitting	2	1.8
competition by other transport sectors	1	0.9
long working hours for train crew	1	0.9
inefficent on job training	1	0.9

Source: Research

Respondents gave various recommendations regarding additional measures to be taken to improve train operation. The suggested solutions by respondents indicate the need for buying of spare parts to locomotives and wagons (31.8%) and the maintenance of up to standard of tracks (30.9%). Around one fifth of the responses (19.1%) proposed the building of more stations while (16.4%) of the responses proposed the building of standard gauge railway tracks.

Respondents were also of the view that the staff should be motivated through improved remuneration packages as evidenced by (13.6%) of the responses. Conversely, (12.7%) of the responses suggested that locomotives should be maintained to remain in good conditions while (9.1%) of the responses were of the view that proper scheduling of train timing and adhering to the set schedule would improve train operation.

Respondents also suggested tight crossing and improved train crossing arrangement, improved communication channels, employment of more personnel, supplying of necessary operation requirements for trains, repair of all signal points, ensuring adequate lighting especially at night, improved condition of rolling stock and on-job training of staff as necessary additional measures that should be taken to improve train operation.

Table 8: Factors that can improve train operations

	Responses	Percent of Cases
buying spare parts to locomotive and wagons	35	31.8
maintaining the track to be up to standard	34	30.9
building more stations	21	19.1
building standard gauge railway track	18	16.4
motivation of staff(improve staff welfare by paying good salaries)	15	13.6
buying new locomotives (coaches and wagons)	14	12.7
Maintain locomotives to be in good condition	14	12.7
working on formerly set scheduled working time table	10	9.1
improve train crossing arrangments	7	6.4
embrace improved technology in controlling trains	7	6.4
supply necessary requirements for train works	4	3.6
tight crossing	3	2.7
improve communication channels	3	2.7
training of employees and staff	2	1.8
employ more persennel	1	0.9
repair all signal points	1	0.9
ensure adequate lighting -supply enough fuel for lighting	1	0.9

Source: Research

3.1.4 REQUIREMENTS DEFINITION

The system is to be available to all operational staff in RVR from anywhere in the country through a web browser. The users of the Train scheduling optimization system are categorized as detailed below:

- Planning User Group – this includes Chief controller, Desk controller, Loco controllers
- Operating User Group – Train drivers, station masters, Depot Superintendent
- View user Group – General Manager Planning, Chief Operation Officer and Management on need to know basis
- System Administrators - IT support team who will administer and maintain the system to ensure optimal operation.

As part of feasibility study, review was done on existing historical train charts and data populated as detailed in Appendix V.

From feasibility study carried out the following requirements were deemed to be important to enable the proposed system be operational and successful.

Table 9: Requirements Table

No	**Requirement**
1	All Stations + Names
2	Train Names/Number
3	Departure Times at stations
4	Arrival Times at stations
5	Schedule Number
6	Train Priority
7	Nature of Train Load
8	Length of Train
9	Crossing of Trains
10	Signalling
11	Communication
12	Line blockage

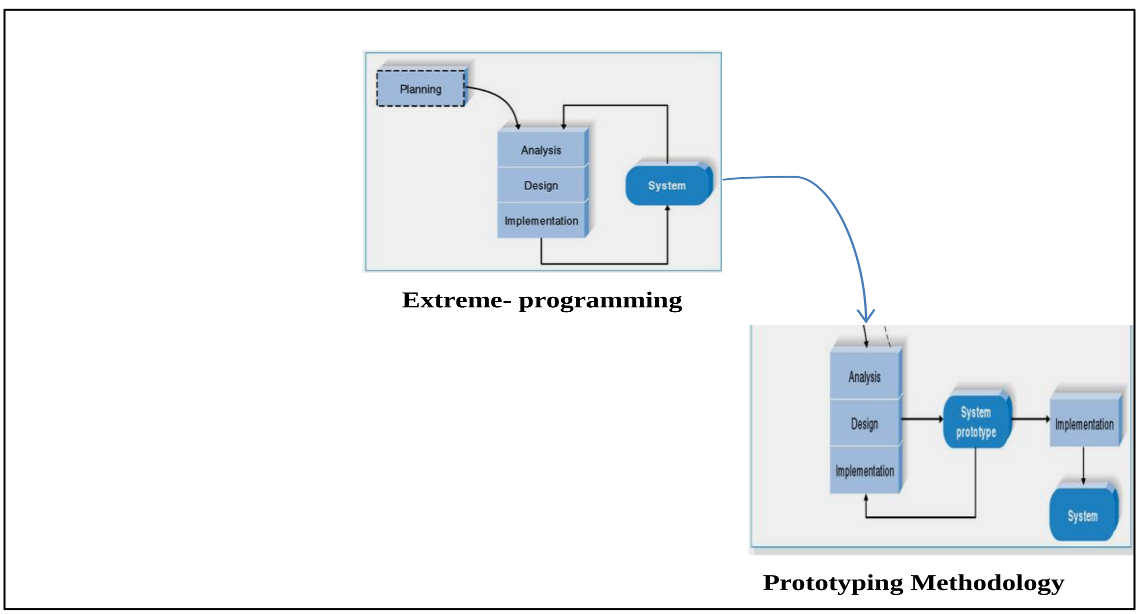
Source: Research

3.2 SYSTEM DESIGN

The system is intended to automate the business processes at RVR with the integration of a data management file that stores information about train operation that can be retrieved in a structured way for decision making. With this in mind, this research aims to automate the scheduling process and ensure that through optimization same or better schedule is achieved. A feasibility study was carried out with aim of objectively and rationally uncovering the strengths and weaknesses of the past and current Railway train operation, the standard practices and problem/challenge areas as presented by the stakeholders, this concentrated on train operations. The system is not supposed to replace the train controllers but to help them in taking the best possible solutions. In other words, this model is a useful tool that allows train controllers to foresee the consequences of their decisions and also provides them with other feasible and probably better solutions.

System Development Methodology (SDM) research proposed by Nunamaker [Nunamaker - 1991] is used as the design approach, where the four stages in this approach, conceptual design, construct design of the system, prototyping and evaluating use of the system is followed. Both Extreme Programming and Prototyping method was adapted as the formal step by step approach to the system development lifecycle.

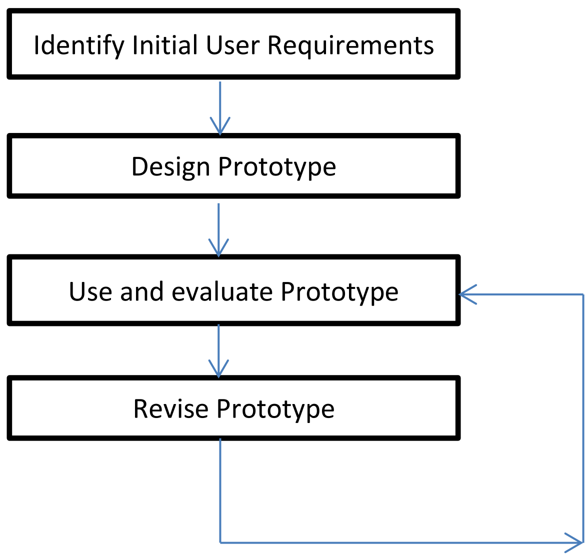
Figure 8: Structured System development methodology



Source: Research

User requirements were got from interviews, desktop reviews and documentation review and this was used to design the initial system where extreme programming was used to ensure quick availability of a system under the short project period. This was then subjected to prototyping methodology where analysis, design and implementation phases were performed repeatedly in cycle while liaising with system stakeholders till the system was completed as detailed below.

Figure 9: Methodology Breakdown



Source: Whitten et al 2000

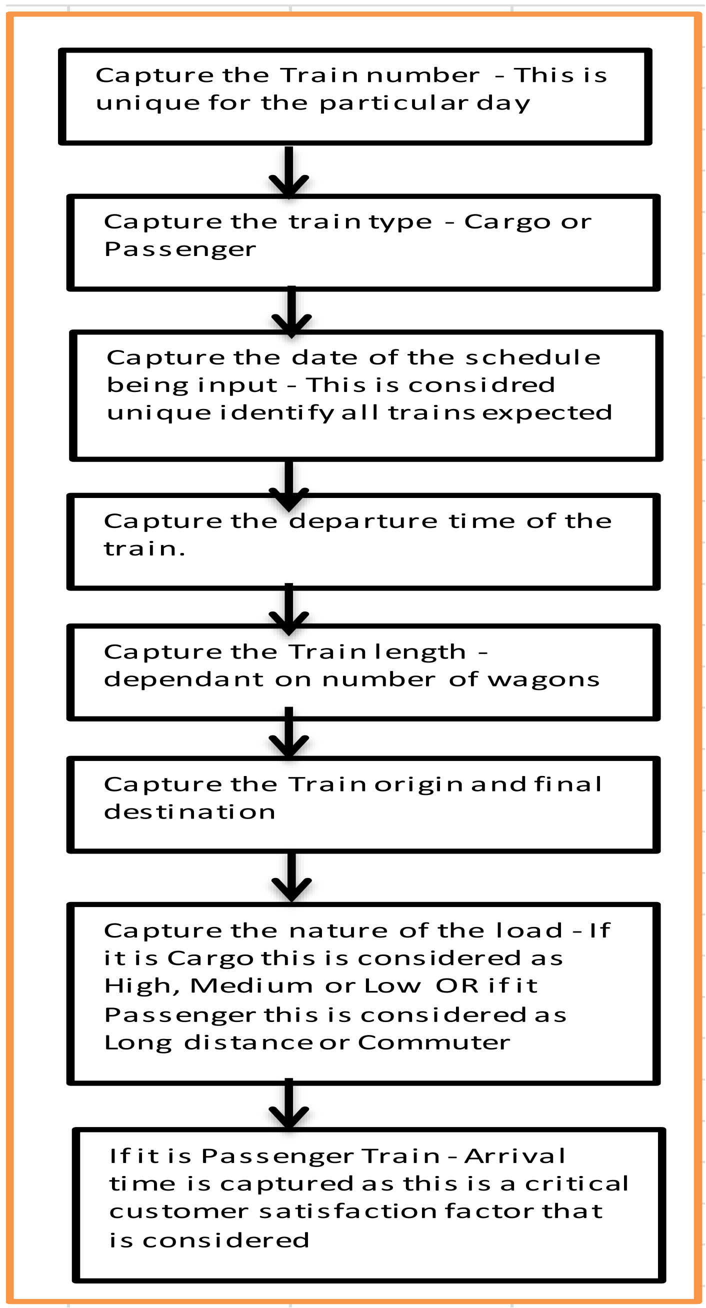
The advantage of prototyping methodology is that it allowed for running the system and getting inputs from stakeholders, while making recommended changes during the short time schedule of the project.

3.2.1 HEURISTIC ALGORITHM

The model used considered a single railway line that serves trains travelling in both directions. The research considered 4 key areas having in mind that the intended algorithm are supposed to be fast and effective. This included evaluating train priority, train load, station capacity and FOFI scheduling.

The outlined factors above were combined and used to come up with a Flowchart of the general procedure as detailed in Figure 10 below.

Figure 10: General Procedure Flowchart.

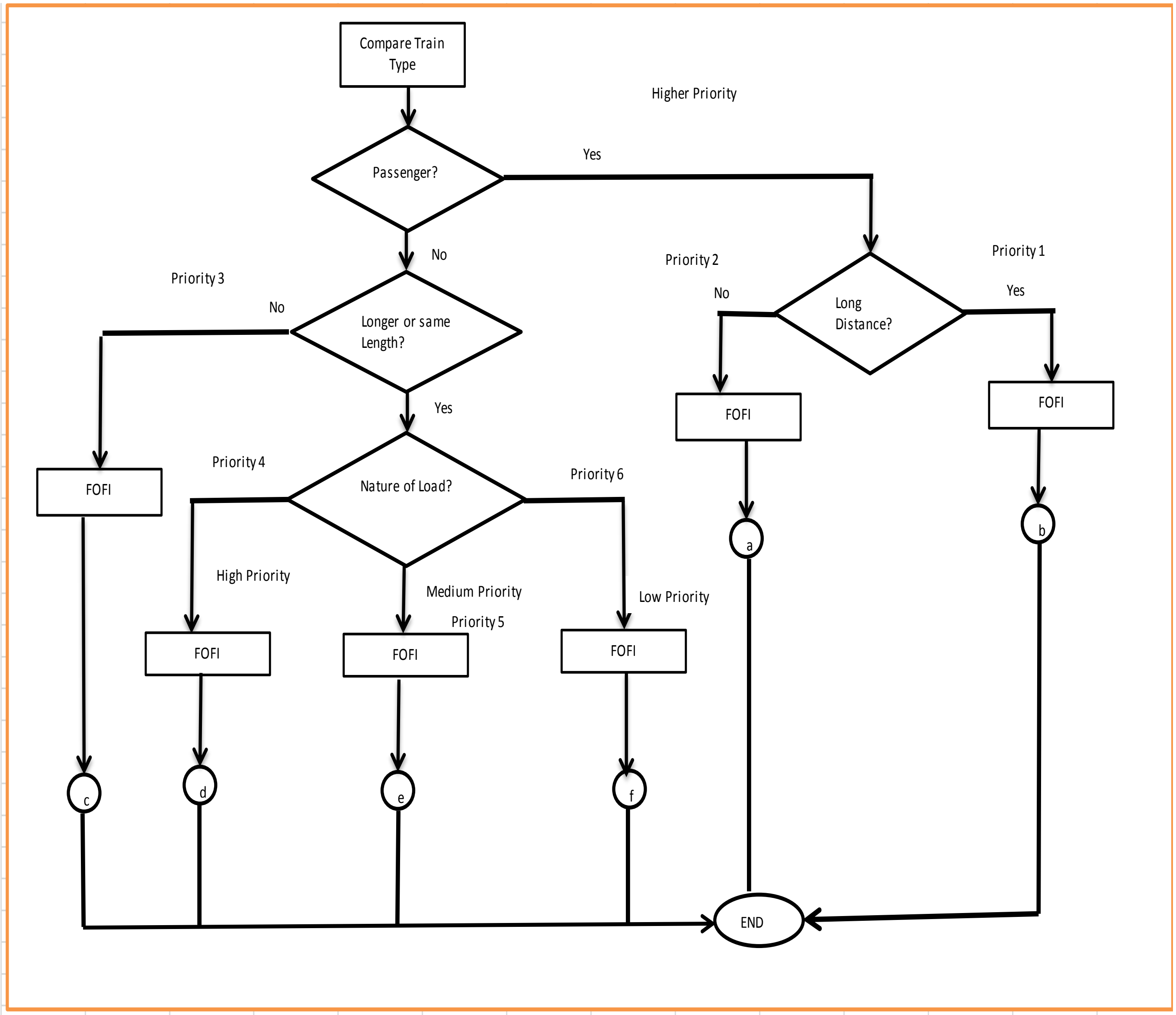


Source: Research

This is illustrated by the Flowchart of the Heuristic algorithm which is represented in Figure 11 below.

Figure 11: Flowchart of the Heuristic algorithm

tabletable



Source: Research

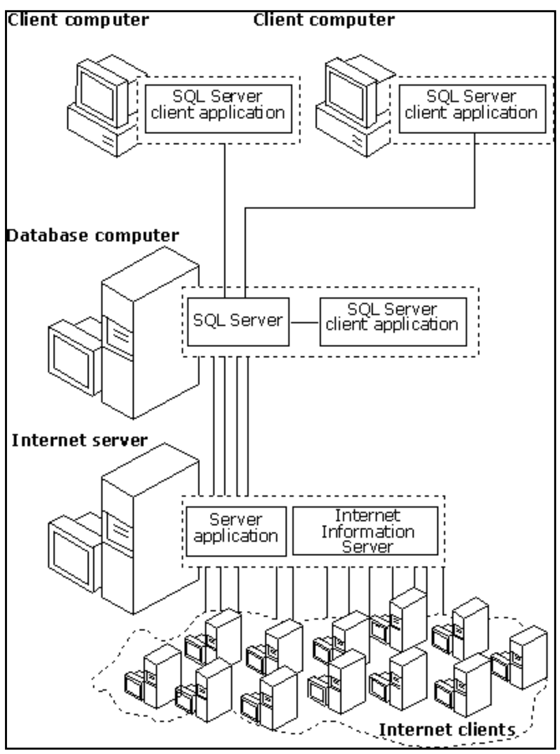
The algorithm is a key success factor in the scheduling process as it determines the prioritization and safe operation of trains through structured crossing prioritization. It ensures reduction of human intervention with regards to prioritization and eliminates manual re-scheduling in event of disturbance of original set schedule. The algorithm guarantees that an arrival at one station is always later than the departure from the previous one. Simultaneous departures at a station, in opposite direction can occur with this algorithm.   The algorithm will ensure that no station capacity is exceeded and will look at train length to determine which train stops while the other passes, with the shorter train stopping while the longer passes. This ensures safety. Finally, the algorithm will send an alert email to receiving station 10 minutes before expected train arrives.

3.2.2 SYSTEM ARCHITECTURE

The system is implemented using the Client-Server Architecture where the system is setup in the server and linked to the end user via a network connection either locally in the network domain or via the internet. The access end points for the normal user are through use of computers. The computers are installed with a Web based solution implemented using PHP, MYSQL and graphing framework to deliver the proposed system. The system runs on WampServer 2.2 which is combined MySQL 5.5.16, PHP 5.3.8 and Apache 2.2.21.

The front end Graphic User Interface is implemented using PHP development language and the connection to the MySQL database is done via TCP connection.

Figure 12: System Architecture



Source: Research

3.2.3 DATABASE DESIGN

The Database will store log and schedule details giving unique schedule composition which is based on the schedule date, train number, origin and destination, departure and arrival times. This is all stored in the Database server.

Database Tables

Table 10: User Table

Field	Data Type	Description
userID	int	Unique user ID
name	varchar	Login user name
username	varchar	Users actual Name
password	varchar	Password
email	varchar	Mail Address
role	enum	Admin or User
regDate	date	Date created
logDate	date	Login date

Source: Research

Table 11: Stations Table

Field	Data Type	Description
station_id	int	Unique Station code
station_name	varchar	Station Name
sectionID	int	Numeric section ID

Source: Research

Table 12: Train Table

Field	Data Type	Description
trainID	int	
trainName	varchar	Train Number
status	enum	

Source: Research

Table 13: Schedule Table

Field	Data Type	Description
scheduleID	int	
trainID	int	Train Identification
trainType	int	Train Type
length	int	Length
nature	int	Nature of Load
depTime	time	Departure Time
arrTime	time	Arrival Time
origin	int	Origin Station
destination	int	Destination Station
routeID	int	Up or down train
mby	int	
mdate	date	
cby	int	
cdate	date	

Source: Research

Table 14: Schedule path Table

Field	Data Type	Description
id	int	
TrainID	int	Train Identification
ScheduleID	int	Schedule identification
stationID	int	Station Identification
time	time	
date	date	
notification	enum	Email notification
lastmodified	timestamp	

Source: Research

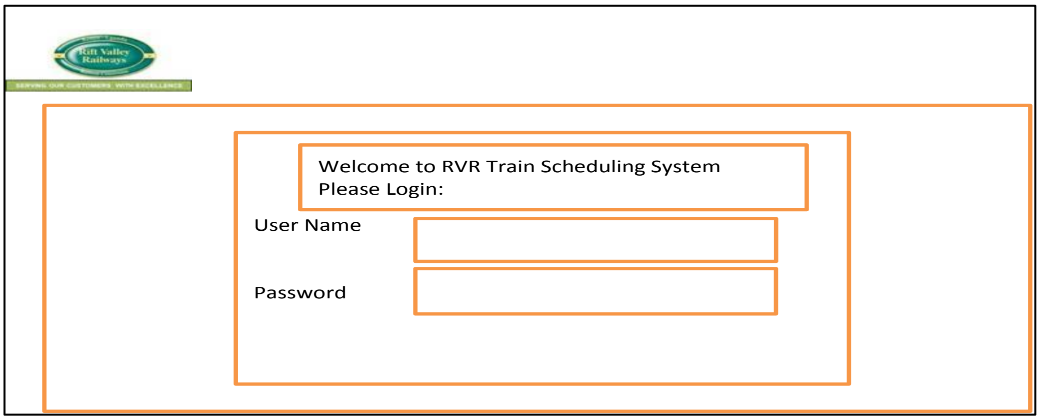
Table 15: Section Time table

Field	Data Type	Description
id	int	
sectionID	varchar	Section Identification
Up	Int	Section running time for up train
Down	int	Section running time for up train

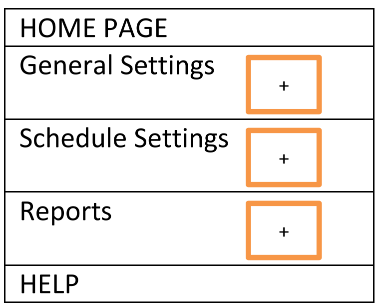
Source: Research

3.2.4 User Interface design diagrams

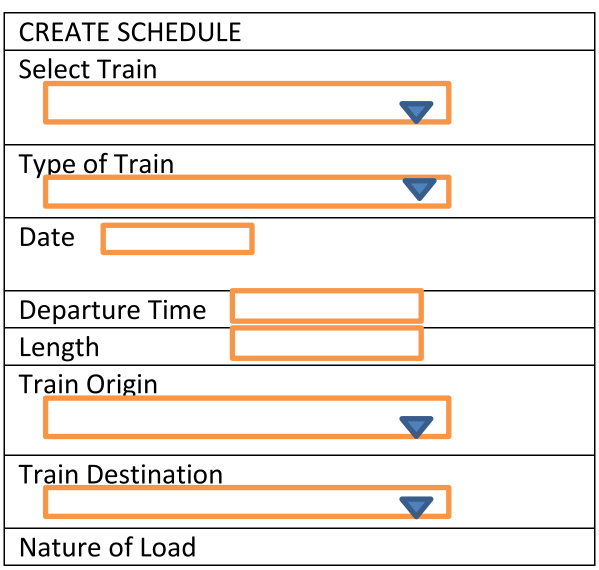
The system will be developed to have a graphical user interface that will initially have users login to the system through the screen below.



Upon login, the home page with tabs for setting up the system as well as capturing data will be enabled as shown below.



Under the schedule setting tab one of the options is to create a schedule which will be achieved through design of screen below.



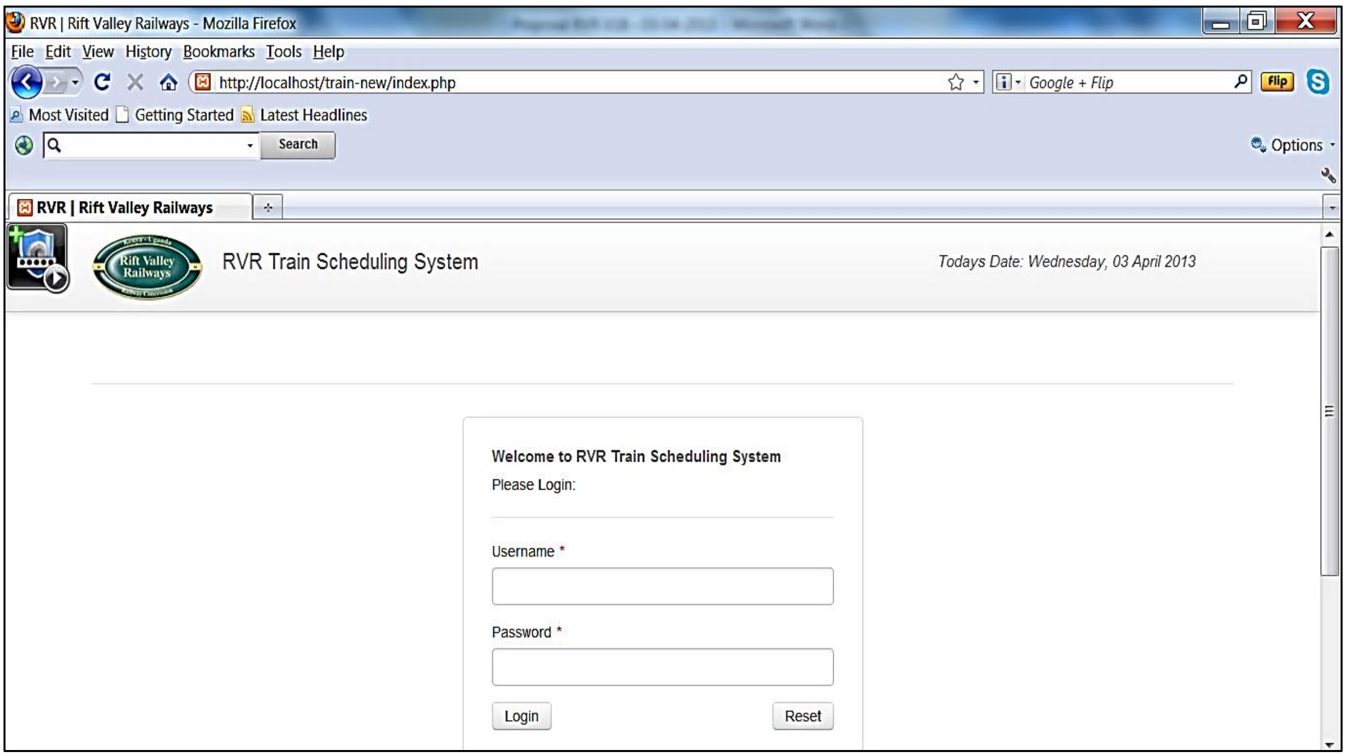
CHAPTER FOUR

SYSTEM IMPLEMENTATION AND TESTING

4.0 System Screens and Inputs

Input to the system is through a graphical user interface presented to the user through a web browser. The system requires authentication as shown in the screen shot below and detailed in the end user manual in Appendix VIII

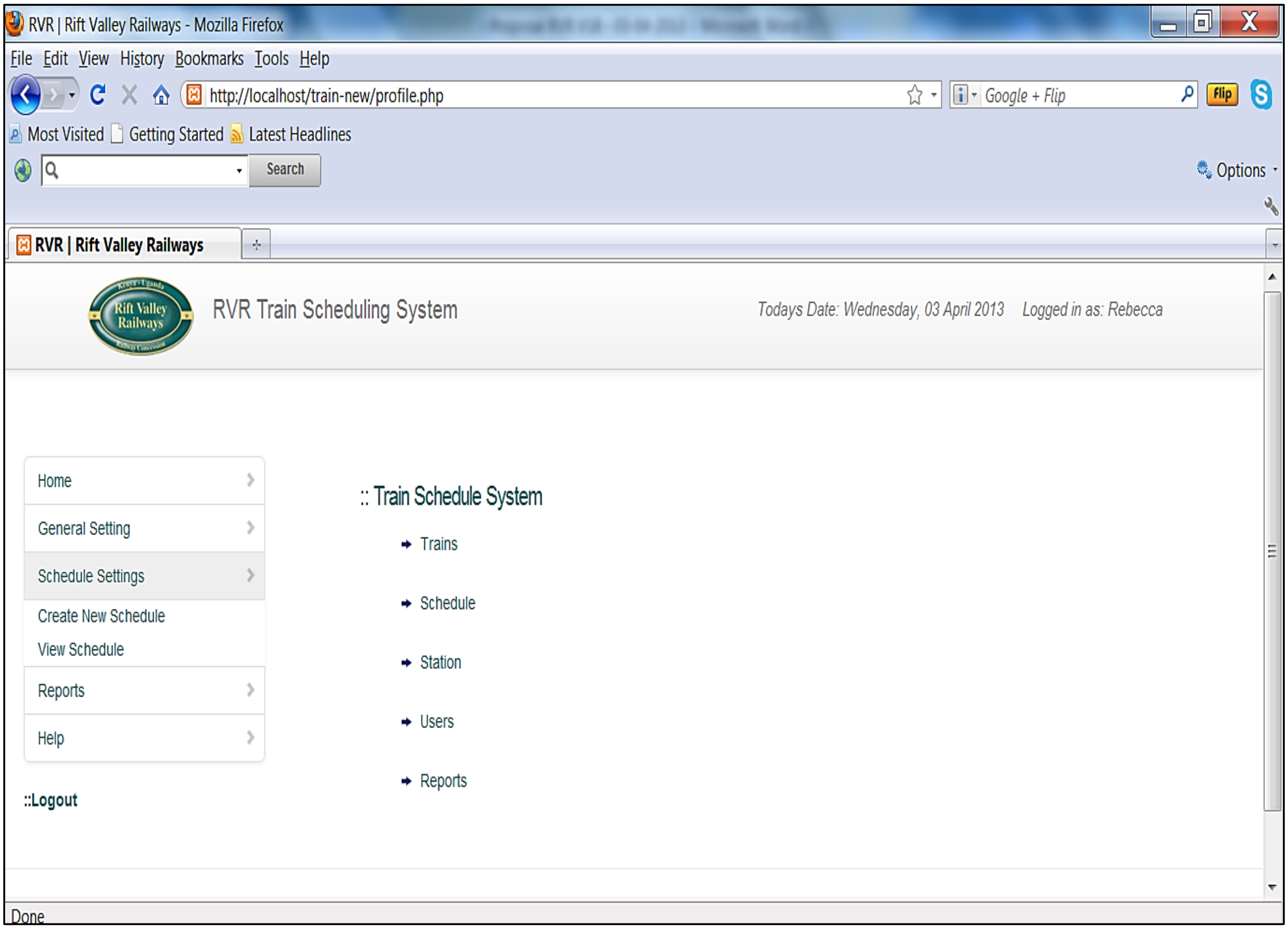
Figure 13: System Login Screen



Source: Research

The main menu of the system upon login brings the screen shot below. The General setting tab allows for setting up Users plus their management and setup/management of system trains and stations. The Schedule setting Tab allows for creation of a schedule capturing all factors as described in the Heuristic model flowchart. It also allows the viewing of this schedule once captured.

Figure 14: Main Menu screen



Source: Research

4.1 TESTING THE PROTOTYPE

The model was tested by:

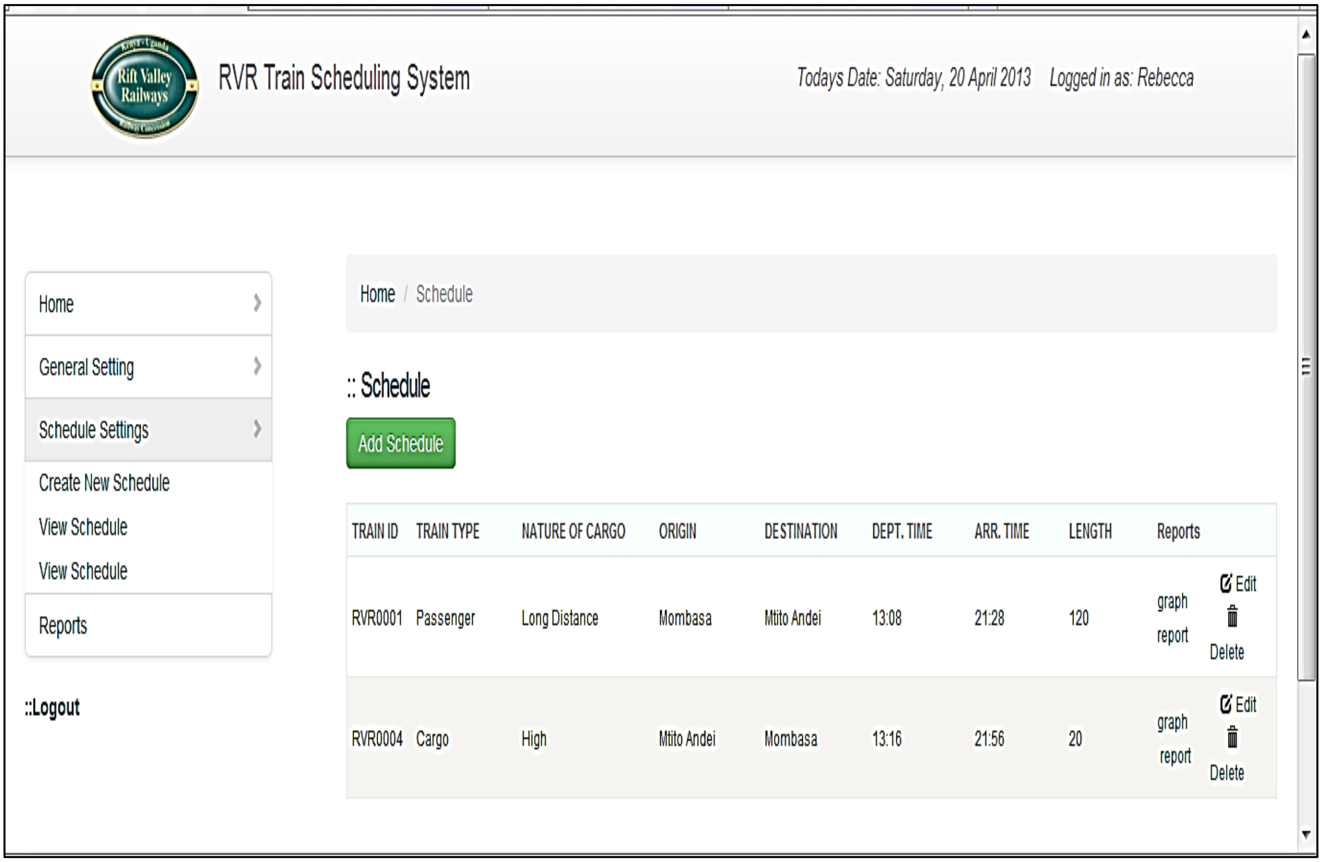
- Reexamining the formulation of the problem and uncovering possible flaws
- Ascertain that all mathematical expressions are dimensionally consistent
    - The detailed system algorithm is detailed in Appendix VI.
- Vary input parameters and check output from model

.

4.2 SYSTEM OUTPUT

Schedules for different options of trains and varied system factors were captured. Once captured using the Heuristic Algorithm the system is able to display trains in order of priority as shown below by clicking the view schedule tab.

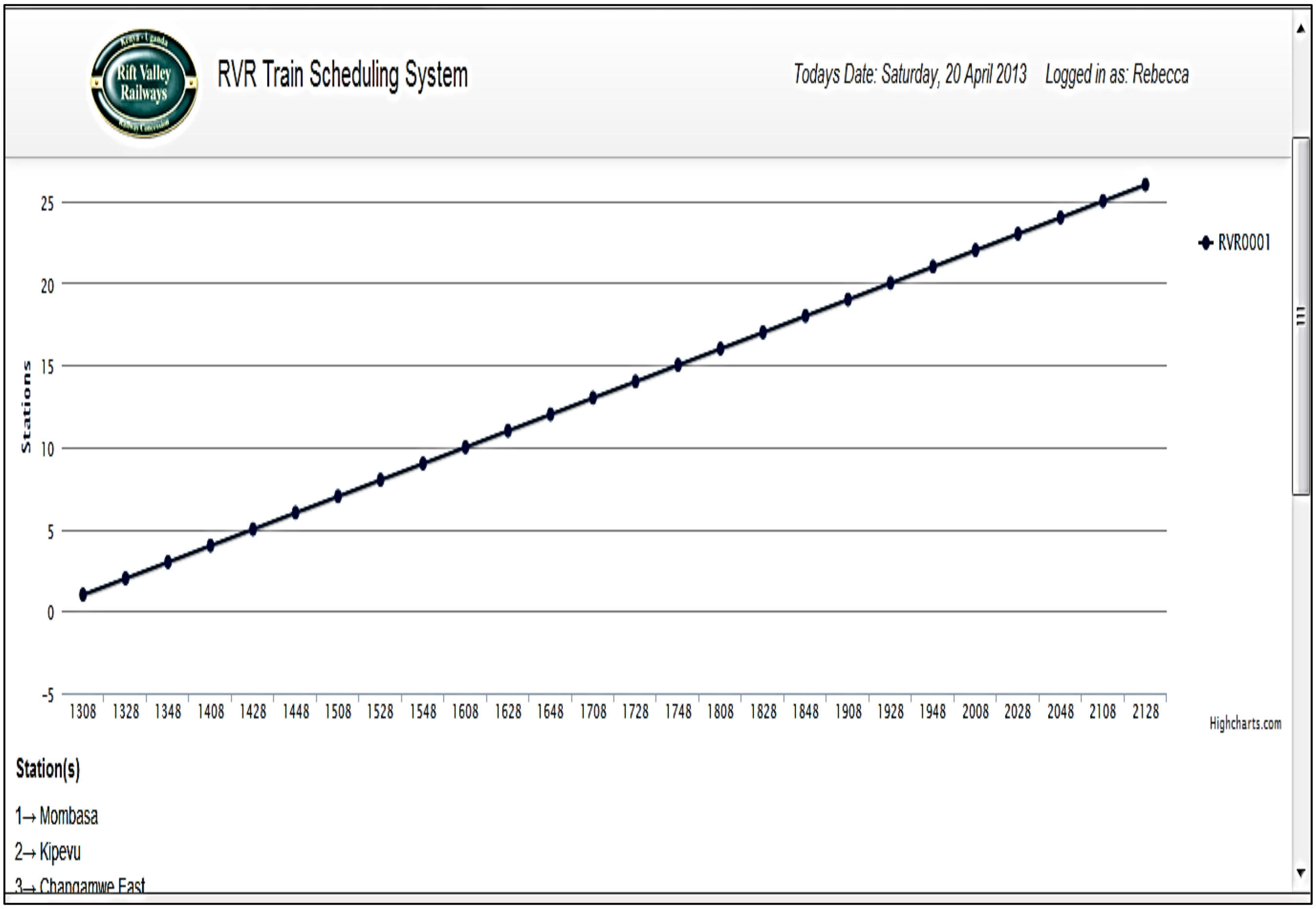
Figure 15: Schedule prioritization screen



Source: Research

One is then able to view the graphical output of each train by clicking on the reports column of a particular train as illustrated below for train RVR0001 in screen shot above.

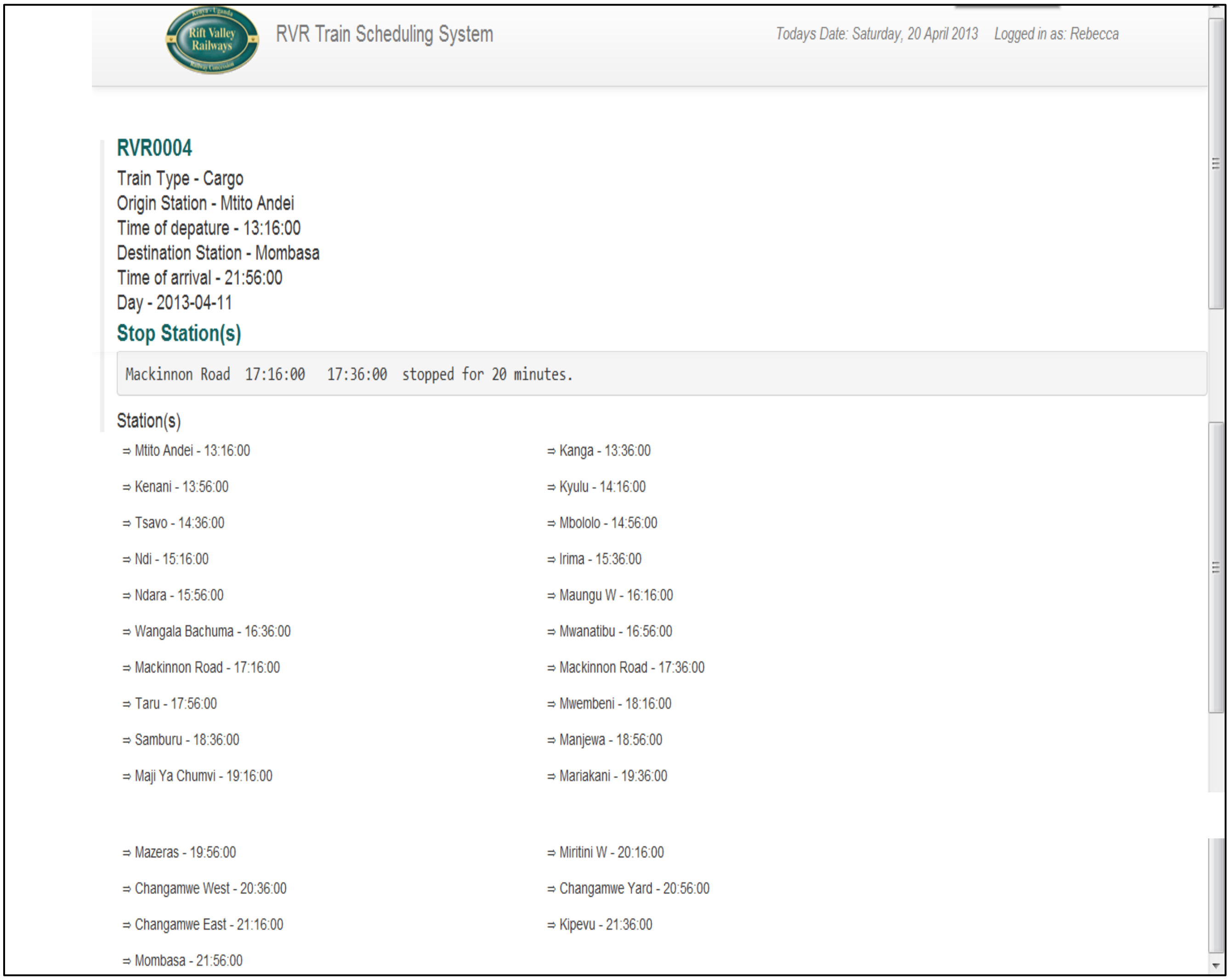
Figure 16: Graphical output of train schedule



Source: Research

Under the report column one is able to get the report of movement at each station giving a narrative of the graphical output in figure 16 above. This is illustrated in report below for train RVR0004 on schedule in figure 15 above.

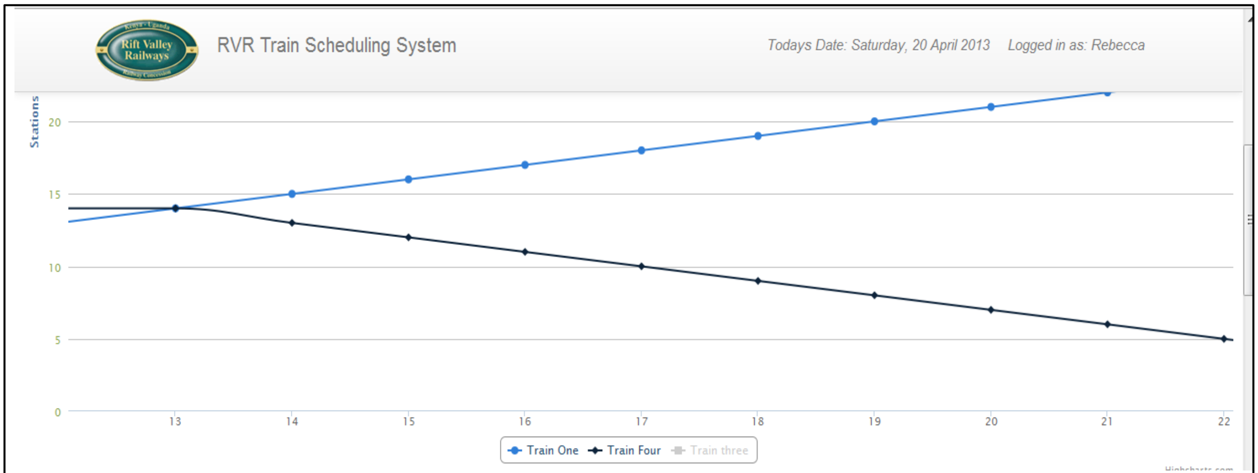
Figure 17: Time report on train movement



Source: Research

Based on schedule shown on figure 15, we are able to get a consolidated graphical image for both trains as shown below:

Figure 18: Consolidated schedule graph



Station Number	Station Name
1	MOMBASA
2	KIPEVU
3	CHANGAMWE EAST
4	CHANGAMWE YARD
5	CHANGAMWE WEST
6	MIRITINI W
7	MAZERAS
8	MARIAKANI
9	MAJI YA CHUMVI
10	MANJEWA
11	SAMBURU
12	MWEMBENI
13	TARU
14	MACKINNON ROAD
15	MWANATIBU
16	WANGALA BACHUMA
17	MAUNGU W
18	NDARA
19	IRIMA
20	NDI
21	MBOLOLO
22	TSAVO
23	KYULU
24	KENANI
25	KANGA
26	MTITO ANDEI

Source: Research

4.3 SYSTEM TESTING AND RESULTS

The system was tested by varying input data and comparing output results to ascertain that the algorithm was working as intended. Schedule was varied with priority factors and output results verified to ensure that intended prioritization works as elaborated below.

4.3.1 Testing Train type priority

Passenger Train always takes priority over Cargo Train, with long distance Passenger Train taking higher priority than Commuter Passenger Train. This was tested by capturing Long distance Passenger train with a Commuter train, and then another long distance passenger train was captured to see the prioritization effect. Finally a cargo train was captured and results below in terms of train type prioritization were got.

Table 16: Passenger Train Prioritization

Schedule Output for - Capture Long distance Passenger Train Mombasa to Mtito Andei

System Priority	**Train ID**	**Train Type**	**Nature of Cargo**	**Origin Station**	**Dest. Station**	**Dept Time**	**Length**
1	0001	Passenger	Long Distance	Mombasa	Mtito Andei	13.09	120

On the same schedule when add a Commuter Passenger Train we get the results below

System Priority	**Train ID**	**Train Type**	**Nature of Cargo**	**Origin Station**	**Dest. Station**	**Dept Time**	**Length**
1	0001	Passenger	Long Distance	Mombasa	Mtito Andei	13.09	120
2	0004	Passenger	Commuter	Mtito Andei	Mombasa	13.07	120

When add another long distance Passenger train we get results below

System Priority	**Train ID**	**Train Type**	**Nature of Cargo**	**Origin Station**	**Dest. Station**	**Dept Time**	**Length**
1	0001	Passenger	Long Distance	Mombasa	Mtito Andei	13.09	120
2	0005	Passenger	Long Distance	Changamwe East	Ndara	09.00	120
3	0004	Passenger	Commuter	Mtito Andei	Mombasa	13.07	120

Source: Research

The Commuter train has been given priority 3 after all the long distance passenger trains.

When add Cargo train to the schedule we get results below

Table 17: Passenger versus Cargo Train prioritization

System Priority	Train ID	Train Type	Nature of Cargo	Origin Station	Dest. Station	Dept Time	Length
1	0001	Passenger	Long Distance	Mombasa	Mtito Andei	13.09	120
2	0005	Passenger	Long Distance	Changamwe East	Ndara	09.00	120
3	0004	Passenger	Commuter	Mtito Andei	Mombasa	13.07	120
4	0006	Cargo	Medium	Mombasa	Kenani	10.00	120

Source: Research

When add a Cargo train this is given priority after the passenger train as is seen in the table above. Thus Long distance passenger train has the highest priority followed by commuter and then cargo train when it comes to prioritization in terms of train type.

4.3.2 Testing train length priority

The train length for trains in 4.3.1 above was varied with a view of determining if the output prioritization would change accordingly. Changing train length and leaving nature of load constant. When you change the length of train 0001 to 60 and leave the nature of load the same we get the following order of prioritization below:

Table 18: Train length prioritization

System Priority	Train ID	Train Type	Nature of Cargo	Origin Station	Dest. Station	Dept Time	Length
1	0005	Passenger	Long Distance	Changamwe East	Ndara	09.00	120
2	0004	Passenger	Commuter	Mtito Andei	Mombasa	13.07	120
3	0001	Passenger	Long Distance	Mombasa	Mtito Andei	13.09	60
4	0006	Cargo	Medium	Mombasa	Kenani	10.00	120

Source: Research

Length of train takes priority over train type, with longer trains being given higher priority. Train 0001 that had the 1st priority is given priority 3 when the length is changed from 120 to 60, the length takes precedence over train type.

Further the Cargo train length was changed to 240 and the results below were achieved.

Table 19: Longer Train prioritization

System Priority	**Train ID**	**Train Type**	**Nature of Cargo**	**Origin Station**	**Dest. Station**	**Dept Time**	**Length**
1	0005	Passenger	Long Distance	Changamwe East	Ndara	09.00	120
2	0004	Passenger	Commuter	Mtito Andei	Mombasa	13.07	120
3	0001	Passenger	Long Distance	Mombasa	Mtito Andei	13.09	60
4	0006	Cargo	Medium	Mombasa	Kenani	10.00	240

Source: Research

The system gives priority to passenger train in order of their length and then cargo trains.

4.3.3 Testing nature of load priority

The system was tested while varying nature of load for cargo train between high, medium and low prioritization options.

Table 20: Nature of Load Prioritization

System Priority	**Train ID**	**Train Type**	**Nature of Cargo**	**Origin Station**	**Dest. Station**	**Dept Time**	**Length**
1	0001	Cargo	High	Mtito Andei	Mombasa	09.13	20

If add another cargo train to the schedule with medium priority and length of 100 we get the results below where length takes higher priority followed by the nature of load as shown below:

System Priority	**Train ID**	**Train Type**	**Nature of Cargo**	**Origin Station**	**Dest. Station**	**Dept Time**	**Length**
1	0004	Cargo	Medium	Mombasa	Mtito Andei	10.12	100
2	0001	Cargo	High	Mtito andei	Mombasa	09.13	20

When: capture cargo train with length of 100 and with high nature of load the high nature of load train takes higher priority than the medium nature of load as shown below.

Table 21: length with High nature of load priority

System Priority	Train ID	Train Type	Nature of Cargo	Origin Station	Dest. Station	Dept Time	Length
1	0005	Cargo	High	Kipevu	Taru	15.06	100
2	0004	Cargo	Medium	Mombasa	Mtito Andei	10.12	100
3	0001	Cargo	High	Mtito andei	Mombasa	09.13	20

Source: Research

When: capture cargo train with length of 100 and with low nature of load the high nature of load train takes higher priority than the medium nature of load and finally the low nature of load as shown below.

Table 22: length with Low nature of load priority

System Priority	Train ID	Train Type	Nature of Cargo	Origin Station	Dest. Station	Dept Time	Length
1	0005	Cargo	High	Kipevu	Taru	15.06	100
2	0004	Cargo	Medium	Mombasa	Mtito Andei	10.12	100
3	0006	Cargo	Low	Manjewa	Irima	19.00	100
4	0001	Cargo	High	Mtito andei	Mombasa	09.13	20

Source: Research

4.3.4 Notification through email

This notification is given to receiving station through an email 5 minutes before arrival time of the train. It reads “Train XXXX is expected to arrive at station ZZ at time HH.MM from Station YY”.

4.4 RESULTS

4.4.1 FROM INTERVIEWS

Train Operations at RVR is predominantly a male profession with most staff having risen over the ranks hence having an all-round knowledge of the different areas of operation. Majority of these staff have Certificate educational level with two thirds of these being station masters. Train Driver position is the major position held in Train operations followed by the Station Master position. Of the total number interviewed only 14.7% mentioned computer as a working tool. 18.7 % of the respondents were of the opinion that the tools were sufficient enough to enable them meet their KPIs this means that majority (81.3%) of the respondents are of the opinion that the tools are insufficient to enable them meet their KPIs. There is high and low season within the Rail business and most of the time the business is run the same. Causes of delay can be attributed to infrastructure/ equipment dilapidation, crossing at stations, communication between train and station and scheduling and dispatching of trains.

4.4.2 FROM SYSTEM

While manipulating the system with the priority variables the following observations were made:

- The passenger train takes highest priority in all the 3 different schedules captured. When capture 2 trains, long distance passenger train and commuter train, passenger train takes priority. When add another long distance passenger train, this still takes priority over the commuter train.
- When varying the length of a train and comparing 2 trains to determine which one will stop and which one will pass at a station, the longer train always takes the higher priority hence passes without stopping.
- When varying nature of load for freight trains, high priority always takes precedence followed by medium then low.

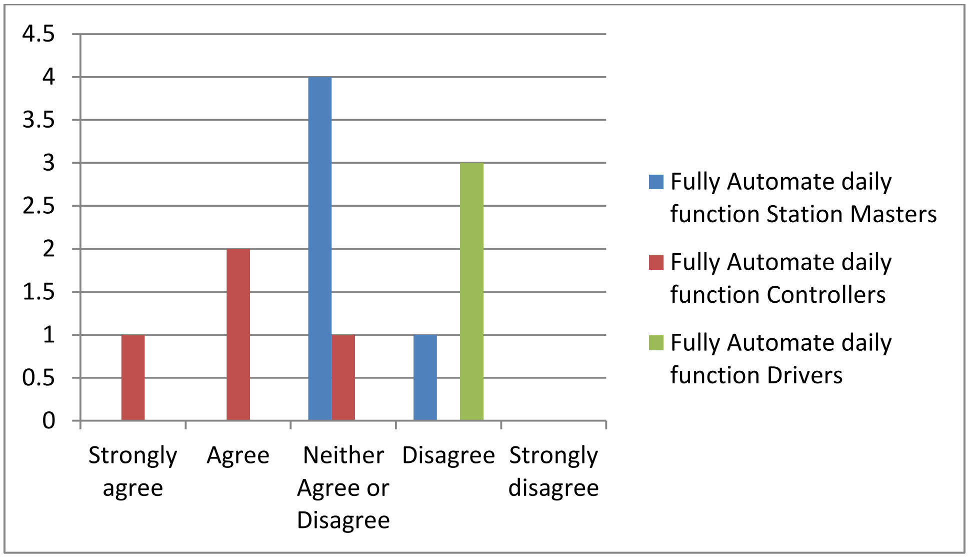
4.4.3 USER EVALUATION

Interviews were carried out on the system with the different stakeholders. The interview is as per Appendix VII and involved 4 Controllers, 5 station masters and 3 train drivers.

Analysis of Section 1 on Relevance of the system

The research sort to find out if the system fully automates the job function of the different stakeholders in train operation process and it was found that 3 out of 4 controllers agree that the system fully automates their daily functions, while 4 out of the 5 station masters interviewed neither agreed nor disagreed and 1 disagreed. All the 3 drivers interviewed disagreed that the system fully automates their daily functions. This is illustrated by the bar chart below:

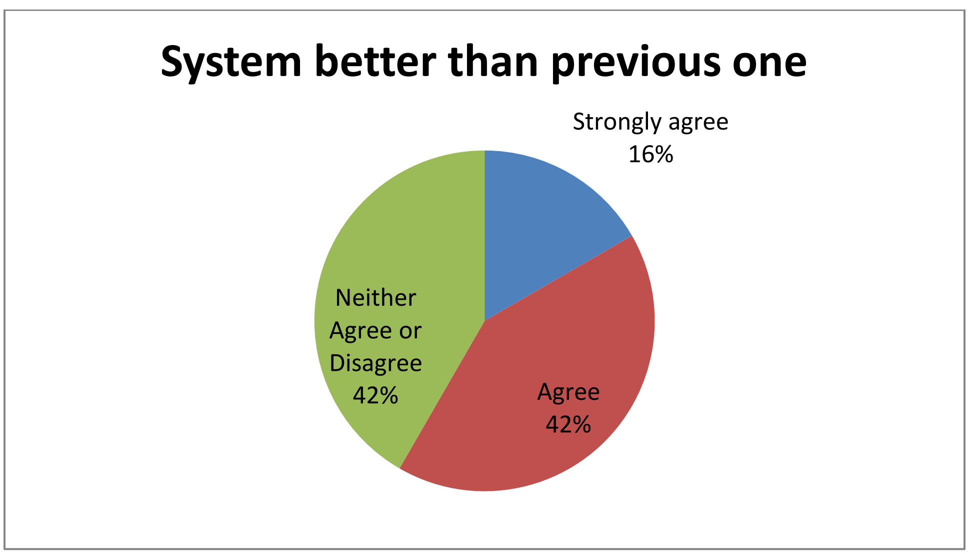
Figure 19: Response on system fully automating job function



Source: Research

The question assessing whether the developed system was better than the previous one found that 16% of the total respondents strongly agree that the system is better than the previous one, while 42% agree. Another 42% neither agree nor disagree as shown in figure 20 below

Figure 20: Distribution of respondents on if system better than previous one



Source: Research

Analysis of Section 2 on System Usage and features

Results of the research show that the system is simple and easy to use as illustrated in figure 21 below

Figure 21: Response on simplicity and ease of system usage

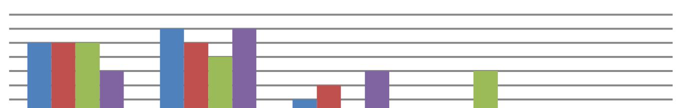
Is system simple and easy to use	Responses	Percent of Cases
Strongly Agree	3	25
Agree	7	58.3
Neither Agree nor Disagree	2	16.7
Disagree	0	0
Strongly Disagree	0	0

Source: Research

The research further established that most respondents neither agreed nor disagreed on whether the system had all the required features for scheduling with 10 out of the 12 respondents neither agreeing nor disagreeing and 2 disagreeing.

The research sought to find out if the system is able to store previous information, enables faster re-scheduling, enables visibility of all train operation areas as well as enable better prioritization compared with the previous system. The results are detailed in figure 22 and graphically summarized in figure 23 below from 12 respondents.

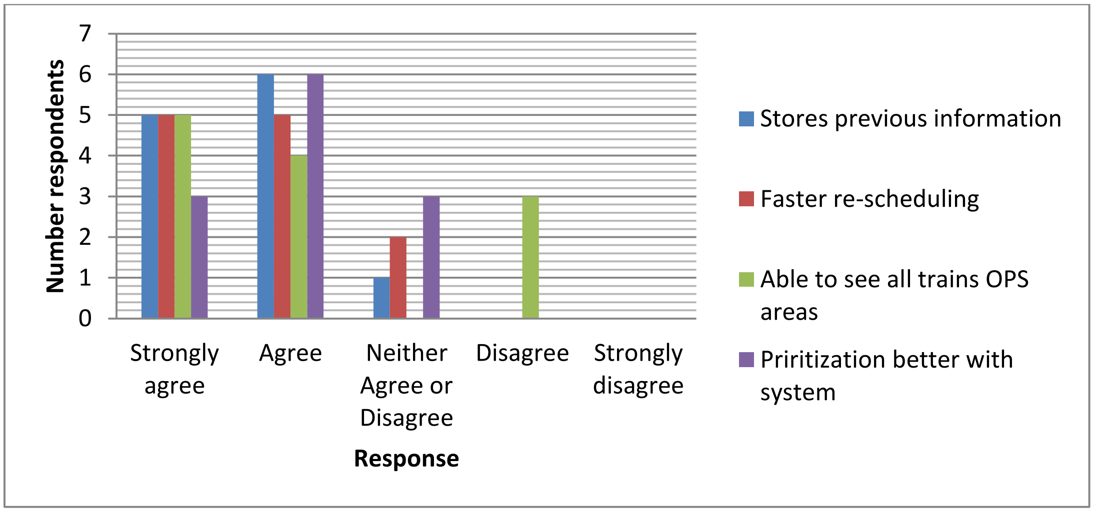
Figure 22: System features analysis



	Strongly agree	Agree	Neither Agree or Disagree	Disagree	Strongly disagree
Stores previous information	5	6	1	0	0
Faster re-scheduling	5	5	2	0	0
Able to see all trains OPS areas	5	4	0	3	0
Priritization better with system	3	6	3	0	0

Source: Research

Figure 23: System feature summary analysis graph

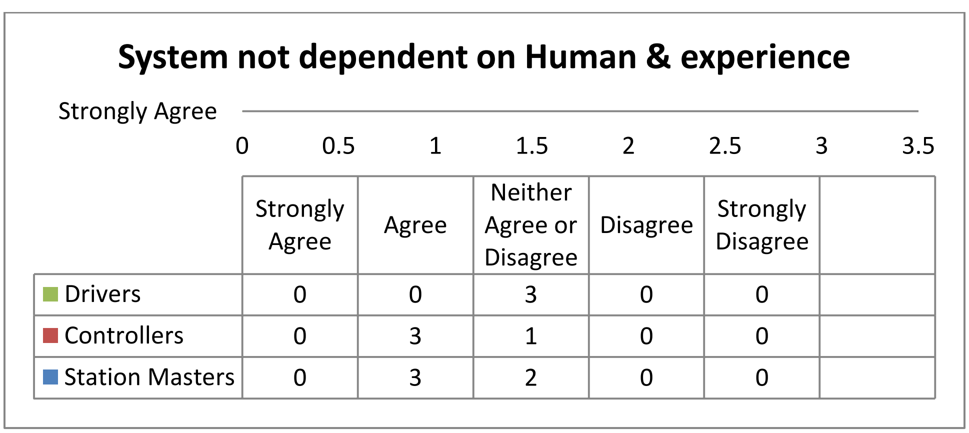


Source: Research

All the respondents agreed that they are able to see other operation areas expect for all the 3 train drivers who disagreed. 75% of the respondents agreed that prioritization was better with the system than with the previous used system while 83.3% of the respondents agreed that the system would achieve faster re-scheduling.

On whether the developed system is not dependent on human and experience, 50% of the respondent agreed that it was not dependent on human and experience and 50% neither agreed nor disagreed. The responses were distributed between the controllers, stations masters and drivers as detailed below.

Figure 24: System dependency on Human & experience analysis



	Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree	
Drivers	0	0	3	0	0	
Controllers	0	3	1	0	0	
Station Masters	0	3	2	0	0	

Source: Research

Analysis of Section 3 on additional operational process or factors that can be used to improve the system

Respondents gave various recommendations regarding additional measures to be taken to improve train operation system. Additional factors that can improve trains operation system suggested by respondents included the following:

1. The system needs to show occupied lines in station so that these are not used for crossing moving trains.
2. Station masters need to be trained on usage of computers
3. The system needs to capture actual loops lengths for each station rather than always have the longest train passing even if it is of a lower priority in terms of other factors.
4. The system needs to input scheduled permanent way (track) maintenance e.g. closure of line, speed restriction.
5. Prioritization of nature of cargo should be more detailed than just high, medium and low to further reduce human decision making while using the system
6. The system should include capturing of reason for re-scheduling and this should be done centrally by one person
7. The system should be made to capture actual train movement and this compared with the planned
8. Need to have computers on train so that drivers have the schedule information.
9. Need to automate handling of points and signals to enable automatic change of line depending on train length and available non-occupied station lines for purposes of crossing.

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATION FOR FURTHER WORK

5.1 DISCUSSION

The aim of the study was to use simulation techniques by providing a prototype to show how automated trains scheduling can for scheduling trains, anticipating detecting and resolving conflicts, for single track railways while using set prioritization factors. The study has effectively tackled the objectives by fully understudying the existing scheduling system at RVR and identifying the challenges. The study has developed a conceptual and system model and simulated the same while showing how the proposed system will solve scheduling conflicts through prioritization.

The key objective of the Research was to use simulation techniques to show how scheduling algorithms can be used to improve operational efficiency at RVR by optimizing the train movement planning process. This was achieved through prioritization of trains as shown in the results of testing the system, where higher priority is given to passenger train than freight train, with longer distance passenger trains being given higher priority than commuter trains as detailed in section 4.3.1. Priority is also based on length of a train whereby when comparing 2 trains; the longer one is given higher priority as is illustrated in the results gotten from testing the system in section 4.3.2. Priority is further given depending on nature of load and this is categorized as high, medium and low and is prioritized accordingly as illustrated by results in section 4.3.3. From this it can be concluded that the system is capable of optimizing train movement process based on prioritization factors that are set by the business. Further the research sort to:

- Understudy and document existing train movement planning system at RVR in order to identify challenges and opportunities within the system. This objective was met through interviews carried out on all stakeholders (refer Appendix IV) involved in trains operation. Existing documents detailed in section 3.1.2 were also understudied as well as desk reviews carried out. The challenges identified included the manual nature of scheduling trains with high dependency on human decision and experience, lack of visibility of entire train operation area while carrying out ones function and manual nature of charting schedules.

- Develop conceptual and system models for train operation system and simulate the model for train operation system. This was achieved through the conceptual model detailed in figure 5 of this document. One of the great achievements from the conceptual model was the algorithm shown in appendix VI that was written to enable development of the system that was simulated to test expected results while varying set priority factors as detailed in section 4.3 of this document. This was made possible through the Heuristic flowchart detailed in Figure 11.
- Recommend optimal train operation system based on existing resources. This objective was not fully achieved as critical operational factors were identified by controllers and station masters on the prototype. This included factoring in recommendations made in section 4.4.3 to ensure better results from the system. However prioritization through formal set factors was achieved by the system while ensuring safe crossing of trains at stations.

User evaluation on the system indicated optimism about the system with 58% agreeing to the fact that the developed system is better than the current system in use. 83% of the interviewed users agree that the system is simple and easy to use. From the analysis 50% of the users agreed that the system is not dependent on human and experience. Out of the 4 controller interviewed 3 agreed to this fact and one neither agreed nor disagreed. During the interview it was evident that users felt that the current system is heavily manual, fully dependent on individual decision/experience with regards to crossing of trains. 9 out of the 12 users interviewed agree that the developed system would be make other operational areas visible. In terms of prioritization the 75% of the users interviewed felt that prioritization is better achieved with the developed system. 83.3% responded that faster re-scheduling would be achieved if they were to use the developed system. From the evaluation a number of gaps were identified as detailed in section 4.4.3 above. These are factors that the users felt need to be incorporated into the developed system to enable better system capabilities, that would enable better output.

The model compares with literature in the Inter-train conflict model that was developed by Ismail Sahin, where a heuristic algorithm for rescheduling trains in a single-track railway was developed with the objective of obtaining better conflict solutions than train dispatchers. It also aimed at getting an optimal or near optimal solutions in a reasonable amount of time. Similarity also lies in the time horizon considered of a single day [Sahin – 1999].

5.2 CONCLUSION

It is possible to automate train scheduling and improve train operation process by introducing prioritization based on business set parameters rather than relying on human experience and decision with regards to prioritization. The research also shows that it is possible to get a cheap solution for scheduling trains while using low cost technologies and open source software. The system would be a starting point for RVR with regards to automated schedules, and is much cheaper than current technologies which it has considered in the near past whose overall cost has been to the tune of $7 million, being quite prohibitive for a company that is currently not breaking even on revenue and expenditure.

The scheduling system will reduce operational cost with respect to human resource overheads by reducing number of controllers and time saved doing re-scheduling in the event that there is a disruption to original schedule, reduce fuel cost as heavier trains will be given priority as well as enhance safety by giving visibility of schedule to all stakeholders, priority to longer trains priority and dangerous goods as well as give email notification on expected arrival of trains to station masters. All this will be with minimal investment.

It is thus conclusive from the research that:

- Train scheduling can be done better at RVR through use of technology to achieve safety, better prioritization with reduced human intervention/decision in train operation
- Formality needs to be introduced in prioritization using heuristic algorithm that has set prioritization factors.
- Simplicity of system is a key success factor in places like RVR where use of technological tools is limited.

Assumptions

- Section running time is upheld by operating trains (fixed-time)
- Connectivity to all system stakeholders will be available

The section running time affected the research as it made it not possible to accurately compare the actual train running times against the output system schedule.

Problems Experienced

- Open source software for Charting the Graphical output is limited in graphing capability, hence could not compare manually previous chart output and optimized output on one chart.
- Delayed relay of email notification due to intermittent network failure at RVR

Limitations and Constraints

- The Prototype developed for Mombasa to Mtito section only out of a total of three sections and one sub section that also includes Mtito Andei – Nairobi section and Nairobi – Kampala section and Nakuru – Kisumu sub-section. This was tested with only 3 previously manually captured schedules.
- Difficulties in getting a charting software led to lengthy delays in completing the project

Recommendations and Further Work

This Project when implemented will be of great benefit in terms of efficient train operation and implementation costs to Rift Valley Railways that is currently on a downward revenue trend businesswise.

It is recommended that further studies be done on:

- Uploading track speed restrictions to scheduling module to enable variable section time hence giving actual section time movement by a train.
- Real time schedule update as actual trains move while interfacing with GPS and GIS systems.
- On Board train computers to relay Control, station messages and section messages regarding trains operations to all stakeholders.
- Alerts forwarding to stations through GSM network to further enhance real time alerts on train expected arrivals at stations.

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APPENDIX I

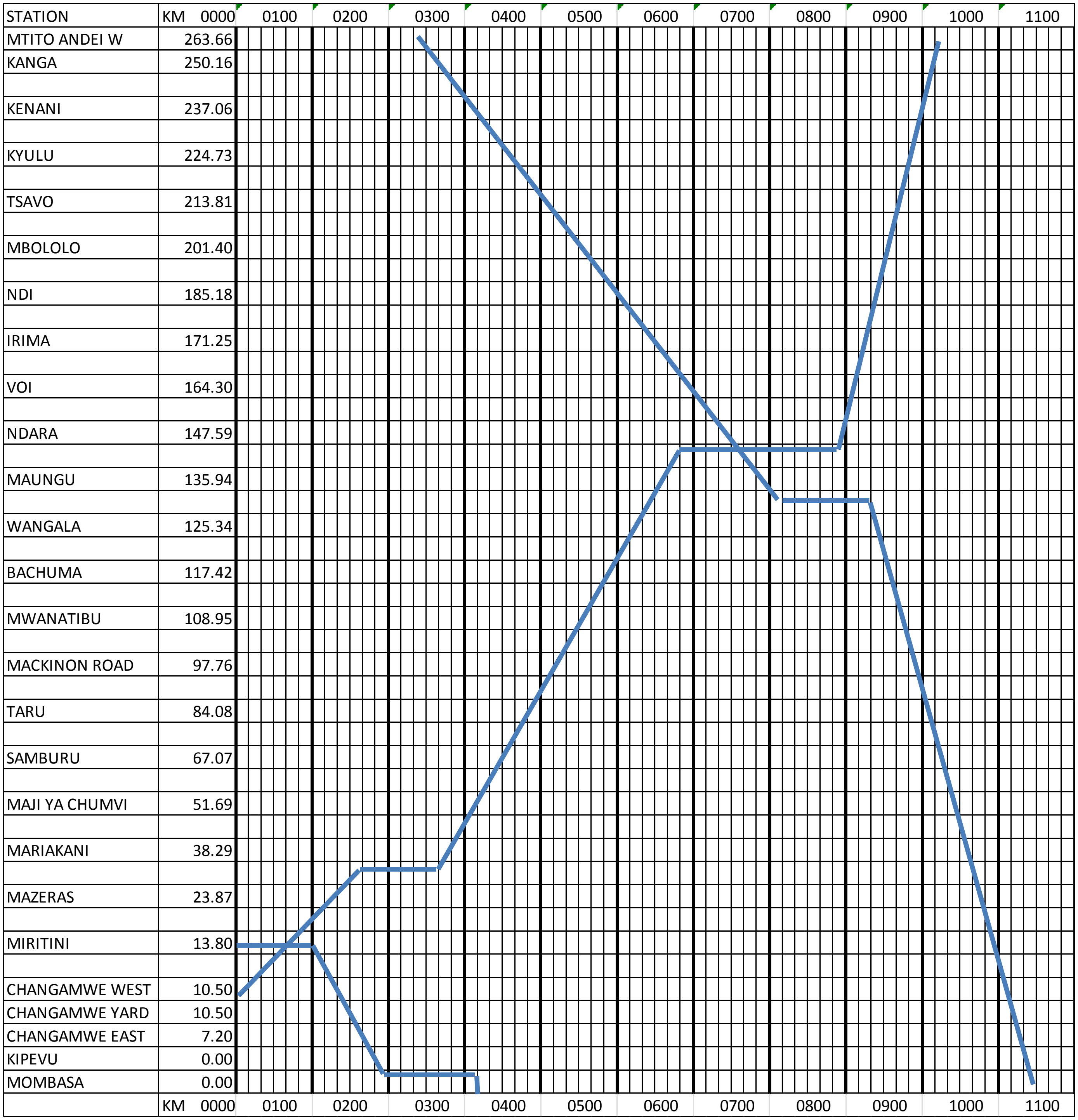
WORKING TIMETABLE (TRAIN PLAN SCHEDULE)

TRAIN PLAN SCHEDULE													
NAIROBI – MOMBASA AND EKV													
TRAIN	LOCO	DEP MSA	DRIVER CGW	TRAINS ASS	DEP MTO	DRIVER MTO	TRAIN ASS	TRAIN	LOCO	DEP NRB	DRIVER NRB	TRAIN ASS	TRAIN ASS MTO
A7J		00.05						A32		02.00			
A33-		03.00						A8J		03.30			
A21		08.00						A34		05.00			
A23-		11.00						A36		09.30			
A9J		12.00						A10J		12.30			
A27		15.00						A22		13.30			
A01		19.00						A26		15.00			
A43-		20.00						A02		19.00			
A45-		22.30						A40		20.00			
AOK		06.45						AOX		16.30			
AOL		18.30						AOY		05.00			
								A8R		02.00			
								AOR		17.50			
								A80		9.00			
NAIROBI-NAKURU-ELDORET													
X33-		02.00						BO8		02.40			
X35-		04.30						X32		03.00			
B4A		03.00											
X23-		10.00						X20		09.00			
X27-		15.00						X22		11.30			
BOA		17.40						X40		16.30			
BO7		18.30						X42		22.00			
X41		20.30						BOR		06.20			
ELDORET – MLB - TOR													
D31		00.00						D30		05.00			
D33		06.00						D22		12.40			
D41		18.00						D24		17.40			
NAKURU – KISUMU AND COMMUTERS													
H29		02.19						H32		05.10			
H31		03.20						H34		11.59			
H33		04.20						HO8		18.30			
H35		11.20						H40		23.00			
H37		13.40											
H43		18.45											
K3A		02.00						KOR		05.45			
K3B		03.00						KOS		06.20			
K3C		09.00						KOT		08.00			
KOA		17.30						KOU					
KOB		18.10						KOV					
KOC		17.35						KOW					
KOD		18.35						KOX					
KOE								KOY					
KOF								KOZ					

Source: OCC RVR

APPENDIX II

Train control chart example



Source: OCC RVR

Interview guide with Planning and Control General Manager and Chief Controller

RIFT VALLEY RAILWAY OPERATION STAFF QUESTIONNAIRE

I am student at University of Nairobi undertaking a Masters degree course in Information Systems. I am conducting research on train operation system. The purpose of this research is to learn how current train operations is carried out and see how best this can be improved through automated systems thus improving the quality of the railway service delivery, operational efficiency and ultimately the business performance at Rift Valley Railways.

Confidentiality

I do hereby guarantee that the information collected is solely for the purpose outlined in the above and any information from the respondents will be treated with utmost confidence and will not be divulged to any third party without the respondent's knowledge and permission.

SECTION A

1. What is the Control and Planning department overview? – brief of what the department supports within the business

2. What is the workflow within the department? – Organogram and brief job functions

3. What is the Service overview of the department?

4. What is the interdependence of the department with other departments?

5. What are policies and documents that govern the department?

6. What are the departments KPIs?

7. What are the current challenges faced within the department? And any suggestions on how to resolve

SECTION B

Use the following Scale in Rating the Applications

1: Strongly Agree; **2:** Agree; **3:** Neither Agree nor Disagree; 4: Disagree; **5**: Strongly Disagree

Item	**Rating (Please Tick One)**				
	1	**2**	**3**	**4**	**5**
1. Service delivery and Efficiency					
a) Do trains follow the prescribed train plan schedule					
b) Do trains arrive and leave on time as per forecasted chart					
c) Do trains take the prescribed time for Daily Turn Round Service					
d) Resources are always available for days business plan					
2. Quality Rate the quality of the service in terms the following i. On time Loading and dispatching of trains ii. On time crossing of trains iii. Delivery to customer on time iv. Good condition of the track					
3. Timeliness a) Timely freight services are being offered					
b) Passenger services to any destination arrive in time					
c) cargo arrive and leave on time					

Interview guide with senior controller, desk controller, station master, train driver, train Guard, Depot Superintendent, Locomotive Inspector

RIFT VALLEY RAILWAY OPERATION STAFF QUESTIONNAIRE

I am student at University of Nairobi undertaking a Masters degree course in Information Systems. I am conducting research on train operation system. The purpose of this research is to learn how current train operations is carried out and see how best this can be improved through automated systems thus improving the quality of the railway service delivery, operational efficiency and ultimately the business performance at Rift Valley Railways.

Confidentiality

I do hereby guarantee that the information collected is solely for the purpose outlined in the above and any information from the respondents will be treated with utmost confidence and will not be divulged to any third party without the respondent's knowledge and permission.

SECTION A: Background Information (Please mark √ in the relevant box)

1. Gender

   Male [ ] **Female [ ]**

2. Kindly tick your education level?

   Certificate [ ]

   Diploma [ ]

   Higher Diploma [ ]

   Bachelors [ ]

   Masters [ ]

   Phd [ ]

3. Tick your Job position

   Senior Controller [ ]

   Desk Controller [ ]

Station Master [ ]

Train Driver [ ]

Train guard [ ]

Depot Superintendent [ ]

Locomotive Inspector[ ]

4. What is the period you have served in the current position?

   < 1 Year [ ] 1-2 Years [ ] 2-4 Years [ ] 5-6 Years [ ] > 6 Years [ ]

5. For how many years have you worked with RVR

   < 1 Year [ ] 1-2 Years [ ] 2-4 Years [ ] 5-6 Years [ ] > 6 Years [ ]

6. Did you move from Kenya Railways Corporation to RVR?

   Yes [ ] No [ ]

7. For how many years did you work with Kenya Railways Corporation

   0 Year [ ] 1-5 Years [ ] 6-10 Years [ ] 11-15 Years [ ] > 15 Years [ ]

8. Please specify the positions you have held while at Kenya Railways Corporation (*Please fill your response in space provided below)*

   ……………………………………………………………………………

   ……………………………………………………………………………

   ……………………………………………………………………………

   ……………………………………………………………………………

SECTION B: Work Environment

9. Please specify what documents/tools you use to support your job function. (*Please fill your response in space provided below*)

   ………………………………………………………………………

   ………………………………………………………………………

   ………………………………………………………………………

   ………………………………………………………………………

10. Are these tools sufficient to enable you meet your KPIs?

    Yes [ ] No [ ]

11. Are there high and low business seasons?

    Yes [ ] No [ ]

12. Is there a difference in work plan during high and low season?

    Yes [ ] No [ ]

13. Please tick causes of delay of train arrival/dispatching time

    Rolling stock availability [ ]

    Rolling stock condition [ ]

    Crossing at stations [ ]

    Daily Turn Round Service [ ]

    Communication between train & stations [ ]

    Scheduling & dispatching of trains [ ]

    Others *(Please specify)*…………………………………………………………..

    ………………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

14. Is scheduling and dispatching of train re-organized after delay in arrival/dispatching times?

    Yes [ ] No [ ]

15. Specify below how you manage train delays to meet timings close to initial set schedule (*Please fill your response in space provided below*)

    ………………………………………………………………………

    ………………………………………………………………………

    ………………………………………………………………………

    ………………………………………………………………………

16. Briefly specify below challenges you currently experience in trains (*Please fill your response in space provided below*)

    ………………………………………………………………………

    ………………………………………………………………………

    ………………………………………………………………………

    ………………………………………………………………………

17. Are there any additional operational process/s or factors that can improve trains operation? (*Please fill your response in space provided below*)

    ………………………………………………………………………

    ………………………………………………………………………

    ………………………………………………………………………

SECTION C: Service Delivery, Efficiency, Quality and Timeliness

18. To what extent do you agree with the statements below on service delivery, efficiency, quality and timeliness of trains operation at RVR

Use the following Scale in Rating the Applications and **mark √ where appropriate**
1: Strongly Agree; **2:** Agree; **3:** Neither Agree nor Disagree; 4: Disagree; **5**: Strongly Disagree

Item	Rating (Please Tick One)				
	1	2	3	4	5
Trains always follow the prescribed train plan schedule					
Trains arrive on time as per forecasted chart					
Trains leave on time as per forecasted chart					
Trains take the prescribed time for Daily Turn Round Service					
Resources are always available for days business plan					
Load carried affects speed hence arrival time					
Section run time is static for all trains					
Train priority determines first in first out from station					
Length of the train determines restriction to any line					
Two trains can occupy a section in same direction at any one time					
There is a minimum time before a train can follow another into a section					
Most Conflicts occur due to poor planning					
There are process that ensure safety of trains operation					
There are ICT systems that ensure safety of train operations					
Train delays affect overall business performance targets					
Controllers experience determines accuracy of daily schedules					
The scheduling and dispatching of trains is manually done					
There are no tools of assessing the quality of timetables/ schedules					
There is always adjustment to original timetables					
An adjustment to original timetables is determined by individual section controllers.					

Loading and dispatching of trains are always on time Products are always delivered to customer on time					
Timely freight services are being offered					
Passenger services to destination arrive in time					
cargo arrive and leave on time					
Condition of turnout at stations often affect crossing					
crossing of trains occur on time as required					
Railway tracks are in good condition					

END

(THANK YOU FOR YOUR VALIABLE TIME AND INPUT TOWARDS THIS RESEARCH)

Appendix IV

Sample Population

Category	Population	Sample Size
GM Control & Planning	1	1
Chief Controller	1	1
Senior Controllers	4	4
Desk Controllers	12	12
Loco Controllers	4	4
Station Masters	101	28
Train Drivers	106	30
Train Guards	56	8
Loco Inspectors	8	8
Depot Superintendent	4	4
Total	**297**	**100**

Appendix V

Past Train Schedules

Train Schedule for 1st July, 2012.

Day	Train	Origin Station	Departure Time	Destination Station	Arrival Time	Waiting time at departure station
1/7/2012	A33/AF71	CGW	02.35	CGW West	02.50	
		CGW West	02.50	MTI	03.00	0
		MTI	03.00	MRS	03.30	0
		MRS	03.30	MKI	04.02	0
		MKI	04.02	MCV	04.40	0.64
		MCV	05.04	SBU	05.50	3.6
		SBU	09.10	MAK	13.03	1.52
		MAK	14.55	BMA	15.30	0.28
		BMA	15.58	MGU	16.20	0
		MGU	16.20	VOI	17.10	0
		VOI	17.10	NDI	17.40	0
		NDI	17.40	MOL	18.02	0
		MOL	18.02	SVO	18.22	0.83
		SVO	19.05	KNI	19.55	0
		KNI	19.55	MTO	21.55	0
TOTAL WAITING TIME AT DESTINATION STATION						**6.87**

Day	Train	Origin Station	Departure Time	Destination Station	Arrival Time	Waiting time at departure station
1/7/2012	A33/AF71	MSA	4.2	CGW East	4.55	
		CGW East	4.55	CGW Yard	5	0
		CGW Yard	5.38	CGW West	5.5	0.38
		CGW	5.5	MTI	6	0

		West				
		MTI	6	MRS	6.35	0
		MRS	6.35	MKI	7.08	0
		MKI	7.08	MCV	7.46	0
		MCV	9.55	SBU	10.25	2.09
		SBU	14.25	MAK	15.3	4
		MAK	15.35	BMA	16.06	0.05
		BMA	16.24	MGU	16.5	0.18
		MGU	17.18	VOI	17.55	0.68
		VOI	17.55	NDI	18.2	0
		NDI	18.35	MOL	18.55	0.15
		MOL	19.36	SVO	20.02	0.81
		SVO	20.02	KNI	20.47	0
		KNI	23.05	MTO	23.45	2.58
TOTAL WAITING TIME AT DEPARTURE STATION						**10.54**

Day	Train	Origin Station	Departure Time	Destination Station	Arrival Time	Waiting time at departure station
01-07-2012	A01	MSA	19	CGW East	19.17	
		CGW East	19.17	CGW Yard	19.22	0
		CGW Yard	19.22	CGW West	19.3	0
		CGW West	19.3	MTI	19.35	0
		MTI	19.35	MRS	20	0
		MRS	20.02	MKI	20.32	0.02
		MKI	20.34	MCV	21.1	0.02
		MCV	21.1	SBU	21.4	0
		SBU	21.55	MAK	22.53	0.15
		MAK	23.28	BMA		0.75
TOTAL WAITING TIME AT DEPARTURE STATION						**0.94**

Train Schedule for 1st July 2012

Day	Train	Origin Station	Departure Time	Destination Station	Arrival Time	Waiting time at departure station
01-07-2012	A3S/EA63	MTO	10.5	KNI	11.34	
		KNI	11.35	SVO	12.2	0.01
		SVO	12.2	MOL	12.46	0
		MOL	12.46	NDI	13.1	0
		NDI	13.2	VOI	13.4	0.1
		VOI	14.3	MGU	15.15	0.9
		MGU	15.15	BMA	15.58	0
		BMA	16.13	MAK	16.48	0.55
		MAK	16.48	SBU	18.1	0
		SBU	19.18	MCV	20.05	1.08
		MCV	21.2	MKI	22.13	1.15
		MKI	22.13	MRS	22.55	0
		MRS	22.55	MTI	23.25	0
		MTI	23.25	CGW West	23.35	0
		CGW West	23.35	CGW Yard	23.45	0
TOTAL WAITING TIME AT DEPARTURE STATION						**3.78**

Day	Train	Origin Station	Departure Time	Destination Station	Arrival Time	Waiting time at departure station
01-07-2012	A9R	MTO	16.1	KNI	16.45	
		KNI	16.45	SVO	17.2	0
		SVO	17.2	MOL	17.4	0
		MOL	18.07	NDI	18.25	0.67
		NDI	18.25	VOI	18.5	0
		VOI	19	MGU	19.32	0.5
		MGU	19.32	BMA	19.5	0
		BMA	22.2	MAK	22.49	2.7
TOTAL WAITING TIME AT DEPARTURE STATION						**3.87**

APPENDIX VI

SYSTEM ALGORITHM

```
<?PHP

	//$total_counter = 0;

	$data_origin = array();

	$query = "SELECT id, origin, count(origin) as count_origin, start_time, submitted_date FROM scheduler group by origin having count(origin) > 1 AND  submitted_date = DATE(NOW())";

	$result = mysql_query($query) or die("Couldn't execute query $query");

do {

	$id = $data[ 'id' ];

	$stations = $data[ 'origin' ];

//for($i = 0; $i = $total_counter; $i++){

	if($stations = 1){

		$count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler where id = '".$id."' and origin = $stations order by priority_id desc";

		$count_result = mysql_query($count_query) or die("Couldn't execute query $query");

		while($modified = mysql_fetch_array($count_result)){

		$newid = $modified[ 'count(id' ];

		$start_time = $modified[ 'start_time' ];

		$data_origin[] = $modified;

		$first = $modified[0]['id'];

		$new_start_time = $start_time + 15;

		$first_item = $first;


			if (!$counter++){

			$first_item = $first;
```

```
$update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$new_start_time."' where id = $newid");

$update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$start_time."' where id = $first_item");

}

}

}

if($stations = 2){

$count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler
where id = '".$id."' and origin = $stations order by priority_id desc";

$count_result = mysql_query($count_query) or die("Couldn't execute query $query");

while($modified = mysql_fetch_array($count_result)){

$newid = $modified[ 'count(id' ];

$start_time = $modified[ 'start_time' ];

$data_origin[] = $modified;

$first = $modified[0]['id'];

$new_start_time = $start_time + 15;

$first_item = $first;


if (!$counter++){

$first_item = $first;

$update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$new_start_time."' where id = $newid");

$update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$start_time."' where id = $first_item");


}

}
```

```
}

if($stations = 3){

        $count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler
where id = '".$id."' and origin = $stations order by priority_id desc";

        $count_result = mysql_query($count_query) or die("Couldn't execute query $query");



        while($modified = mysql_fetch_array($count_result)){

        $newid = $modified[ 'count(id' ];

        $start_time = $modified[ 'start_time' ];

        $data_origin[] = $modified;

        $first = $modified[0]['id'];



        $new_start_time = $start_time + 15;

                $first_item = $first;



                if (!$counter++){

                $first_item = $first;

                $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$new_start_time."' where id = $newid");

                $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$start_time."' where id = $first_item");



                }

        }

}

if($stations = 4){
```

```
            $count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler where id = '".$id."' and origin = $stations order by priority_id desc";

            $count_result = mysql_query($count_query) or die("Couldn't execute query $query");


            while($modified = mysql_fetch_array($count_result)){

            $newid = $modified[ 'count(id' ];

            $start_time = $modified[ 'start_time' ];

            $data_origin[] = $modified;

            $first = $modified[0]['id'];


            $new_start_time = $start_time + 15;

                $first_item = $first;


                if (!$counter++){

                $first_item = $first;

                $update_query = mysql_query("UPDATE scheduler SET new_start_time = '".$new_start_time."' where id = $newid");

                $update_query = mysql_query("UPDATE scheduler SET new_start_time = '".$start_time."' where id = $first_item");


                }

            }

        }

        if($stations = 5){

            $count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler where id = '".$id."' and origin = $stations order by priority_id desc";

            $count_result = mysql_query($count_query) or die("Couldn't execute query $query");
```

```
		while($modified = mysql_fetch_array($count_result)){

		$newid = $modified[ 'count(id' ];

		$start_time = $modified[ 'start_time' ];

		$data_origin[] = $modified;

		$first = $modified[0]['id'];



		$new_start_time = $start_time + 15;

			$first_item = $first;



			if (!$counter++){

			$first_item = $first;

			$update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$new_start_time."' where id = $newid");

			$update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$start_time."' where id = $first_item");



			}

		}

	}

	if($stations = 6){

		$count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler
where id = '".$id."' and origin = $stations order by priority_id desc";

		$count_result = mysql_query($count_query) or die("Couldn't execute query $query");



		while($modified = mysql_fetch_array($count_result)){

		$newid = $modified[ 'count(id' ];
```

```
                    $start_time = $modified[ 'start_time' ];

                    $data_origin[] = $modified;

                    $first = $modified[0]['id'];


                    $new_start_time = $start_time + 15;

                              $first_item = $first;


                              if (!$counter++){

                              $first_item = $first;

                              $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$new_start_time."' where id = $newid");

                              $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$start_time."' where id = $first_item");


                              }

                    }

          }

          if($stations = 7){

                    $count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler
where id = '".$id."' and origin = $stations order by priority_id desc";

                    $count_result = mysql_query($count_query) or die("Couldn't execute query $query");


                    while($modified = mysql_fetch_array($count_result)){

                    $newid = $modified[ 'count(id' ];

                    $start_time = $modified[ 'start_time' ];

                    $data_origin[] = $modified;

                    $first = $modified[0]['id'];
```

```
			$new_start_time = $start_time + 15;

				$first_item = $first;



				if (!$counter++){

				$first_item = $first;

				$update_query = mysql_query("UPDATE scheduler SET new_start_time = 
'".$new_start_time."' where id = $newid");

				$update_query = mysql_query("UPDATE scheduler SET new_start_time = 
'".$start_time."' where id = $first_item");



				}

			}

		}

		if($stations = 8){

			$count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler 
where id = '".$id."' and origin = $stations order by priority_id desc";

			$count_result = mysql_query($count_query) or die("Couldn't execute query $query");



			while($modified = mysql_fetch_array($count_result)){

			$newid = $modified[ 'count(id' ];

			$start_time = $modified[ 'start_time' ];

			$data_origin[] = $modified;

			$first = $modified[0]['id'];



			$new_start_time = $start_time + 15;

				$first_item = $first;
```

```
                        if (!$counter++){

                        $first_item = $first;

                        $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$new_start_time."' where id = $newid");

                        $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$start_time."' where id = $first_item");



                        }

                }

        }

        if($stations = 9){

                $count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler
where id = '".$id."' and origin = $stations order by priority_id desc";

                $count_result = mysql_query($count_query) or die("Couldn't execute query $query");


                while($modified = mysql_fetch_array($count_result)){

                $newid = $modified[ 'count(id' ];

                $start_time = $modified[ 'start_time' ];

                $data_origin[] = $modified;

                $first = $modified[0]['id'];


                $new_start_time = $start_time + 15;

                        $first_item = $first;


                        if (!$counter++){

                        $first_item = $first;
```

```
                    $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$new_start_time."' where id = $newid");

                    $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$start_time."' where id = $first_item");



                    }

            }

    }

    if($stations = 10){

            $count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler
where id = '".$id."' and origin = $stations order by priority_id desc";

            $count_result = mysql_query($count_query) or die("Couldn't execute query $query");



            while($modified = mysql_fetch_array($count_result)){

            $newid = $modified[ 'count(id' ];

            $start_time = $modified[ 'start_time' ];

            $data_origin[] = $modified;

            $first = $modified[0]['id'];



            $new_start_time = $start_time + 15;

                    $first_item = $first;



                    if (!$counter++){

                    $first_item = $first;

                    $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$new_start_time."' where id = $newid");

                    $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$start_time."' where id = $first_item");
```

```
                    }
                }
            }
            if($stations = 11){
                $count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler
where id = '".$id."' and origin = $stations order by priority_id desc";
                $count_result = mysql_query($count_query) or die("Couldn't execute query $query");

                while($modified = mysql_fetch_array($count_result)){
                $newid = $modified[ 'count(id' ];
                $start_time = $modified[ 'start_time' ];
                $data_origin[] = $modified;
                $first = $modified[0]['id'];

                $new_start_time = $start_time + 15;
                    $first_item = $first;

                    if (!$counter++){
                    $first_item = $first;
                    $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$new_start_time."' where id = $newid");
                    $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$start_time."' where id = $first_item");

                    }
                }
```

```
}

if($stations = 12){

        $count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler
where id = '".$id."' and origin = $stations order by priority_id desc";

        $count_result = mysql_query($count_query) or die("Couldn't execute query $query");


        while($modified = mysql_fetch_array($count_result)){

        $newid = $modified[ 'count(id' ];

        $start_time = $modified[ 'start_time' ];

        $data_origin[] = $modified;

        $first = $modified[0]['id'];


        $new_start_time = $start_time + 15;

                $first_item = $first;


                if (!$counter++){

                $first_item = $first;

                $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$new_start_time."' where id = $newid");

                $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$start_time."' where id = $first_item");


                }

        }

}

if($stations = 13){
```

```
		$count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler where id = '".$id."' and origin = $stations order by priority_id desc";

		$count_result = mysql_query($count_query) or die("Couldn't execute query $query");


		while($modified = mysql_fetch_array($count_result)){

		$newid = $modified[ 'count(id' ];

		$start_time = $modified[ 'start_time' ];

		$data_origin[] = $modified;

		$first = $modified[0]['id'];


		$new_start_time = $start_time + 15;

			$first_item = $first;


			if (!$counter++){

			$first_item = $first;

			$update_query = mysql_query("UPDATE scheduler SET new_start_time = '".$new_start_time."' where id = $newid");

			$update_query = mysql_query("UPDATE scheduler SET new_start_time = '".$start_time."' where id = $first_item");


			}

		}

	}

	if($stations = 14){

		$count_query = "select id,origin,start_time,priority_id,submitted_date from scheduler where id = '".$id."' and origin = $stations order by priority_id desc";

		$count_result = mysql_query($count_query) or die("Couldn't execute query $query");
```

```
                    while($modified = mysql_fetch_array($count_result)){

                    $newid = $modified[ 'count(id' ];

                    $start_time = $modified[ 'start_time' ];

                    $data_origin[] = $modified;

                    $first = $modified[0]['id'];



                    $new_start_time = $start_time + 15;

                              $first_item = $first;



                              if (!$counter++){

                              $first_item = $first;

                              $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$new_start_time."' where id = $newid");

                              $update_query = mysql_query("UPDATE scheduler SET new_start_time =
'".$start_time."' where id = $first_item");



                              }

                    }

          }

//}



} while ($data = mysql_fetch_array($result));




?>
```

APPENDIX VII

USER TESTING

1. Tick your Job position
   Senior Controller **[ ]**
   Desk Controller **[ ]**
   Station Master **[ ]**
   Train Driver **[ ]**

2. Use the following Scale in Rating the Applications

1: Strongly Agree; **2:** Agree; **3:** Neither Agree nor Disagree; 4: Disagree; **5**: Strongly Disagree

Item	**Rating (Please Tick One)**				
	1	**2**	**3**	**4**	**5**
1. System Relevance					
a) Does the system fully automate your daily function					
b) Is the system better than the previous one (manual)					
2. System Usage/features i. System is simple and easy to use ii. System has all required features for scheduling iii. Enables better achievement of set KPIs iv. System is able to store previous schedule information v. Faster re-scheduling with system vi. Able to see other train Operation areas vii. Prioritization better with system viii. System not dependent on human and experience					

3. Are there any additional operational process/s or factors that can improve trains operation system? (*Please fill your response in space provided below*)

………

………

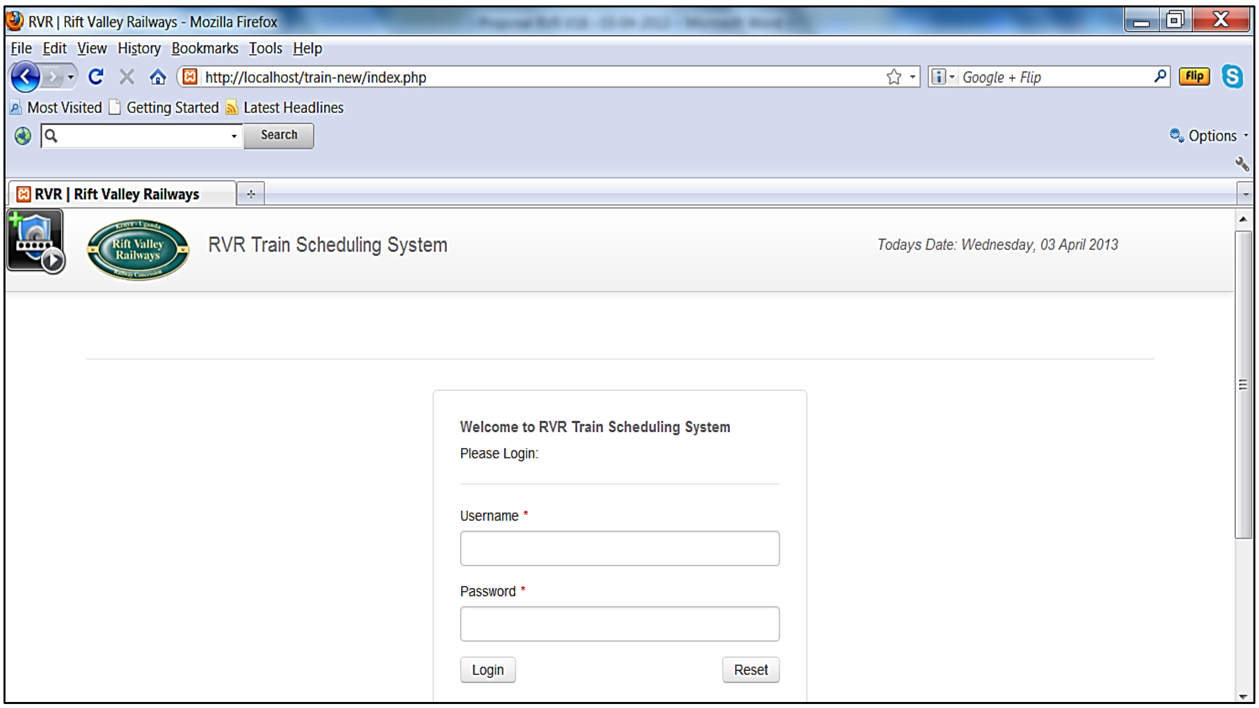
………

Appendix VIII

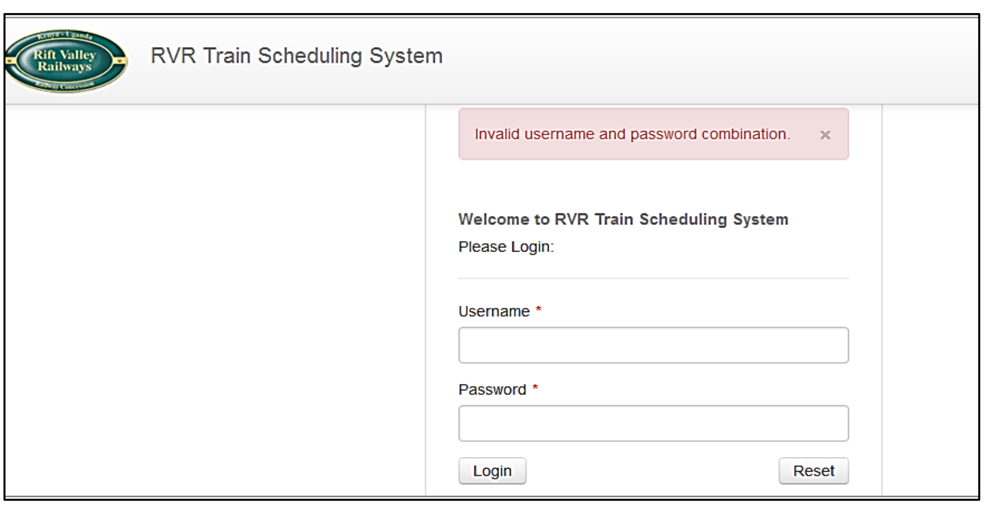
End User Manual

<u>System Login</u>

1. Click onto the Scheduling System Icon on the desktop
2. The login screen screen below appears



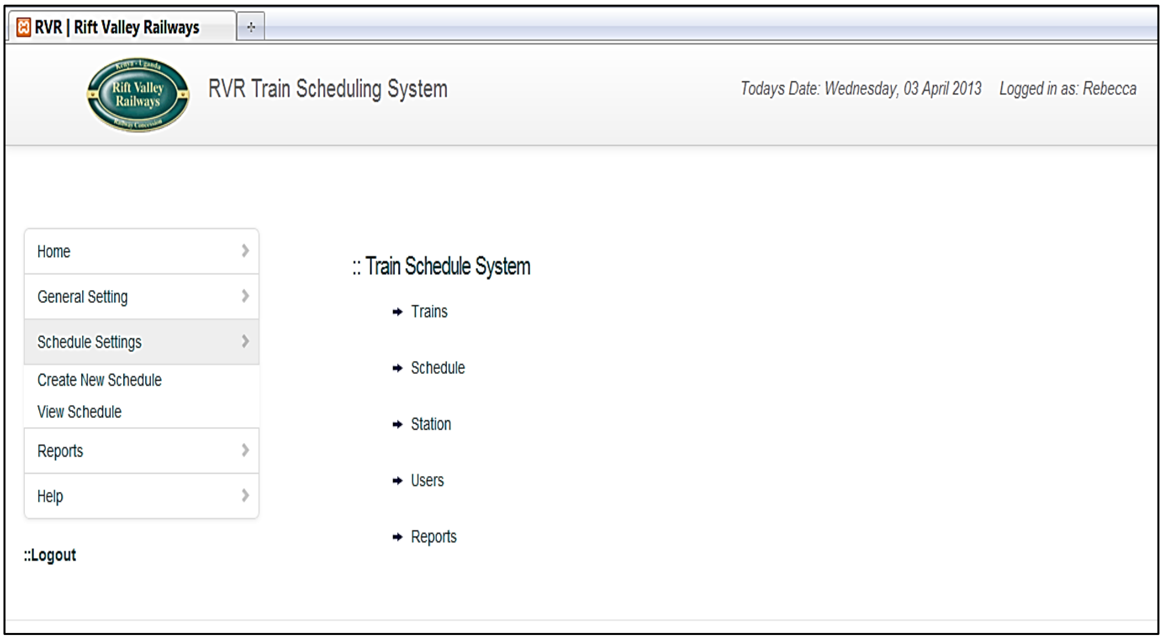
Enter your user name and password and click the Logon button. If you use the wrong user name or password the screen below will appear



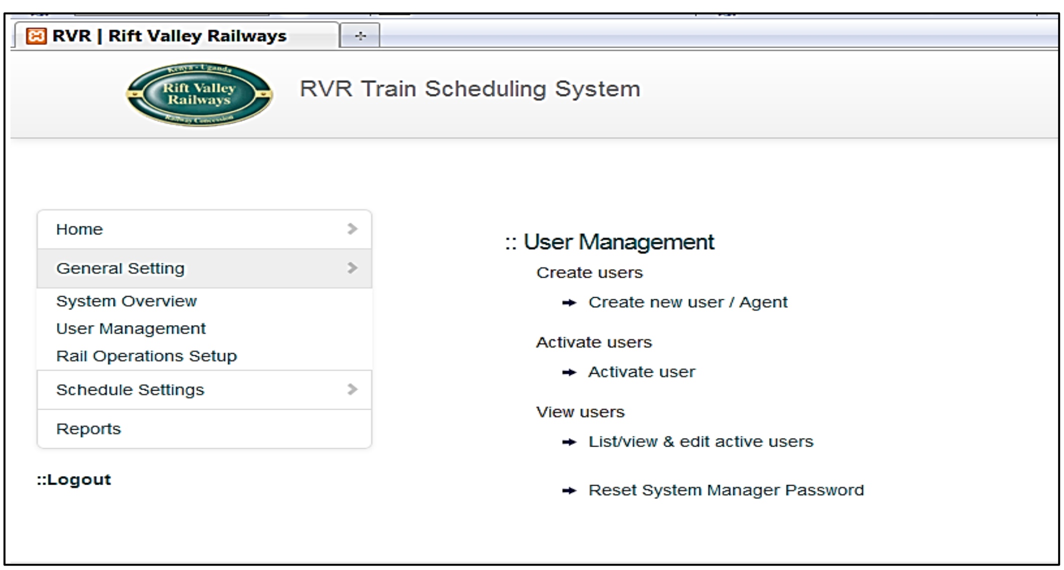
IF YOU ARE NOT ABLE TO REMEMBER YOUR USERNAME OR PASSWORD – CONTACT THE ICT SERVICE DESK THROUGH support@rvr.co.ke or Ext. 2222

Main Menu Screen

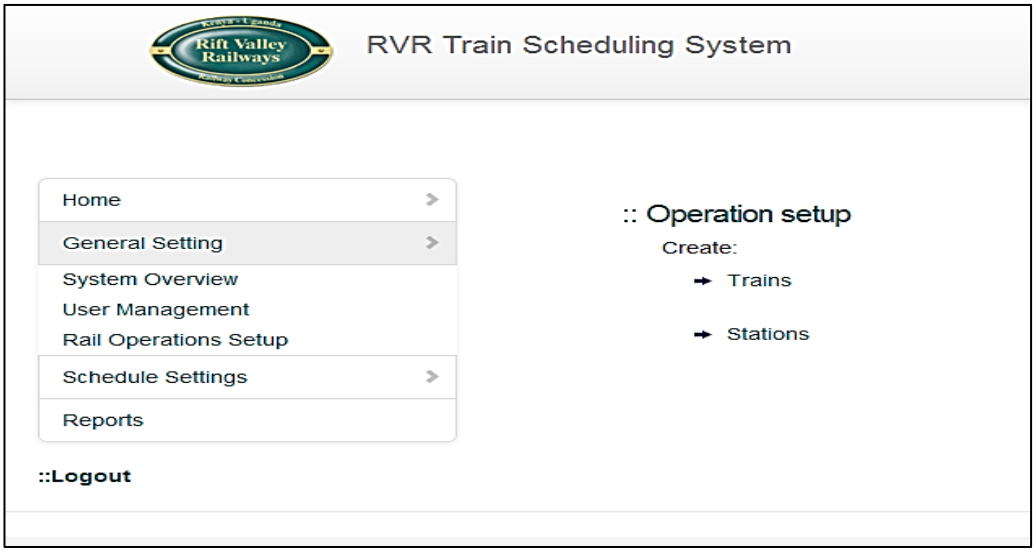
Once you input correct username and password, and login to the system the main screen below appears



The General Setting highlighted below is used only by System administrator to manage users through the user Management option

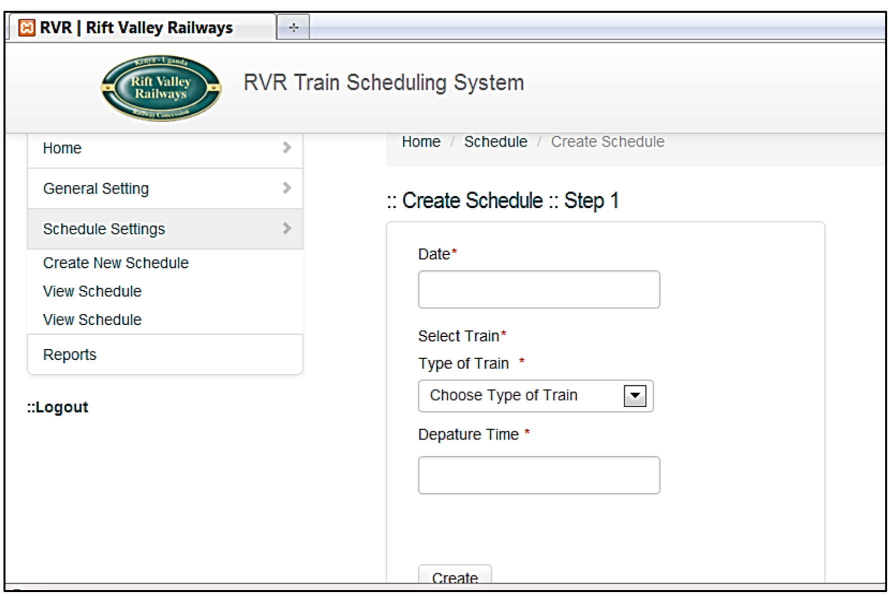


The Rail Operations setup option will enable set up of trains and stations to be used by the system as per screen shot below



<u>Scheduling of Trains</u>

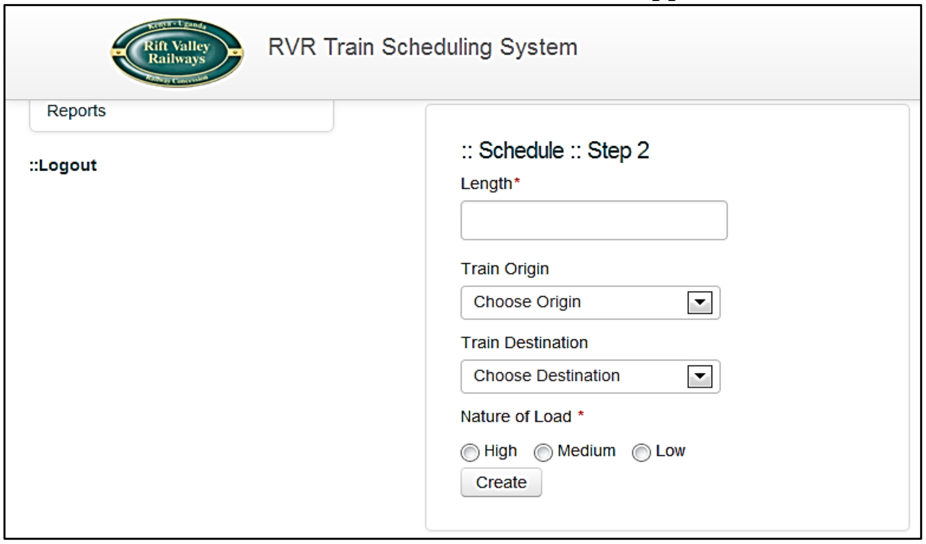
1. Create a new Schedule



a. Click on the create new Schedule Tab
b. Enter the Date the train is supposed to run
c. Choose the train type – **Passenger or Cargo**
d. **Clearly enter the departure time**

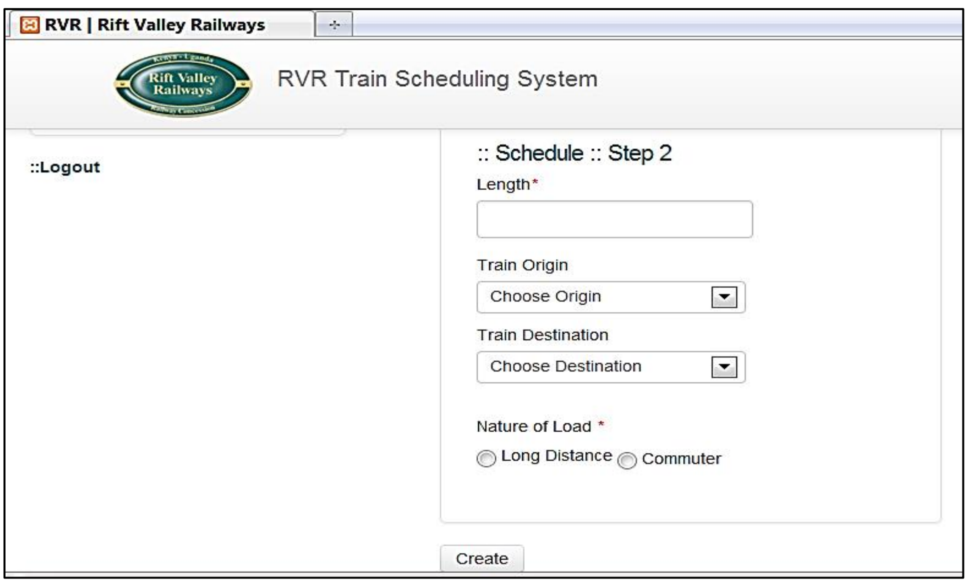
e. Click the create button

f. **IF IT IS A CARGO TRAIN** – the screen below appears



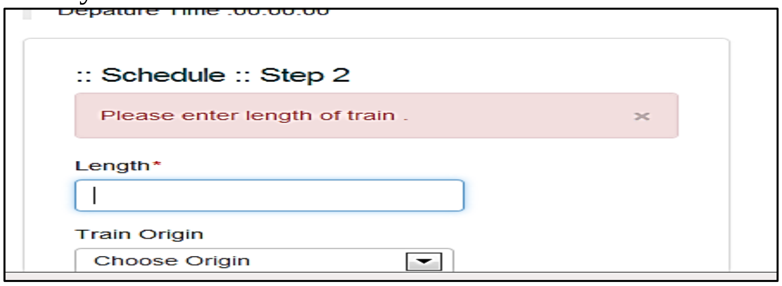
g. Enter the length, choose the origin and destination THEN choose nature of load and click the create button

h. **IF IT IS A PASSENGER TRAIN** – the screen below appears

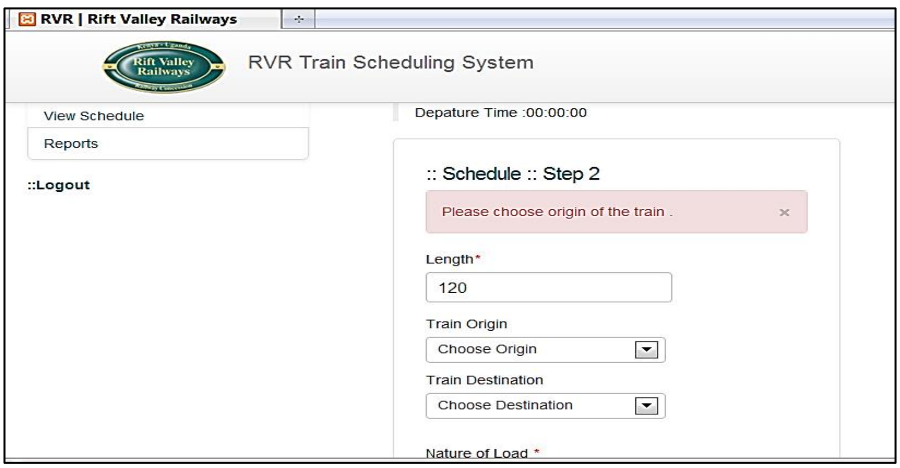


i. Enter the length, choose the origin and destination THEN choose nature of load as either Long distance or commuter and click the create button

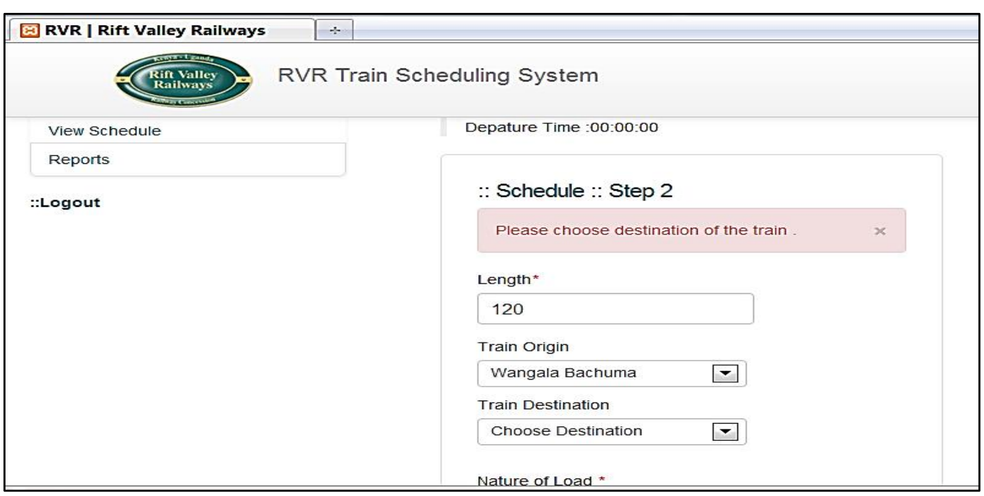
j. **IF YOU DO NOT ENTER THE TRAIN LENGTH,** the screen below appears when you click the create button



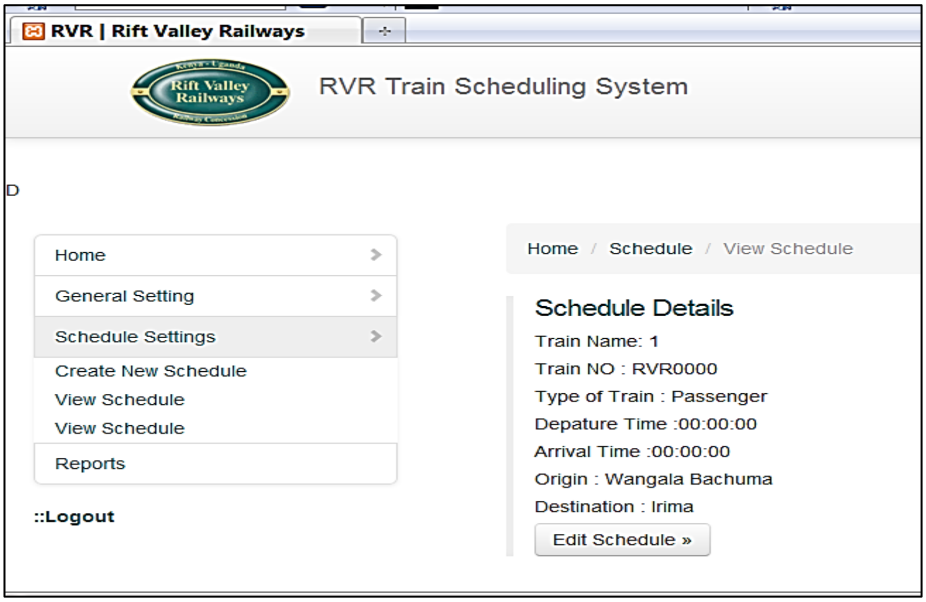
k. **IF YOU DO NOT ENTER TRAIN ORIGIN –** screen below appears when you click the create button



l. **IF YOU DO NOT ENTER TRAIN DESTINATION–** screen below appears when you click the create button



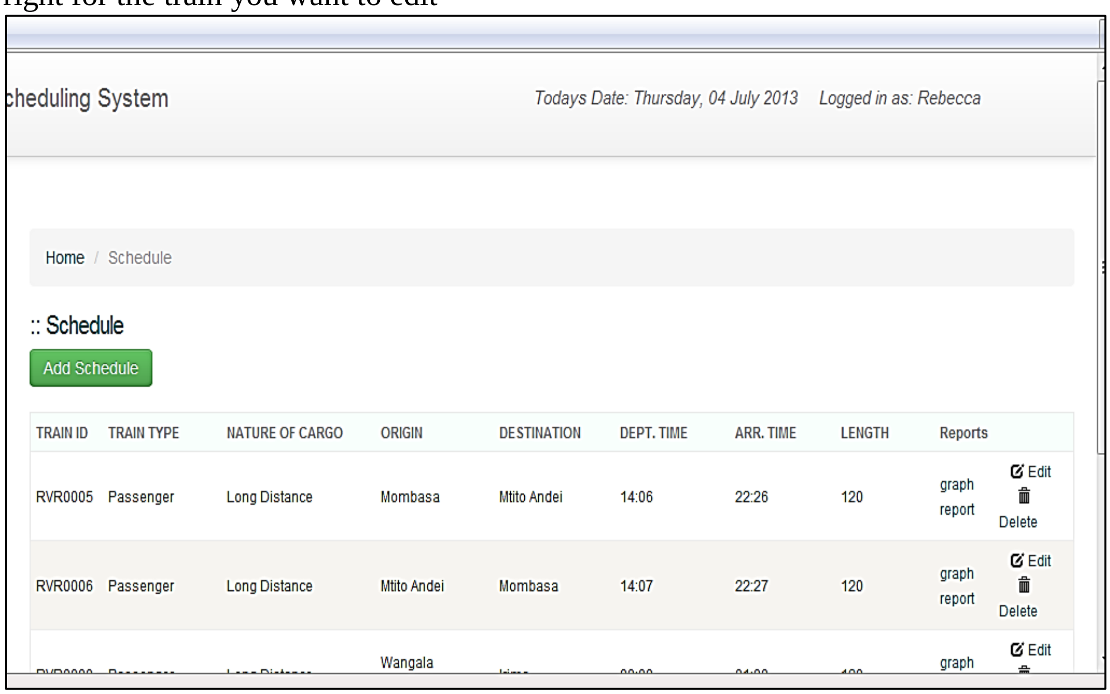
m. If all the mandatory fields are correctly entered the screen below appears upon clicking the create button.



2. Edit Created Schedule – There are 2 ways to do this

a. Click on the Edit Schedule button shown in 1m above OR

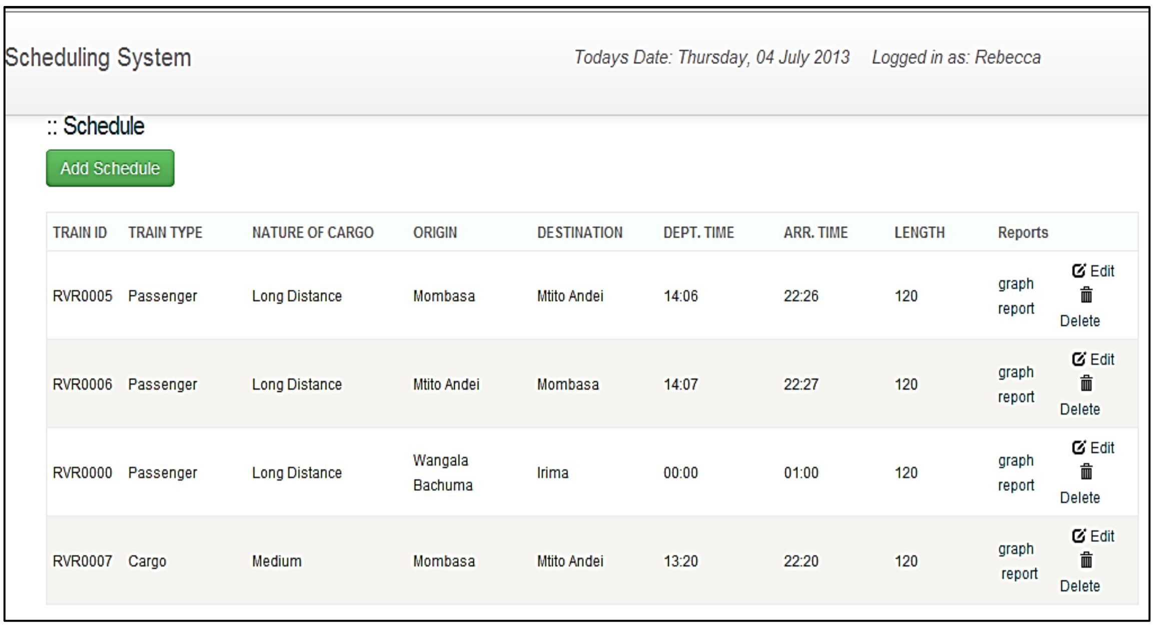
b. Click View Schedule option and screen below appears. Click on edit on extreme right for the train you want to edit



c. Once click on Edit you will get the screen below that allows you to edit **LENGTH, ORIGIN, DESTINATION, DEPARTURE TIME and NATURE OF LOAD**
d. **Click the Update button once you have finished editing**

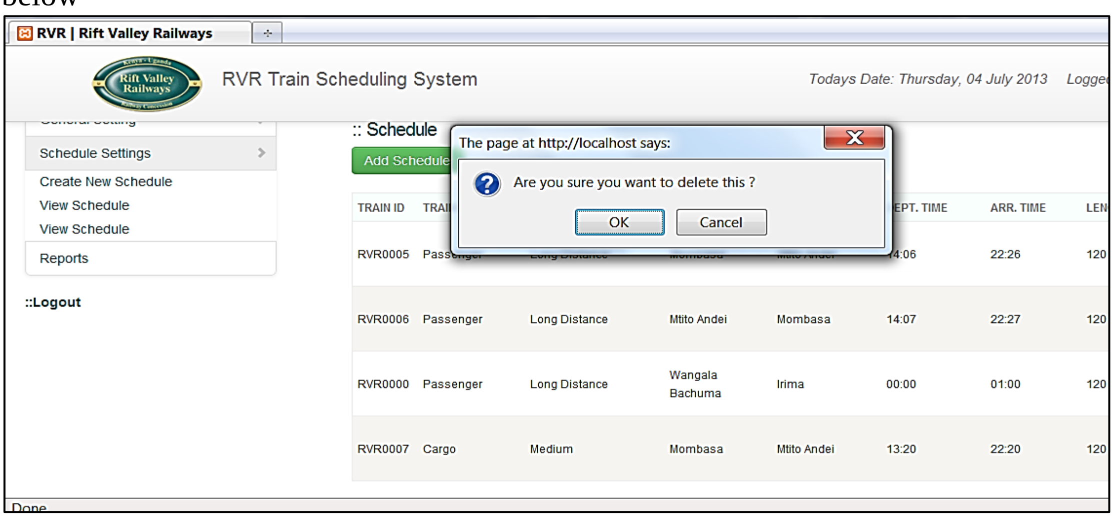
3. View Created Schedule

Click the View Schedule Option and the below screen appears giving details of all trains scheduled for that particular day in their order of prioritization.



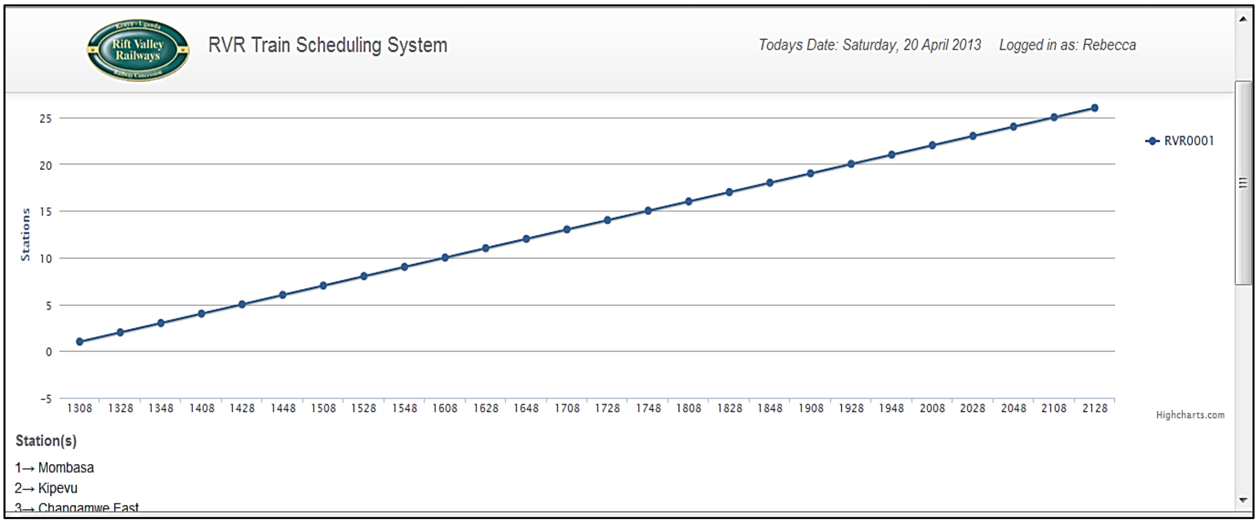
4. Delete a Train from a Schedule

Delete a Train from a Schedule – Click the **delete option** of the train to be removed from the extreme right hand corner while viewing the schedule. This will give the screen below

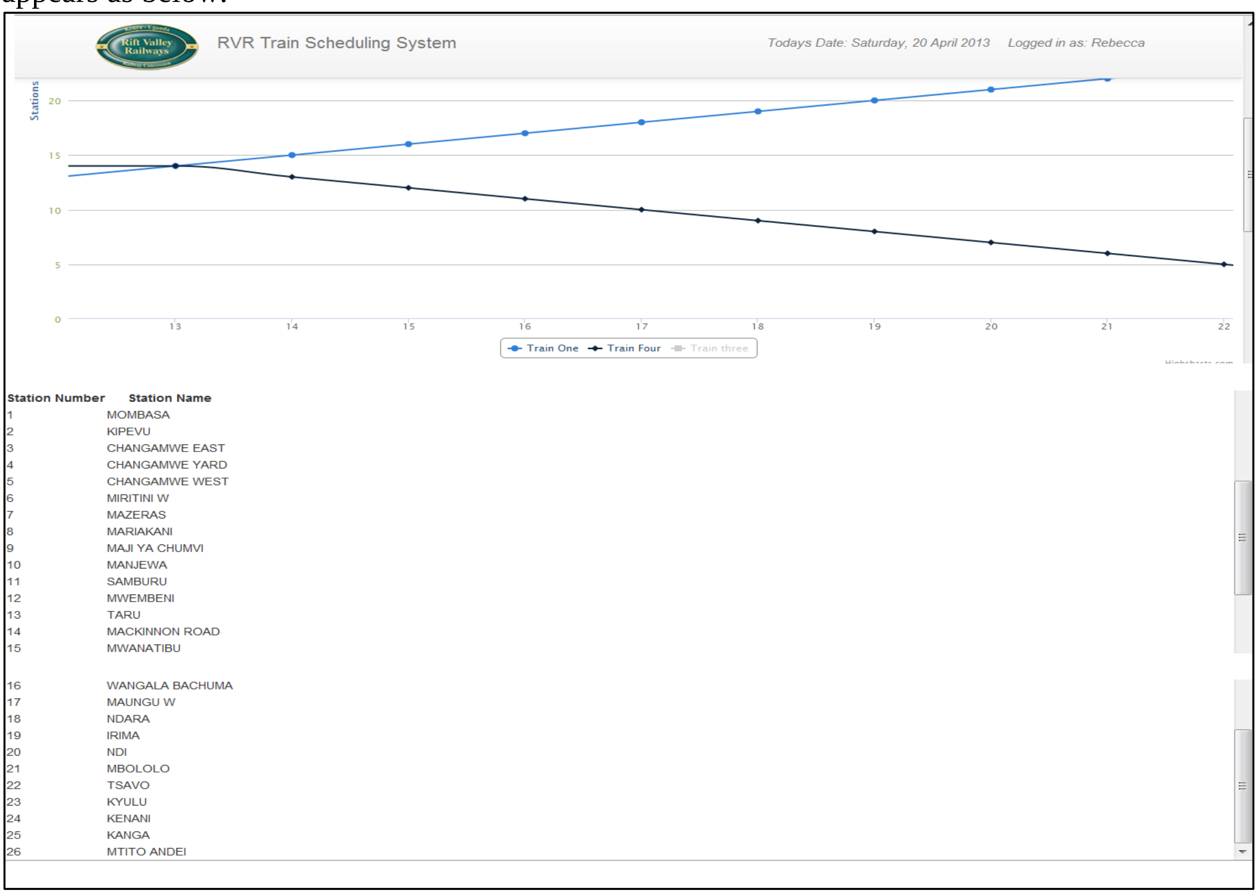


Click OK button if you are sure you want to DELETE else CANCEL

5. **View Train Graph path** – Click **graph report** for the train to be viewed while on the view schedule option. This will give the screen shot below.



6. **View Graph for all trains in a schedule -** Click the Report option and a screen shot appears as below.



7. **Log out of the System -** Click the Logout option on the left hand side of the screen.
USER MUST ALWAYS LOGOUT ONCE DONE WITH THE SYSTEM.