



Thesis On "DESIGN OF EFFECTIVE RAILWAY TIMETABLE GENERATION IN ETHIOPIA"



Transportation

Price	30000	Rate	1.5	T	100.00
MAXIMUM	20000	MINIMUM	10		
Capacity	10				

Timetable

Train No	1	2	3	4	5
MAXIMUM	0	0	0	0	0
MINIMUM	0	0	0	0	0
Capacity	0	0	0	0	0



T-Code	Route From	Route To	Departure Time	Arrival Time
0011ERC	kality	leghar	8:12:0	3:49:47
0013ERC	stadium	kality	5:15:5	6:14:57
001ERC	ayat1	kality	1:30:0	2:39:1





ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

**“DESIGN OF EFFECTIVE RAILWAY TIMETABLE GENERATION IN
ETHIOPIA”**

**A thesis submitted to the school of Graduate Studies of Addis Ababa University in
Partial fulfillment of the degree of Master of Science in Mechanical Engineering
under railway stream**

BY

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October, 2014,

ADDIS ABABA



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Abstract

The manual system of preparing timetable in railway system with complex network line is very time consuming and usually ends up with various train conflicting either at some stations or at some sub-stations having more than one train at a time. To overcome all these problems it is important to propose to make an automated system. The system takes various inputs like details of railway timetable requirements. Then finding the railway timetable requirements is one of the main ideas in this study. Depending upon these inputs it generates a possible time table.

Train timetabling has been a significant issue in the railway industry. This paper presents and develops a railway timetable generation program using PHP which is a powerful server-side scripting language for creating dynamic and interactive websites. This is a new method. The application of this railway timetable generation program is used to generate timetable common for all type of trains (passenger and freight) and for all type of infrastructures (single track and double track). In this study identifying railway timetable requirements and then developing mathematical model of these requirements are the key inputs to create this railway timetable generation program. The main core idea of this work is on the design of railway timetable generation for the purpose of finding departure and arrival time at railway stations and then every train has a defined departure and arrival times at various stations.

The result of this work is used to generate periodic timetable, non- periodic timetable or for mixed periodic and non- periodic timetable because of its flexibility program.

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List of notations

art	Arriving time in any stations or sub-station
dt	Departing time from any station or substation
drt	Driving time from one route to another route
det	Delay time between starting and end stations or substation
st	Starting time from any station or substation
dwt	Dwell time in station or substation
mt	Maintenance time of a train
alt	Allowance time during train movement
swt	Switching time during switching
ht	Headway time between two trains
tt	Transferring time during transferring passengers or goods

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CHAPTER ONE

Problem and its Approach

1.1. Background of the study

Rail transport is an energy-efficient and capital-intensive means of mechanized land transport of people and cargo. Locomotives, which are power units that pull trains, represent one of the biggest capital investments of railroads. Each locomotive unit represents a one-time investment of at least a million dollars.

Ethiopian railway new network line is under construction; which is a nation-wide railway passenger and cargo transportation system consisting of about more than 5000 kilometers of railway trucks that connects different regions. End of 2014 the first phase project of light rail transit in Addis Ababa city may start service. [1]

If once installed the infrastructure; it needs a correct planning of railway timetable in order to give a safe and profitable service to its customers.

A railway system consisting of a number of railway stations and a number of sections on which a number of trains are running. The departure times and arriving times of all the trains in a railway system are fixed by a timetable. So, a timetable is a schedule for a railway system. The quality of a timetable is determined by how good it meets certain requirements.

The railway timetable-development activity plan is to meet general public transportation demand. This demand in any country varies during the hours of the day, the days of the week, from one season to another, and even from one year to another. It reflects the business, industrial, cultural, educational, social, and recreational transportation needs of the community. One purpose of this study, then, is to set a common model used to generate alternative timetables as the plan of the organization for each transit route in order to meet variations in public demand. Alternative timetables are determined on the basis of passenger counts.

In order to provide attractive services for public transportation, including local, regional and international traffic, it is essential to match the timetables for all means of public transportation, so

that they can satisfy every demand of the potential passengers. On the other hand, it has no less importance to keep the costs as low as possible.

The railway transportation system is one of the most commonly used modes of transport and its importance and utility are very substantial for the society. With the advancement of technology, the changing environment and increasing customer demands, railways have to upgrade their various operational activities constantly.

Railway infrastructure plays its part in constructing railway timetable indirectly. Once the infrastructure is installed, it is ready to use with correct planning. Since the initial cost of railway infrastructure is high, so to become profitable it must use a proper planning. Planning of railway timetabling is one of the most important planning stage makes the organization profitable in railway lines. It is well-known that there are three levels of planning in Railway as shown in the figure below.

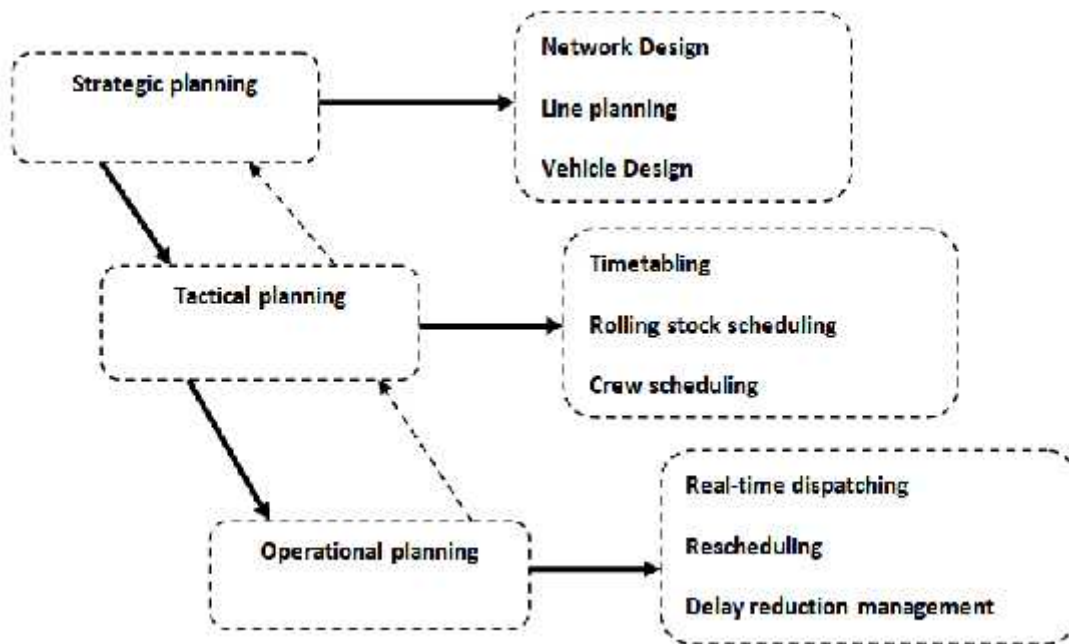


Figure 1.1: level of planning [2]

Railway network lines are important for transportation service of goods and passengers. Cost effective and safe railway transport gives benefits economy, society and environment. Railway in Ethiopia is an exploited area and it is new except the old Ethio-Djbuti line. Then this thesis study's

about constructing effective railway timetable by developing a mathematical model first and then creates a program using programming language knowledge. The railway timetable must include investigating what are the railway timetabling requirements, what type of method carried out to model, how the model converts to programming, which method meets the objective of the infrastructure. Very effective railway timetable is needed to satisfy not only the customer but also for the sector to be profitable. A timetable must be drawn up, to know how the train service will operate and where the trains will start and finish. This is not the one the passengers see; it is a detailed one for staff. It shows all details of all train movements, including empty moves and times in and out of depots.

Railway timetable is classified in to cyclic and non-cyclic. Most of the time timetable shows a cyclic nature; therefore, train connections are operated regularly with respect to a cycle time. So, a train for a certain destination leaves a certain station at the same time every cycle time, say every half an hour, every hour, or every two hours at the same time from a certain station for a certain direction. [2, 3] Cyclic timetables are mainly used for passenger railways, though cargo rail schedules are sometimes also cyclic to some extent.

But this thesis focuses on both passenger and a freight railway timetable which includes cyclic and non-cyclic nature of timetable program. A railway timetable determines the arrival and departure of a train at each station.

As a key component of public transit operations and management, the passenger train timetable design on an urban rail transit line must determine the arrival and departure times for each train at each station. [4]

A railway timetable consists of two elements:

- (i) The arrival and departure times of the trains at the stations , and
- (ii) The assignment of each train to an appropriate location such as junctions, bridges, platform and corresponding route direction in every station. [23]

Due to the complexity of rail operations, the expected growth of traffic and the limited possibilities of enhancing the infrastructure, effective timetable design and real-time traffic management strategies play a key role in improving the level of railway service. [7]

This paper presents how to construct railway timetables by identifying the railway timetable requirements, modeling these requirements and develop a simple and useful timetable generation program.

Identifying a railway timetable requirements or factors is the main idea of this study because these timetable requirements are the key factors to find the arrival and departure of any moving train in any stations or sub-stations. After identifying the railway timetable requirements; making a model or relation makes easy and simple to find the exact value of the departure time and arrival time without any error. Then finding appropriate software which is simple and easy to create a program based on the mathematical model and from this used to generate a railway timetable common for any train and infrastructure is the final study in this paper.

1.2.Problem of the Statement

Infrastructure managers are facing increasing demands from traffic operators as well as passengers to ensure a safe, reliable and comfortable railway service. To achieve these objectives the quality of the infrastructure needs to well-designed railway timetable. The well-designed railway timetable activities of the railway infrastructure have certain powerful goals which are linked to the organizational goals and objectives and which help in achieving the overall objectives of the infrastructure. Visions of railway timetable activities are based on overall goals for securing safety, reliability, comfort and cost-effectiveness.

Managing and scheduling activities keeping in view of competing activities and constraints has always been a tedious task in railway system. Due to manual approach of generating timetable, proper utilization of resources is neither effective nor efficient. Time table generation, also known as timetabling problem, for railways having limited resources is a typical problem of scheduling tasks due to the fact that trains are managed according to proper planning timetable.

Train timetabling is one of the most interesting problems in transportation planning systems. The goal of train timetabling models is to determine the departure time of trains from stations while satisfying a set of operational constraints. A railway system is a complex system with many interacting processes that depend on technical devices, human behavior, and the external environment, and therefore contains many risks of disturbances. If once a delayed train deviates from its original time-distance path, it may delay following trains that are scheduled over the same railway infrastructure or it may conflict in passing or meetings with other trains. Hence, a delayed train may propagate its delay to other trains due to infrastructure, signaling or timing conflicts. This all is effective timetable design problem which is the topic of this thesis. Therefore, there is a need to develop effective railway timetable decision support models which can achieve the overall goals of the infrastructure in a cost effective way.

1.2.1. Research Questions

1. How should solve the problem of generating an effective timetable which is common for any country?
2. How can punctuality of railway timetable be improved?
3. What adjustments need to be made to the requirements in order to obtain an effective timetable?
4. What type of method helps to solve the above questions?

1.3. Objective

1.3.1. General Objective

- The main objective of this thesis is to create a program used to generate an effective railway timetable to find the correct departure and arrival time of the train in every station of a train movement in order to reduce or completely stop the disturbances of the traffic flow.

1.3.2. Specific Objective

1. To investigate the railway timetabling requirements and identifying the variables.
2. To examine how to develop mathematical models of railway timetabling requirements.
3. To examine a suitable programming languages to this study.
4. To examine how to develop a programming using the mathematical models of railway timetabling requirements as an input.

1.4. Significance of the study

The Significance of this thesis is developing a mathematical model and then to create a programming to generate an effective railway timetable in Ethiopia. As such, this research provides a valuable contribution to existing mathematical timetabling methods and creates new programming model, which tends to focus on the problem of constructing a railway timetable with clearly taking an objective into account. Moreover, in the practical construction of railway timetables, objectives are clearly of great importance.

Some of the uses of constructing effective railway timetable come to our mind are:-

1. Satisfying customers,
2. Creating a stable railway system,
3. Easy to control costs,
4. Maximizing sector profit,
5. Simple to managing etc...

1.5. Scope of the Study

Railway timetabling design is a complex system because it varies from country to country. Even when taking one country it is very complex. This includes determining or finding exact time of each every railway timetabling requirements or factor such as determining the driving time, headway time, dwell time, passenger transfer time; connecting train time, maintenance time etc. Then not

every detail calculation is taking place to find the exact value in this thesis but it study about the steps and techniques how to find and develop a program which is general for any value ;for any type of train and for any type of infrastructures. Because finding exact value of every requirement needs a field study in a functional railway system but in Ethiopia at this time it is under construction.

The main core ideaof this thesis is identifying the railway timetable requirements; develop mathematical model and then creating a program used to generate a railway timetable by selecting appropriate software.

1.6. Organization of the study

The organization of the thesis is structured as follows.

The first chapter describes about problem and its approach.It clearly shows background, objective, significance, scope and problem of the thesis.

The second chaptersurveys related literature regarding to the topic of the thesis.

The third chapter describes the Methodology of the study.It describes the practical aspects of railway timetable design method. It also describes briefly the methodology of constructing timetable detail producer.

The forth chapter deals with model development.Here in this chapter clearly develop a mathematical model which is helpful to create a program.

Finally, Chapterfive deals with conclusion and recommendation, the conclusions of, and a reflection on, the results achieved in the thesis are presented in this chapter.

CHAPTER TWO

Related literature review

This chapter presents a review on the state of the art of the literature on railway timetable design and identifying the requirements or factors which are helpful to design the timetable of this study.

2.1. Introduction

Train dispatchers have two main tools to supervise the network which are the timetable and the train diagram. The timetable is a schedule of trains on a given railway infrastructure. It contains the arrival and departure times of the trains, not only from stations, but also from intermediate stations and sidings.[8]

The operational features of a railway line are highly dependent on the timetable. In many cases railway operation analyses are based on some kind of timetable assumption that implies that only one or a few timetable alternatives are tested.[9]

Timetabling and traffic management are two basic elements of public transport operations, which are inherently linked. The function of the timetable in practice, however, is often only loosely connected to its implementation. Customers, drivers, conductors, and dispatchers interpret the timetable differently and depend on specific sources of information and technical support. Further, the feasibility of railway schedules and operations is subordinated to the constraints of the signaling and safety systems. For trip planning and decision making, railway passengers used timetable books and displays at stations, supported by telephone advice, personal travel information assistance and ticket sales. In recent years, live travel information and booking via the internet have become more and more available.

In many railways, however, train drivers and conductors still receive only a printed daily schedule indicating the relevant departure, passing and arrival times, as well as the times and locations for the start, change and end of their duties, and a train radio or mobile phone for communication with the traffic control centers. Electronic on-board timetable information in the driver's cab and in the passenger coaches has, so far, been introduced only by a limited number of railways. During train

operations, drivers must observe the signals and cab displays, which indicate the necessary safety information with respect to movement authority, permitted maximum speed, and in some modern trains the critical target distance. It is perhaps surprising that continuously updated actual delay information for train drivers is still generally missing, although standard on-board information displays were introduced on buses, tramways and light rail lines more than 20 years ago. A more precise and actual traffic information feedback to drivers and conductors would help them to better recognize deviations from schedules, to predict conflicts, and to raise operational performance.

The information made available to signallers, dispatchers and network supervisors in traffic control centers has improved significantly. This has been due to the introduction of first, relays, and then electronic interlocking, associated with wall-based displays followed by computer screen monitoring of the actual set-up of routes, track occupancy and sectional clearances for each train.

Further, time-distance diagrams of the daily scheduled and the realized paths became available at the newly built control centers. These are equipped with modern information, telecommunications and computer technology.

Advanced tools enable a much higher quality of timetabling and contribute to more reliable operations. However, the punctuality levels achieved by railways in general do not give evidence of higher performance – except from Japan. It is hypothesized that the disappointing train punctuality performance of many networks stems only partly from the high traffic volumes and capacity usage. The main cause is an insufficient degree of optimization, exactness and robustness of the current practice of timetabling, which misses the feedback of detailed operational performance data. [10]

Railway schedules are necessary for the coordination of resources in different planning and production stages in order to match transport demand, capacity and to inform stakeholders and customers.

Timetables must assure that the expected transport demand can be realized according to the requirements of passengers, shippers, train operating companies, infrastructure manager and public authorities effectively and efficiently. Effectively means a high quantity and quality of available

infrastructure, rolling stock, personnel, transport and traffic services, while efficiently requires a maximum output with the least possible input.

The principal goal of railway transport is to attract a maximum number of customers and load on planned or existing lines with a minimum of investment cost, personnel, equipment, energy consumption, operating and maintenance costs. The acceptance by passengers, shippers and public authorities depends in a competitive market on performance criteria as speed, frequency, comfort, reliability, punctuality, safety and price of services. The effectiveness of a timetable can be expressed by indicators as:

1. Number of trains, passengers and load per time period,
2. Amount of passenger-kilometer and ton kilometer per time period,
3. Operating and circulating speed of trains,
4. Headways times,
5. Scheduled waiting times,
6. Time and effort for modification and updating (reschedule).

Distinction is made between non-cyclic and cyclic timetables. The latter are more and more international standard, because cyclic (clock faced) timetables are easy to remember for passengers and easier to handle for railway personnel. The scheduled intervals between the trains of the same line of a cyclic timetable are regular over the (daily) service period, but may be increased to an integer multiple of the base interval or decreased by an integer divisor e.g. during peak periods. The trains from both directions of a line then meet each other twice during one interval creating a symmetry axis of the train graph if the running times per direction are not (much) different. A symmetric cyclic timetable exists if the symmetry axes of all lines are identical e.g. situated at every full hour. Integrated cyclic timetables in networks are characterized by scheduled transfer connections between different lines at (major) railway stations (hubs), where the trains meet each other at regular intervals (at least hourly).[11]

Designing public transit timetables is complex scheduling task requires a systematic consideration of time-varying and stochastic passenger demand patterns, available locomotive and train unit resources, as well as many practical regulations. Designing public transit timetables has received much attention in recent decades. From the problem of constructing periodic timetables of public rail systems under unsaturated conditions, many studies concentrate on how to model train delays and resolve conflicts, with limited focus on passenger waiting times. [4]

The timetable is also the basis for dispatchers or automatic route setting systems to set the routes for each approaching and ready-to-depart train according to the scheduled route and arrival/departure/through time. Also duty rosters of train crews (drivers, conductors) depend on the timetable, and so do rolling stock circulations, including shunting at stations, deadheading (empty running), cleaning at terminals, and periodic maintenance at depots. Hence, in case of disruptions timetable perturbations may cause wide-spread logistic problems. Train units, locomotives, coaches, and train crews may be in the wrong place at the wrong time resulting in altered train compositions and an increasingly distorted rolling stock and crew allocation. [5]

Railway timetabling models and methods are usually based on deterministic process times (running times, dwell times, transfer times, headway times). Moreover, running times are rounded and train paths are bended to fit timetable or infrastructure constraints. The validity of these timetabling decisions and simplifications must be evaluated to guarantee feasibility, stability, and robustness, with respect to network interrelations and variations in process times. [6]

European passenger railways are typically based on a periodic railway timetable, where train lines are operated with regular intervals throughout a day and consistent transfers are provided at transfer stations between train lines of different type or directions. The basic cycle time is typically one hour, which means that the same pattern of train services repeats each hour. A periodic timetable is popular and effective to transport networks with diffused origin-destination demand matrices, where train lines are synchronized at transfer stations to offer seamless connections between many different origins and destinations. A main advantage of periodic timetables is that transport chains are fixed throughout the day and travelers only have to remember the departure time of their (first) train in a basic hour, e.g. 'departure at 05 and 35 minutes of each hour'.

Depending on transport demand the periodic timetable may be made more (or less) dense by adding (removing) train services in peak (off-peak) periods. [23]

The timetable is constructed based on the limitations of the railway; for example, maximum allowed axle load and maximum allowed length of trains in the case of single track, as trains have to meet at stations of a certain length. Requirements regarding timeliness, that is, the requests of the train operating companies and their customers regarding departure and arrival times, together with the requests of infrastructure manager and for maintenance contractor track possessions, are inputs to the timetable construction process. The timetable might be made less sensitive to small deviations by allowing a train a longer time than is strictly necessary to run a distance. Such allowances might be added to running times of the train route or added to times at planned stops. [6]

2.2. Approaches or methods to construct railway timetable

There are several approaches to solve railway timetable problems in accordance to the researcher's interest. Researchers classify railway timetable into cyclic and non- cyclic railway timetable. Most authors that study cyclic railway timetabling problems use models that are based on the Periodic Event Scheduling Problem. [2], [23]

The train schedule problem is one of the difficult problems in rail transport planning. This planning has been carried out manually and by trial and error methods for over a century. In a manual method, the train arrival and departure times from each station are identified based on the individual's experience and information.

The solution quality and building time in this method are closely related to the individual's experience and ideas. Mathematical programming, simulation, expert systems, heuristic and Meta heuristic methods, and combinational methods are other techniques for train scheduling. Mathematical methods give exact or optimal solutions. Many works are based on different algorithms like Periodic Event Scheduling Problem, mixed integer programming, Genetic algorithm, and Tabu algorithm set etc. [17]

2.3. Concept of railway timetable modeling problem

As stated above most researchers classify a railway timetable in to cyclic railway timetable and non-cyclic railway timetable. The cyclic railway timetable concept is presented in 1931, with a cycle time of one hour. In a cyclic timetable, train connections are operated regularly with respect to a cycle time. So, a train for a certain destination leaves a certain station at the same time every cycle time, say every half an hour, every hour, or every two hours. Cyclic timetables are mainly used for passenger railways, though cargo rail schedules are sometimes also cyclic to some extent. Cyclic timetables have several advantages. Since they are transparent to the customer, there is no need for passengers to memorize complex timetables for their regular connections. It suits to memorize the minutes of the hour at which the trains leave. Moreover, if the cyclic concept is strictly adhered to, passengers face no gaps in train services on parts of the day when transportation demand is low. From a planning point of view, cyclic timetables have the advantage that one only needs to consider one cycle period. A crucial extra requirement, then, is that the situation at the end of the cycle period matches the situation at the start of the period. If the start and end situations match, the basis of a full-day timetable can be obtained by copying the cyclic timetable for all relevant hours of the day. This copy procedure yields a full-day timetable in which the departure times, in minutes, are the same for each train connection and for each cycle period. Clearly, this basic full-day timetable still needs some adjustments, for example, for rush hour traffic or late evening traffic.

A final and related advantage is that cyclic timetables can be represented compactly, that is, only a single cycle period needs to be shown. Cyclic timetables are therefore relatively easy to handle within the railway company itself. A railway operator can focus its planning on one cycle period, not only for the timetable itself, but also for depending plans, such as rolling stock planning and crew planning. However, this does not imply that the depending plans themselves are also cyclic.

In acyclic timetable, railway operators adjust the timetable to the demand for transportation. Such a timetable typically contains many trains during the morning and afternoon rush hours and few trains in low traffic hours. Further, a-cyclic timetable tends to offer a quite dense service on Mondays and Fridays, because of post-weekend and pre-weekend traffic, whereas the weekend timetable may contain many gaps. Extremely fine-tuning a timetable to market demand may result

in a complex timetable that is hard to consult and to memorize. Moreover, the acyclic timetable concept requires the planning of a timetable for the entire day, for each day of the week. This typically results in very large planning problems. On the other hand, cyclic timetables may yield higher costs than a-cyclic ones.

In a cyclic timetable, the late evening hours offer the same train service as the rest of the day. But the occupation degree of the late evening trains is typically much less than during the rest of the day. Therefore, a cyclic timetable usually takes market demand into account to a certain extent. Typically, high capacity trains are used during rush hours, that is, longer and/or double-deck trains. And in low-traffic hours, trains may consist of less carriage. Moreover, a hybrid timetable concept is possible, with a cyclic core timetable, in which extra trains are operated during rush hours, and from which trains are removed during low-traffic hours.

In modeling a cyclic railway timetable the following assumptions are to be given priori.

- ✓ The infrastructure layout of the railway network,
- ✓ The trains to be scheduled, and
- ✓ A set of timetable requirements, representing safety regulations, service levels, and logistic limitations. [2]

The train timetabling problem is defined as follows: for a given set of lines, frequencies and possibly departure times of each train, determine the arrival and departure time at each block and station such that safety constraints are satisfied and possibly other goals are achieved. The literature on train timetabling is abundant compared to other aspects of the railway planning process. Some of the literature focuses on cyclic timetables while other studies focus on non-cyclic ones. Non-cyclic planning is mainly used in freight trains scheduling where the demand for trains is irregular and may be unknown in advance and the travel time of each train may vary from a few hours to a few days. The planner receives requests for trains for the entire planning horizon and has to try to schedule as many trains as possible or maximize the profit for the railway company (in cases where each train represents a different potential profit).

Cyclic Timetabling is mainly used in passengers' trains scheduling where passengers' demands can be estimated far in advance, journey times vary between a few minutes to a few hours and the frequencies of lines are relatively high. In a cyclic timetable, each trip is operated repeatedly once or a few times during each cycle. From the passengers' point of view, such timetables are more convenient because all they need to remember are the times in a cycle when trains arrive at their station. From the planners' point of view, since each event occurs over again in every cycle, it is enough to plan one cycle, thus reducing the search space significantly. Considers infrastructure of type and solves a basic scheduling problem on a single track railroad. The model's objective is to find the best crossing and overtaking locations of trains given their routes and departure times so that weighted average train travel time is minimized. Shows that the problem is analogous to the general job-shop scheduling problem and uses a branch and bound algorithm to solve it. Branching is carried out by selecting two trains and fixing their meeting segment.

The non-cyclic timetable problem takes generally effect in long-distance freight transport that uses infrastructure with limited capacity resulting from a high traffic density or infrastructure on that a high growth of competition in the near future is expected. It has a lower priority in the scheduling step as the cyclic one, and therefore it is deployed directly after this one.

Thus, the regarded data and generated data structures have to be preprocessed to fulfill each safety regulations and not to destroy the schedules created in the previous step.

The main advantages of cyclic timetables are the fact that these schedules are easy to operate and remember for passengers, why this method takes effect on scheduling passenger traffic. On the other hand, these timetables are expensive to operate since no distinction between off-peak and peak hours are made. The only way to handle those differences for a train operator is to vary the length of the performed trains. This modifies the variable operating costs—variable rolling stock as well as crew costs is involved. [14], [13]

2.4. Timetable Requirements

A timetable should meet various requirements, such as safety regulations, service levels to be achieved, and restrictions considering the operational feasibility of the timetable. Each requirement

belongs to one of the categories described below. These categories have proven to cover most practical needs and are therefore the requirements that are taken into account.

a. Dwelling at stations

In practice, limits are specified for the time that a train dwells at a station. On one hand, a minimum dwell time specifies the minimum time needed for passengers to alight and board. On the other hand, one might also want to limit the dwell time at a station because stations only have a limited capacity, and because each dwell minute adds to the train's total travel time.[15]

Dwell time must be affected by multiple factors such as

1. Door opening/closing time,
2. passenger flow (i.e. boarding and alighting) time, and
3. Signal headway.

Other factors such as width/number of car doors, height/gap of platforms, and gender/age of passengers

For efficient services, trains are scheduled to stop at stations with adequate dwell time for passenger boarding and alighting. Determining dwell time is crucial to the design of railway timetables since insufficient dwell time would cause train delays, while excessive dwell time would lead to inefficient operation. In general, dwell time is defined as the time during which a train remains stopped at a railway station, primarily to allow passengers to board and alight. According to the above discussions, passenger flow time is the largest component of dwell time and deserves an in-depth analysis. The development of a passenger flow time model relies on accurate field data. In past studies, counters and stopwatches were typically used to record the number of passengers and passenger flow time. The total passenger flow time is usually estimated by calculating the time interval between the last passenger to board and the first passenger to alight. The average flow time for each passenger is then calculated by the total flow time divided by the number of passengers. However, it is impossible for passengers to be continuously passing through a car door while the train is stopped. Thus, counters and stopwatches in a traditional field survey are not effective in recording the flow time for each

passenger. In order to accurately calculate the number of passengers for each door, automatic passenger counting systems have been applied to collect detailed passenger flow data.

Dwell time is the time interval between train arrival and departure. To make the following analysis clear, dwell time is divided into three parts:

- I. Type A Lost Time: The time interval between train stop and door opened.
- II. Type B Lost Time: The time interval between doors closed and train start.
- III. Passenger Flow Time: The time interval during which passengers alight from and board the train.

During the first and second intervals of train dwell time, passengers are unable to board or alight. Type A lost time can be obtained by calculating the time difference between train stop and door opened.

Similarly, Type B lost time can be obtained by computing the difference between train start and door closed. The amount of lost time may vary among different trains and doors. This study employed descriptive statistics and confidence intervals to estimate lost time.

The third interval (i.e., passenger flow time) is the time available for passengers to alight from or board a train. Since passengers line up inside the train for alighting and at the platform for boarding, each door can be treated as a queuing system. [24]

b. Transferring

Two trains are said to be connected if there is a planned relation between their arrival and departure times at a certain node to transfer passengers or goods. A connection is desirable in two situations. The first situation occurs when a direct train connection between two nodes does not exist. In that case, passengers should still be offered a good travel system between these two nodes. This can be achieved by constructing a timetable in which a train for the destination node leaves from a transfer node shortly after the train from the origin node has arrived. Another situation requiring the connection of two trains arises when two trains need to be combined. This situation occurs when the two trains share a considerable part of their routes. Combining the two trains into one for their

common route saves both human resources and infrastructure resources. Only one train crew is required for the combined train, and infrastructure capacity is saved because otherwise a headway time between the two trains is to be respected. Such a combining of trains obviously requires both trains to be concurrently present at the station. The combining of trains also has disadvantages. It places an extra restriction on the timetable, and can be a source of delays since the combination procedure involves connecting the trains, a break test, and other checks, during which failures may occur.

c. Synchronizing trains

When trains from different train lines share part of their routes, their departure times are often synchronized to offer a higher frequency service on that common part. As an example, if two train lines have frequency equal to one, then synchronizing their departures provides a service with frequency two on the common part of their route. When a single train line has frequency higher than one, synchronization can also be applied to spread the multiple trains of that line evenly across the cycle time. Since this synchronization of train lines, or of trains within a train line, leads to a train service with a higher frequency, the involved constraints are also known as frequency constraints.

d. Turn Around Times at Termini

A rolling stock composition is the set of carriages, either self-powered, or including a locomotive, which operate a certain train line. After a rolling stock composition has arrived at its terminus, it generally turns around after some time, and operates a different connection. Typically, the rolling stock composition operates the return journey of the train line it operated before, but one can also encounter other situations. Before leaving for the opposite trip, the rolling stock is scheduled to spend some time at the terminus in order to be cleaned, for shunting, as buffer time to absorb delays.

e. Fixed arrival and departure times

For some trains, the freedom of selecting arrival and departure times is limited. This especially applies to international trains. The time at which an international train appears at the border of a country is usually the result of negotiations with the neighboring railway companies, rather than a

variable to be decided upon in the timetable planning process. Once the train has entered the country, the timetable can usually be chosen as desired for the further time that the train spends inside the country, as long as the fixed trip times of the train are taken into account.

f. Safety regulations

A final, but clearly very important requirement is due to railway safety regulations. These require any two trains using the same track to be separated by a certain minimum headway time. For any pair of trains using the same track, the minimum headway time must be respected both at the origin node and at the destination node of the track. Moreover, the safety regulations forbid the meeting and overtaking of trains on the same track. The latter follows directly from the definition of nodes and tracks at the start of this section. [2]

For one thing, a constraint might express that two trains must connect at a railway station. Think for instance, of passengers transferring from one train to another or two trains being physically coupled. Such constraints are called operating policy constraints. Another constraint of constraints, called infrastructure constraints are called, arise because the limited infrastructure constraint, arise because the limited does not allow for some simultaneous train movement or it enforces headway times between trains. For example, if train J can leave the railway station no sooner than 2 minutes after i does and vice versa.

To model driving times, headway times, transferring between trains, and so on events coupled by related associate event times. [15]

The calculations of minimum headway are discussed in detail in many books of railway or public transportation.

There are two formulas to find the minimum headway in railway .These are:-

- I. Traffic flow theory and
- II. Railway signaling theory
- I. Railway Traffic Flow Theory

In the railway traffic flow theory if a train may stop instantaneously, the separation between two successively moving trains must be larger than or equal to the braking distance of the second train.

Having a steady speed 'v' and a minimum braking rate 'b', the minimum separation or braking distance is given by (1).

$$s = \frac{v^2}{2b} \quad (1)$$

If the train length is 'L', then the minimum headway 'H' is written as (2).

$$H = \frac{s+L}{v} \quad (2)$$

To minimize 'H', the optimum running speed 'V' is given by (3).

$$V = \sqrt{2bL} \quad (3)$$

At last, take (3) into (2), the minimum headway is rewritten as (4).

$$H = \sqrt{\frac{2L}{b}} \quad (4)$$

II. Railway signaling theory

Fixed block signaling is the most widely used form of signaling, both for urban and inter-city railway operations. Consider a 3-aspect arrangement as shown in Figure 2.1, the minimum headway distance 'h₃' is given by (5).

$$h_3 = 2d_3 + p + s + L \quad (5)$$

Where 'd₃' is the block length for 3-aspects,

'P' is the sight distance,

'O' is the overlap distance beyond the signal, and

'L' is the length of train length.

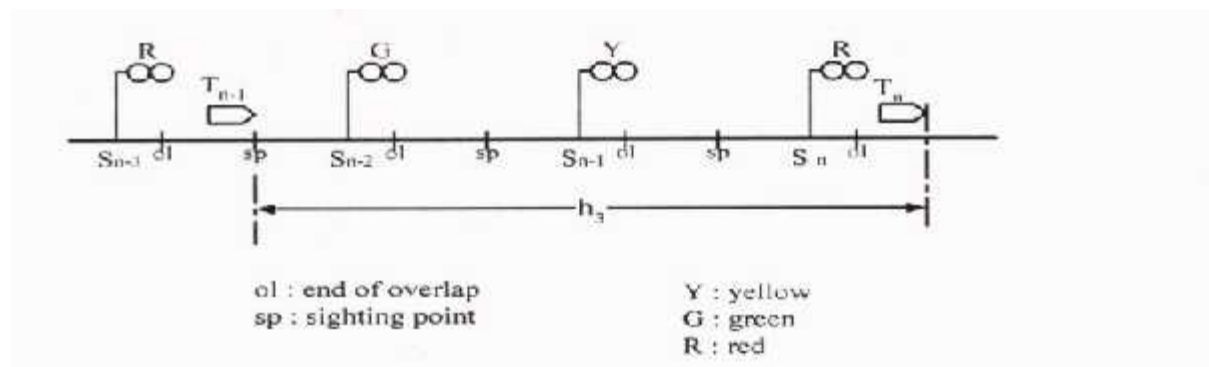


Figure 2.1: A 3-Aspect Fixed Block Layout

In practice, the 3-aspect block length is the braking distance's'. Furthermore, if the 4-aspect is incorporated as shown in Figure 2.2, the minimum headway distance 'ho' is then written as (6).

$$h_4 = 3d_4 + p + o + L \quad (6)$$

The standard practice to the 4-aspect block length is one half of braking distance's'.

It follows that the minimum headway distance for a n-aspect arrangement is given by (7).

$$h_n = \frac{n-1}{n-2} S + P + O + L \quad (7)$$

In order to minimize the headway distance, the optimum speed is given by (8).

$$V = \sqrt{2bk} \quad (8)$$

Where; $k = p + o + L$

Therefore, the minimum headway at the optimum speed for n-aspect can be rewritten as (9).

$$H = \sqrt{\frac{2k(n-1)}{b(n-2)}} \quad (9)$$

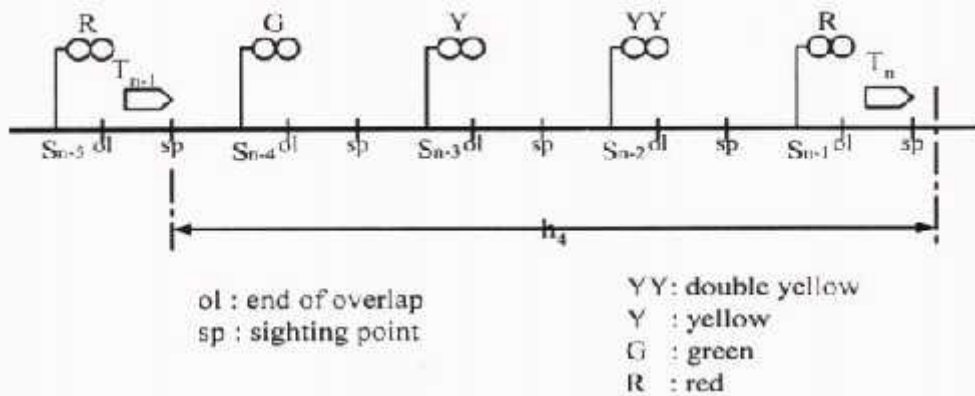


Figure 2.2: A 4-Aspect Fixed Block Layout

When 'n' is a very large number or the moving block signaling is selected, and/or if an intelligent system is chosen to decrease the value of 'p' and 'o', the limit of the minimum headway in formula (9) approaches to that in formula (4). In the minimum headway formula (4), the headway is only dependent on the train length and the braking rate. It implies that a short train will result in a short headway. However, in the design and operation of a transit line, we have to consider not only the headway but also the capacity.[25]

Clearly, the railway safety system also has to be taken into account together with timetable. Each track section is divided into so-called blocks, and each block may be used by at most one train at any time. At the start of a block, a signal light indicates the status of the block to approaching trains. A red light indicates that the block is occupied, so an approaching train may not enter the block. A yellow light indicates that the block is free, but that the next block is occupied. So, on a yellow light, an approaching train can enter the block, but has to start decelerating because the next signal light is red.

A green light indicates that the block is free and can be entered. Figure 2.2 illustrates these three states. The yellow signal light for block 1 indicates that the first train can enter block 1, and that the signal light for the next block is red. This red light for block 2 indicates that block 2 is occupied by the second train. Block 3 is empty, and the block after that too, so the signal lights for both block 3 and the next block are green. In practice, more signal light states are actually used, such as flashing

signals, or signal lights in combination with a number indicating the maximum velocity at which the block can be entered.

Typically, the length of a block is between 1000 and 2000 meter. Therefore, taking every single block into account would require very precise and detailed time-space diagrams. Instead, planners usually choose a less detailed perspective, and model the blocks by so-called minimum headway times that separate any two trains using the same track. The idea is that it takes a train, on average, the headway time to cover a block. So, as long as the headway time is respected in the timetable, it should in practice be possible for all trains to be operated while respecting the safety system.

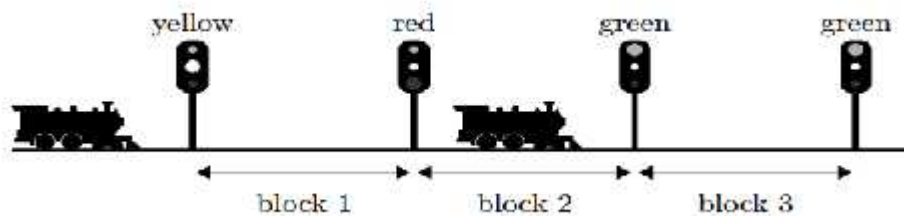


Figure 2.3: Safety block [2]

Rail network is composed of stations, links and block sections separated by signals. For safety reasons, the signals control the train traffic on the routes, and impose minimum distance headway between consecutive trains. Signals, interlocking and Automatic Train Protection (ATP) control the train traffic by imposing a minimum safety separation between trains, setting up conflict-free routes and enforcing speed restrictions on running trains. The minimum safety distance and time headways between two consecutive trains depend on their speeds (running time of the involved trains), the braking rate of the second train (considered in the approaching time to the next signal), the train length of the first train (clearing time), the signal spacing (including sight and reaction time) and the switching time. In case of technical or human failures, ATP ensures safe rail operations. Specifically, ATP causes automatic braking if the train ignores the valid speed restrictions. Signals are located before every junction as well as along the lines and inside the stations. A block section is a track segment between two main signals that governs the train movements, and may host at most one train.

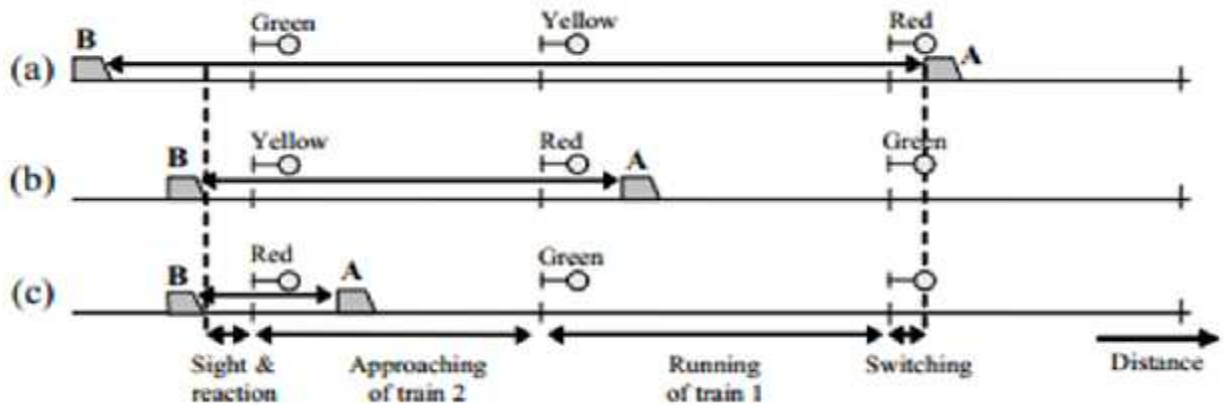


Figure 2.4: Track occupation of two trains (A and B) in case of different signal aspects.

The standard feature of a railway signaling system is characterized by the three-aspect block signaling. For fixed block signaling systems, a train may enter a block section only after the train ahead has completely cleared the block section and is protected by a stop signal. A signal aspect may be red, yellow or green. A red signal aspect means that the subsequent block section is either out of service or occupied by another train (see Figure 2.4(c)), a yellow signal aspect means that the subsequent block section is empty but the following block section is still occupied by another train (see Figure 2.4(b)), and a green signal aspect indicates that the next two block sections are empty (see Figure 2.4(a)). A train is allowed to enter the next block section if the signal aspect is either green or yellow, but the latter requires deceleration and stop before the next signal if this remains red. [16]

The most important data for an appropriate modeling of Macroscopic Railway Infrastructure (Operational Constraints) are:-

- (a) Maximal station capacities,
- (b) (Minimal) driving times,
- (c) (Minimal) turn-around times, and
- (d) Minimal headway times.

The station capacity (a) of a station describes how many trains of a given type can simultaneously wait in or pass through it. The value is calculated by comparing the number and length of the (reachable) internal tracks inside a station with the default length of the regarded train-type and should deliver an upper bound for the next planning step of the so-called Train Plat forming Problem. Unfortunately it is not clear if a so computed capacity value is really valid and has to be checked by running multiple simulations.

The driving time (b) is the minimal journey-time that a train needs to pass a track. This value depends on multiple train-type specific factors like acceleration, maximal speed, or gross load weight, and on track specific factors like incline, track quality, or speed-limit.

Important aspects for the driving time calculations are the driving dynamics of the regarded vehicle. Especially the question if a train departs and arrives in the start and end points of a track either on-the fly or with stoppage, has a great effect on the journey time. Due to the complexity of the calculation one has to solve differential equations that respects as most as possible of the train and track profiles .We calculate these values by simulating with (commercial) simulation tools a run of each train starting and ending in two arbitrary stations with affecting the run by different circumstances, e.g. stopping at all, some or none of the stations.

The simulations should ideally not consider any detrimental effects derived from other trains and be accomplished in a deterministic, traceable process. The value should only consider the pure running time of a train without any external influences. In contrast to this definition, one can also consider a running time that is increased by additional time that should help to recover lost time for delayed trains.

A turn-around time (c) is the time that a train at least needs to spend in a station with the intention to leave a station in the direction it entered. This value is especially important for dead-end stations in which each train, not ending in that station, has to turn. It is estimated and needs subject-specific experience of a planner.

The minimal headway times (d) are the most important safety regulation constraint of a timetable. Headways can be considered in two different ways: Either assigned to the stations that limit a

section, or assigned to the section between two stations. Assigning headways to stations is the more traditional principle and therefore seen as default case in this work. It is defined as the temporary distance between arrival/departure events in a station of two trains running on the physically same track either in the same or on the opposite direction which must at least be hold to avoid rear-end respectively front-end collisions on that track by respecting the specifications of the used block system. So, one can distinguish between four types of headways that can assigned to stations: “depart-depart”, “arrive-arrive”, “depart-arrive” and “arrive-depart” headways. The headways that can be assigned to the section between two stations, is defined as the temporary difference between two successive trains of either direction enter the section. This method has become popular in the last years for analyzing the track capacities. The headway times are in general completed by supplemental time that is denoted as buffer time, and should prevent the transmission of small delays from one train to the other.

Definition of headway times does not consider any additional times and consists only of the technically needed, pure headway times.

A final train schedule has to guarantee that no block-conflict i.e., a train trespasses a blocked track section can arise. First train scheduling models are based on a block-conflict-free formulation which can lead to a huge problem size especially when regarding several tracks. Current models tend to use a headway time based formulation which use so-called headway matrices for each track containing the minimal headway times for each combination of train-types on that track. [14]

2.5.Literature Limitation

Different researchers as discussed in the literature try to solve the problem of the train timetabling generation problem using different approaches according to their interest. But in these different researches have different limitations. Among these:-

1. In identifying the railway timetable requirements
2. They try to solve the problem of cyclic or non-cyclic approach independently
3. They try to solve the problem of single track or double track independently
- 4.

2.5.1. Summary

In order to solve the problem of railway timetable generation problem must identify the railway timetable requirements by finding additional requirements to be creating more effective timetable. And also prepare program which is used to generate a railway timetable which is common for any infrastructure that means for single and double track and suitable for cyclic and non-cyclic type of timetable. That means creating model which is suitable for any type according to the interest of the organization or sector.

Because using railway timetable requirements only which are stated in the literature makes the timetable less effective and more delay. Due to this the profit of the company decrease and customer satisfaction is also less.

CHAPTER THREE

Methodology of the study

3.1. Introduction

This thesis is explanatory; making use of existing data and therefore mostly based upon a literature study. To a large extent, it focus rely on published local and international reports and information from different institutions, academic research, and theoretical reports from different source of data and relevant regulatory institutions like ERC, other thesis and publications from universities. Following the nature of the topic, the collection of information has primarily been through the Internet. The data which is primarily collected through internet provided a data to support this thesis. Additional railway timetable requirements are looking for in addition to the available requirements in the literature. After selecting the requirements a mathematical model is developed and then selecting suit method which is helpful to develop program which is common to any country. Data is collecting according to the objective of the problem of the thesis, which is useful to construct a detailed timetable for a set of trains on a certain part of the railway network.

A railway timetable is collection of calculated time of departure from an origin station to the time of arrival at a destination station of different trains in different route. To fulfill this thesis a programming language method is better to solve the problem of this study. To come to end this study a variety of step or Methodologies are used. See in the figure 3.1 below.

3.2. Research Design

The study will be conducted according to the conceptual framework stated in the figure 3.1 and should focus on designing Railway timetable generation in Ethiopia. Hence, the research design used for this research is based on literature survey.

This study first surveys different documents to identify the most important pillars of the rail way timetabling factors to bring the study to an end and then make searching an appropriate software to develop a railway timetable generator program. The surveying is not only identifying the

requirements but also study how to calculate or know the value of each requirement. A new methodology study cycle is clearly shown below here in this study.

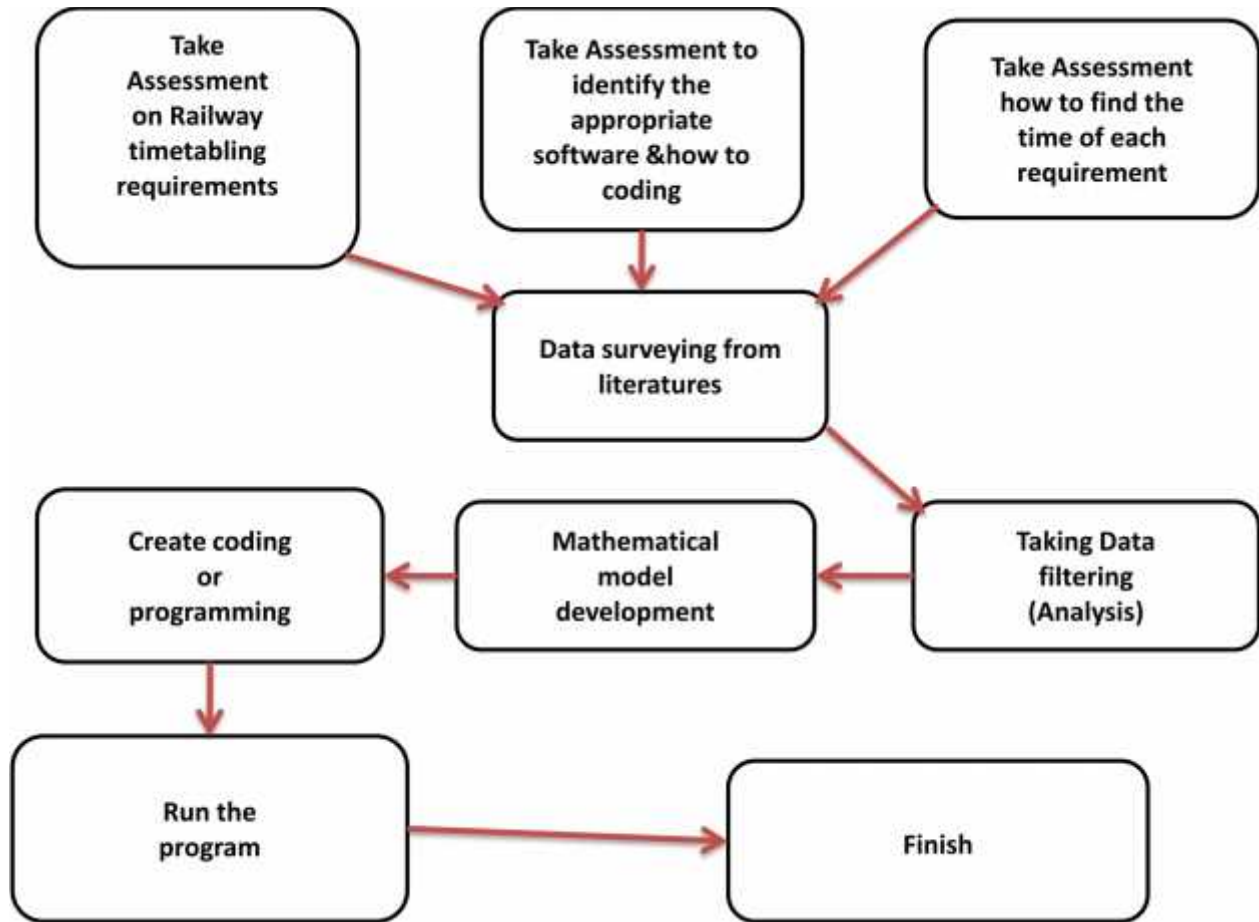


Figure 3.1: study methodology cycle

3.2.1. Data Sources

The study is focusing only on documented data as clearly stated above for the evaluation of railway timetable design. Since Railway in Ethiopia is new, so gathering primary data regarding to timetabling is useless because it is under construction. It is important to collect data using the method of surveying different literatures as a source of data in this study.

A complete literature survey on different written documents regarding on railway timetable and how to design effective railway timetable is taken from the secondary data sources.

Such as

- From browsing different websites,
- Journals, and
- Books etc.

Generally data was collected regarding to the effective design of timetable and on some information's which are useful in preparing this thesis. Under the railway timetable there are various models introduced and discussed in the aim of supporting to construct timetable. In addition, different soft ware's that are available which can suit the system are studied. The figure below shows types of secondary data sources.

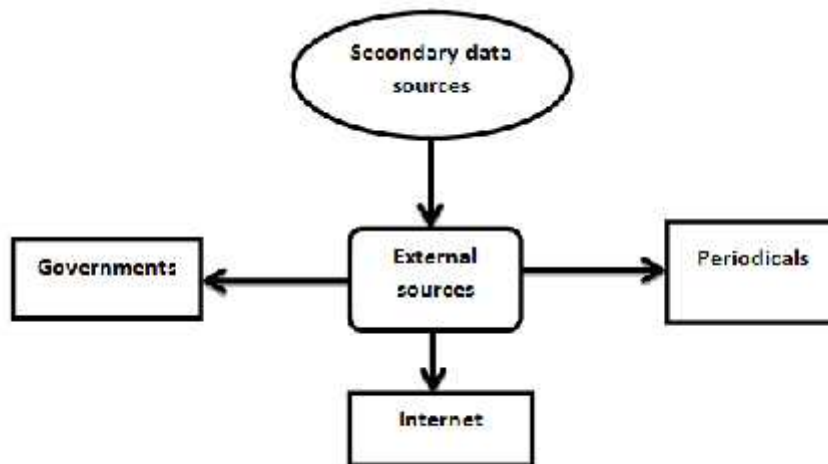


Figure 3.2: Type of secondary data source [29]

Secondary data in this research consists of several sources as shown in the figure above. Primary data cannot be obtained or it becomes difficult to obtain primary data in Ethiopia, so it must bind to use secondary data. The reliability, authenticity and generalizability of secondary data is less as compared to primary data as it has been already manipulated and used by other people. Obtaining primary data requires more human and non-human resources like time, money and energy,

therefore in some studies researchers consider secondary data much better and feasible, then to design railway timetable in Ethiopia data source is secondary data, which is better.

Some of secondary data sources which we used in this study are listed below.

✓ Published Data

Published data is the most basic secondary source of information for data collection. Published data can be obtained from various sources like books, magazines, newspapers, journals and Periodicals etc.

Published data is the most reliable secondary source of information. The validity of published data is greater than unpublished data.

The majority of published records can be obtained from libraries and documents. ERC and Addis Ababa institute of technology Libraries carry a vast variety of books, journals and periodicals. In this study uses this information as a reference in this thesis, dissertation or other research articles. Periodicals and journals provide up to date information and they are also available in libraries. From transportation newspapers also use as a reference. Newspapers are an excellent source of data collection historical research. Some record cannot be obtained from any other source except newspaper as it does not exist in books and journals. Old newspapers record can be obtained from the archives. In published data books are easier to use as data are arranged in order in books while newspapers are difficult to use because in newspapers there is no list of contents or bibliography.

✓ Internet

Internet in today's world is the fastest growing source of information. The internet has become grown-up and today any one can get any information from the internet. Most of the books are available on the internet in e-book format. The information can be obtained faster than we can obtain from any other source. On the internet we can get e-books, e-journals, e-periodicals and e-magazines. The internet is a multiple source of information as all of the above mentioned sources can be obtained from the internet. Most recent and most up to date information can be obtained from the internet as it would not be available in books and other forms. Getting information from

the internet is inexpensive as compared to other sources. Anyone can get membership of different periodicals, sometimes this membership is free otherwise we have to pay a small amount of money.

The data collection includes the following parameters which can be used to identify the requirements or factors of railway timetable design.

- ✓ Available soft ware's which are helpful to create a program
- ✓ Identify requirements used to develop mathematical model

3.3. Data analysis

The collected data is analyzed and filtered according to the study needed. Here there are several requirements or factors which are useful to construct a railway timetable in different researches which are not specified clearly, therefore these are collected and arranged and put to this study.

The collected data will be analyzed and arranged accordingly to give the final outcome of the thesis. Analysis on the railway timetable generation is taking place.

3.4. Mathematical model development

Mathematical model is the key component to design a railway timetable. Then after analyzed the collected data the railway timetable problem is formulated mathematically and all the constraints are presented following with detailed explanation of all the requirements. Once the data has been defined it is possible to formulate a mathematical model to solve a railway timetabling problem satisfying all the infrastructure restrictions and functional requirements. The aim of this mathematical model development is to help to create a coding program to solve timetabling problem by finding a feasible departure and arrival times for every train at every node of its route through the route line infrastructure. These departure and arrival times are the key parts of the timetabling.

3.5. Create a program using appropriate software

Once the mathematical relation (model) has been developed it is possible to formulate a programming in order to solve railway timetabling problem satisfying the functional requirements.

Then using the mathematical model, program is created using Php. PHP, which stands for "PHP: Hypertext Preprocessor" is a widely-used Open Source general-purpose scripting language that is especially suited for Web development and can be embedded into HTML. Its syntax draws upon C, Java, and Perl, and is easy to learn. The main goal of the language is to allow web developers to write dynamically generated web pages quickly, but anyone can do much more with PHP as his knowledge because it is flexible.

PHP is probably the most popular scripting language on the web. It is used to enhance web pages. With PHP can do things like create username and password login pages, check details from a form, create forums, picture galleries, surveys, and a whole lot more.

PHP is known as a server-sided language. That's because the PHP doesn't get executed on a computer, but on the computer it requested the page from. The results are then handed over to us, and displayed in our browser.

CHAPTER FOUR

Model Development

4.1. Introduction

All countries and their railway system have their own railway structure and difficulties when constructing timetables and therefore the timetable design differ between countries. Depending on whether the infrastructure consists of single or double-trucks the timetables must be designed differently. But in this chapter of the paper develops a common model for any type of truck, infrastructure, train (passenger or freight), and stations.

4.2. System Architecture

In this system architecture to develop a model first identify the factors of the timetable requirements is the key idea and then by making a relation of each factor makes model development. New system architecture is clearly shown below.

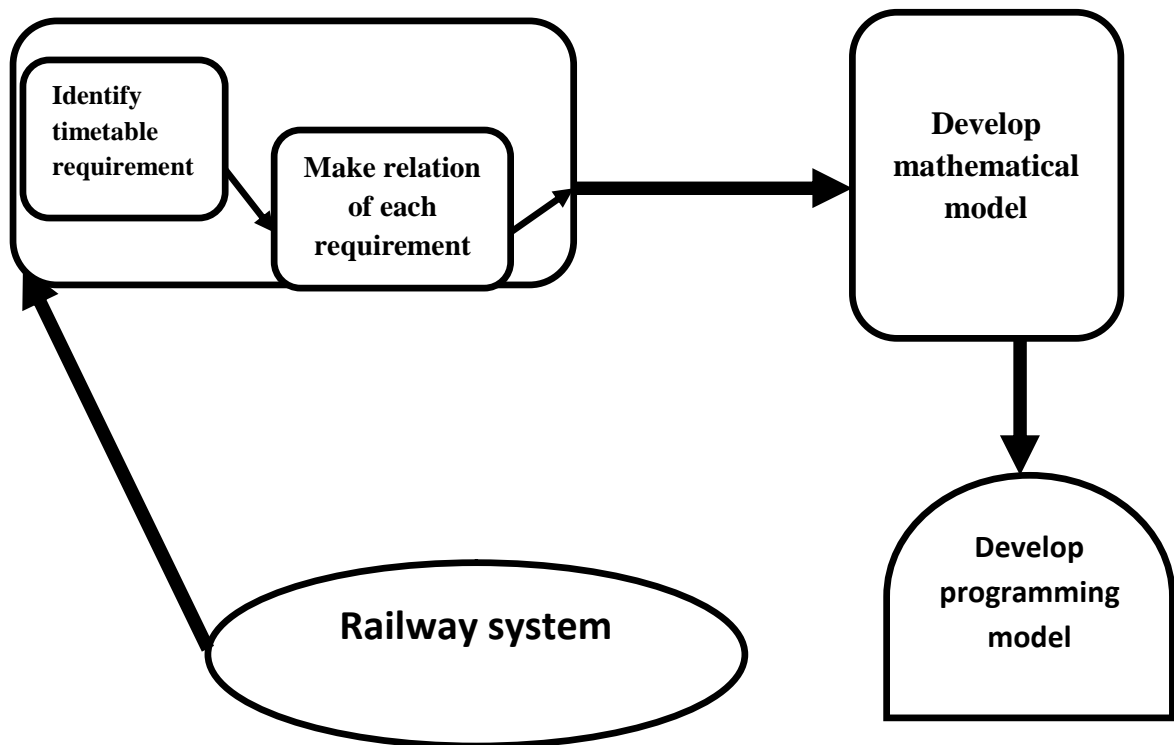


Figure 4.1: System Architecture

4.3. Problem Definition

Railway timetabling is such a rich and complex problem, it is necessary to define all the model's assumptions and inputs. This model considers for both single and double railway line that serves trains travelling in both directions. The railway is formed by track segments and safety blocks as shown below, which make the connection between all the stations and sub-stations (the starting point and ending points).

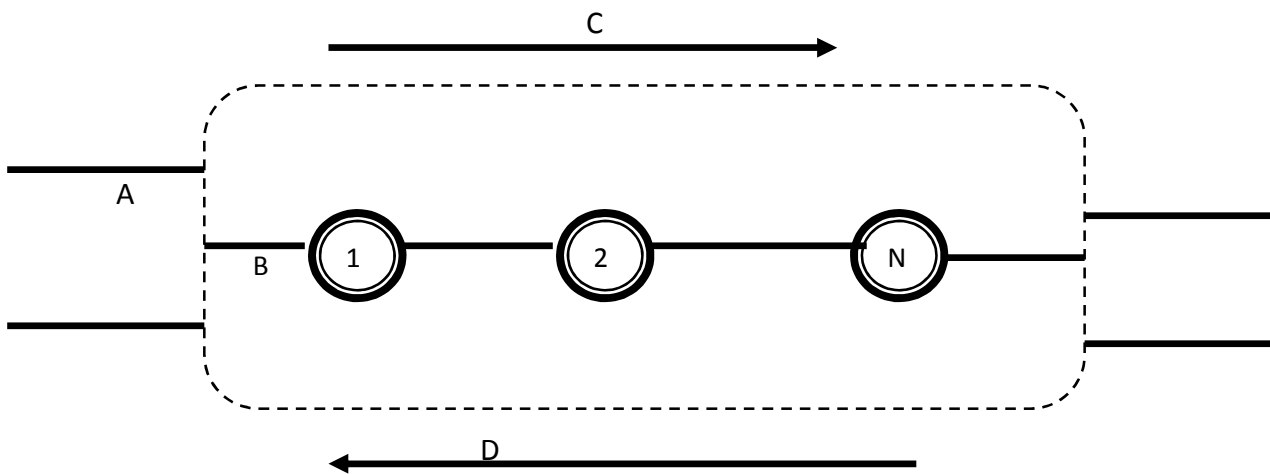


Figure 4.2: railway line model [2]

Where 1, 2 ...N: Stations

A: double track

B: Single track

C: forward direction

D: back ward direction

Solving this arrival and departure time of this type of problem is the solution to the objective of this study. The solution shows clearly in the following sections in detail.

4.4. Identifying railway timetable requirements

Railway timetable is generated based on different requirements even if finding the exact time of the requirements is difficult and complex because of the requirements are dependent on infrastructure, train construction, train speed and train length etc., so the time of these requirements differ from country to country and also from train to train. Then knowing the requirements make easy to find the effective timetable. But as seen in the literature review most of the researchers use the requirements only run time, headway time, transfer time and dwell time. Only these requirements make less effective timetable. Then on the analysis of railway timetable generation, the following factors are selected to design railway timetable to make a railway timetable more effective.

1. Maintenance time
2. Driving time
3. Dwell time
4. Passenger transfers time
5. Switching time
6. Headway times
7. Allowance time
8. Route distance
9. Train speed
10. Route direction or movement (from to)
11. Train (cargo) connecting (disconnecting) time

4.4.1. A Brief Discussion on the railway timetable requirements

To develop a railway timetable or to find the departure time from the origin station and the arrival time to the end station is calculated time of each requirement. Clearly the time of these requirements have different value in different country even differ from train to train. These requirements are clearly discussed one by one in the following sub topics.

4.4.1.1. Dwelling time

Dwelling time is one of the requirements of a railway timetabling. Then the determination of train dwell time is an essential step in planning railway timetables. The magnitude of dwell time affects not only train operation efficiency but also punctuality. As discussed in the literature review researchers use different techniques to estimate the time of dwell time such as mobile devices (notebook PCs, mobile phones, and personal digital assistants) which are helpful to collect data in field survey and Statistical approaches. But dwelling time varies from country to country and also from station to station.[11, 15, 24].

4.4.1.2. Headway time

Headway is a measurement of the distance or time between vehicles in a transit system as discussed in literature. The precise definition varies depending on the application, but it is most commonly measured as the distance from the tip of one vehicle to the tip of the next one behind it, expressed as the time it will take for the trailing vehicle to cover that distance. A "shorter" headway signifies a more frequent service. Freight trains might have headways measured in parts of an hour, metro systems operate with headways on the order of 1 to 5 minutes, and vehicles on a freeway can have as little as 2 seconds headway between them and Ethiopian railway corporation headway time of 6min initially and can be reduced to 90 seconds at ultimate capacity.

Headway is a key input in calculating the overall route capacity of any transit system. A system that requires large headways has more empty space than passenger capacity, which lowers the total number of passengers or cargo quantity being transported for a given length of line (railroad or highway, for instance). In this case, the capacity has to be improved through the use of larger vehicles. On the other end of the scale, a system with short headways, like cars on a freeway, can offer very large capacities even though the vehicles carry few passengers. The term is most often applied to rail transport, where the number of tracks is limited and signaling capabilities require long headways between trains. Newer signaling systems and moving block controls have dramatically reduced headways in modern systems compared to the same lines only a few years ago. In principle, automated personal rapid transit systems and automobile platforms could reduce headways to as little as fractions of a second.

This is the name given to the elapsed time between trains passing a fixed point in the same direction over the same track. It is usually expressed in minutes e.g. "trains were running at 4-minute headway". Another way of expressing it is as trains per hour.

A well run railway will conduct research to determine how many fare paying customers are likely to show up at various times of the day and will operate their trains to suit. In many instances the patronage numbers will show that it is possible to run trains at even intervals or at a given "headway". This may be at two hours for a long distance, main line route or two minutes for a metro.

Once established, the headway is used in calculating the number of trains required for a particular service, the train performance requirements and signaling requirements.

The minimum headway is an important factor for the planning, design and operation of a rail transit line. The calculations of minimum headway are discussed in the literature review. From different studies headway time is varying from country to country and also from train to train. [2, 15, 25]

4.4.1.3. Passenger transfer time

Passenger transfer time also one of the requirements of a railway timetabling. If a passenger transfer connection between two trains is desired, then both trains should be present at the connecting station at about the same time. Moreover, the trains are preferably assigned to opposite sides of the same platform, which creates a so-called cross-platform connection.

The minimum transfer time includes alighting time, walking time (including possible orientation) and boarding time. It depends on the individual walking speed and acquaintance with the station, the relative position of the arrival and departure platform (cross-platform, two platforms apart, etc.), the geography of the station (platform lengths, distances between platforms, widths of corridors and door-ways, presence of escalators, etc.), and the pedestrian flows and densities in the station.

The needed number of transfers is an important factor in timetabling. For passengers with heavy luggage it is not convenient to change trains on their journey. Each transfer can have the risk of

extending the travel time compared to a direct train service. In most cases the passengers will experience a scheduled waiting time in connection with transfers. The minimum interchange time depends on the transfer conditions. If the connecting train uses the same track or platform, the planned transfer time can be down to a few minutes. If the transferring passengers have to get to a different platform or to a different section of the same platform, then the transfer time depends on the station's platform and platform track layout.

An extremely short and extremely long transfer time is negatively appraised. This confirms the a priori expectations. Social-recreational passengers prefer to avoid short transfers and commuters experience particularly the longer transfer times as more negative.

An important finding of the model estimates is that there would seem to be an 'ideal' transfer time. Short transfers are particularly negatively appraised by social-recreational passengers. An obvious reason for this is that a short transfer induces stress. Stress that can originate from either having to hurry or possibly from missing a connection. In the literature, there were no significant findings on short transfer times, although there were suspicions which this study has now corroborated. The disutility of a short transfer time for cross-platform connections is lower than for cross-station.

A longer transfer time becomes waiting time and causes all types of passengers to feel increased resistance. This is less so for those with a large amount of luggage as opposed to those with none.

Passenger transfer time Depend on the following factors

- ✓ Number of transfer passenger
- ✓ Number of exit doors
- ✓ Distance between the trains[2]

Therefore transfer time differs among different countries and even among different trains.

4.4.1.4. Maintenance time

Railways are made up of complex mechanical and electrical systems and there are hundreds of thousands of moving parts. If a railway service is to be reliable, the equipment must be kept in good working order and regular maintenance is the essential ingredient to achieve this. A railway will not

survive for long as a viable operation if it is allowed to deteriorate because of lack of maintenance. Although maintenance is expensive, it will become more expensive to replace the failing equipment early in its life because maintenance has been neglected.

Rolling stock is the most maintenance intensive part of the railway system and it is at risk if maintenance is neglected. A delayed train blocks a railway immediately and reduces a timetable on an intensively used system to an unmanageable shambles for the remainder of the day. Reliability is the key to successful railway operation and maintenance should be the number one priority to ensure reliability is on-going.

Maintenance planners prepare a maintenance program of each rolling stock according to their plan. Maintenance planners; maintenance program can be programmed in one of three ways.

1. By distance,
2. By time or
3. Byconditioningmonitoring(situation observation)

Of these three methods, condition monitoring is the most recent. Traditionally, maintenance was carried out on a time basis, usually related to safety items like braking and wheel condition. Many administrations later adopted a distance based maintenance system, although this is more difficult to operate as you have to keep records of all vehicle distance and this is time consuming unless you have a modern train control and data gathering system. But at this age trains are modern then it is not difficult to record the moving distance. There is also the fact that a train will deteriorate just as quickly if it is stored unused somewhere as it would if it was being run in service every day. Only the items which deteriorate will vary.

Modern trains should be able to run for some weeks without a maintenance inspection. One train operating company may want to get inspection intervals out to 90 days on its new. It is impossible to give fixed time or distance periods here for maintenance as each type of train varies. There are often special rules for high speed trains and for heavy freight. Individual railways have adapted their maintenance to the local conditions and, in many places, certain types of safety inspections are required by law.

Condition monitoring is achieved by checking the operation of the equipment and only changing something if it shows signs of wear beyond preset limits. The checking is often done using on-board monitoring and storing the data gathered in a computer for downloading at the maintenance facility. Of course, it is a recent development made available by the introduction of information technology on trains. Such systems are now becoming so sophisticated that it is possible to have failure predictions of some items of equipment. A combination of on-board data gathering and depot maintenance systems have been developed into complete maintenance management systems on lines where modern rolling stock has been introduced.

➤ Maintenance requirements

A feasible roster solution must satisfy all maintenance requirements. The input information concerning maintenance consists of three parts:

- ❖ Maintenance types: Each train unit must have certain types of maintenance. The most common types are:
 - a) Refuel for diesel locomotives,
 - b) interior cleaning,
 - c) exterior cleaning,
 - d) scheduled repairs, and
 - e) Technical check-ups.

If a train has to wait at a station for a longer period of time, in certain stations it is possible to park the train on a separate track. This is called siding, and will also be treated as maintenance.

- ❖ Maintenance interval: Each maintenance type must be performed on a train unit at certain intervals. These intervals can depend on elapsed time (since last maintenance), distance driven (since last maintenance), or on both.

For example, interior cleaning should be done every 24 hours, exterior cleaning should be done before the train has run for 1,000 kilometers, and a technical check-up needs to be performed, whenever one week has passed or 10,000 kilometers have been driven (whichever occurs first). This

last requirement is both time and distance-dependent. Of course, it is always possible to perform maintenance before the interval is reached, but this increases costs.

- ❖ Maintenance stations: Maintenance stations are scattered rather scarcely all over the network. For each maintenance station we are given information of which types of maintenance can be performed for each train unit type, and hours of operation for the station. Moreover, capacity constraints are also given as part of the input and it is specified how long each maintenance type takes.[27]

From these data a maintenance time is differ from train to train and even from country to country.

4.4.1.5. Switching time

A railroad switch, turnout or points is a mechanical installation enabling railway trains to be guided from one track to another at a railway junction by reducing its speed from the operating speed.

The switch consists of the pair of linked tapering rails, known as points (switch rails or point blades), lying between the diverging outer rails (the stock rails). These points can be moved laterally into one of two positions to direct a train coming from the narrow end toward the straight path or the diverging path. A train moving from the narrow end toward the point blades (i.e. it may go either left or right) is said to be executing a facing-point movement.

Unless the switch is locked, a train coming from either of the converging directs will pass through the points onto the narrow end, regardless of the position of the points, as the vehicle's wheels will force the points to move. Passage through a switch in this direction is known as a trailing-point movement.

A switch generally has a straight throughtruck (such as the main-line) and a diverging route. The handedness of the installation is described by the side that the diverging track leaves. Right-hand switches have a diverging path to the right of the straight track, when coming from the narrow end and a left-handed switch has the diverging track leaving to the opposite side. A straight track is not always present; for example, both tracks may curve, one to the left and one to the right or both tracks may curve, with differing radii, in the same direction.

Model railroad switches, just like real-life railroad switches are used to route rail traffic. In model railroading, switches are most commonly referred to by the technical term "turnouts". In some countries rail switches are referred to as sets of points. Or just points. This is because the moving rails within the switch are called points. Trains enter turnouts by a single track and can be routed to either of two, or sometimes any of three, exiting tracks.

Most switches are power controlled by a train dispatcher, who can be located hundreds of miles away, the switches themselves don't need a computer or embedded chip to work. Most power control switches in some countries are of the dual control type. This means that a switch can be thrown remotely on power by the train dispatcher from far away or can be taken off power and thrown manually (on hand) by a train crew on the ground. We have often told a train crew to take a power switch off power and line themselves through the control point. (A control point or interlocking is the railroad name for a place where trains can switch from track to track). This happens now a then due to any number of things that would cause the switch to fail. These can be ice and snow in the switch points or just the electric motor that moves the points giving out. Now, before a train crew to take a switch on hand the train must first come to a stop at the stop (red) signal that guards the control point where the switch is located. The dispatcher then gives the train permission to pass the stop signal at restricted speed up to the switch in question. Once the train arrives at the switch the conductor must climb down and take the switch off power and line it by hand. Once this is done the train can proceed over the switch still not exceeding restricted speed until the rear end has cleared the switch. The switch can be restored to power once the train starts over it as the shunt caused by the train will not allow the dispatch to throw the switch until the train has cleared the control point.

Now the problem in all this is that instead to traveling through the control point at normal speed through a switch from one track to another the train must stop and line the switches by hand which take considerably longer and tends to slow up the whole railroad line. Now we have established the fact that railroad switches can be thrown by hand before a train begins jumping up and down screaming. [28]

From this there is a time need to switch a train in either the modern switch or old switch. This time is not fixed it varies from country to country even from switch to switch.

4.4.1.6. Train connection time

First, it is important to set out some definitions. A train is defined as one or more railway vehicles capable of being moved. It may consist of a locomotive (sometimes more than one) to provide power with various unpowered vehicles attached to it. It may consist of a multiple unit, i.e. several vehicles formed into a fixed formation or set, which carry their own power and do not require a locomotive. A train may be only a locomotive running light (deadheading) to a point elsewhere on the railway. A train may be passenger carrying, freight or, rarely nowadays, mixed.

If two trains are to be combined to travel on as one single train, they need to be present at the station at exactly the same time. This yields a so-called combination connection.

The smallest interesting entity of a train is a train unit: one or more railcars or locomotives which are linked together. Then it needs a time to link or unlink the railcars or a locomotive which is called connecting time. Train units are routed and maintained as an entity, never to be broken into smaller units in the problems considered here. Depending on different kinds of railcars and locomotives and on the formation of the single cars, there can be different train unit types. A train consists of a number of train units coupled together. The length of a train is the number of train units which form the train. (The physical length of the train, a distance measurement, is also implicitly used in some of the train scheduling constraints.) Some of the train units can move in only one direction, whereas others can move in both directions. These bidirectional units are called push-pull trains. This refers to the transfer of locomotives from an inbound train at a particular station to an outbound train at the same station.

A minimum time required for a locomotive to connect between two trains (it varies from station to station and train to train) is called Minimum Connection Time. If a train reaches its arrival station, it might have to be decomposed into its train units by decoupling and shunting; the train units are subsequently combined into new trains to carry out their next rides. The time needed to complete this procedure depends on the train unit types involved, on whether only coupling or decoupling or

both are needed, and on the station topology. The time needed for this procedure is called station turnaround time. These times are given as part of the input for each possible combination of coupling mode, train unit type, and station. Therefore, a solution of the train length problem may not have any feasible train assignment solution, since the turnaround time at some station is violated. Any feasible solution must fulfill these timing requirements. [27]

From this a train connection time varies from train to train and even from country to country.

4.4.1.7. Allowance time

In order to improve punctuality, railways have always provided recovery time in timetables. This is extra time, above that usually required for a train to complete its trip on time, allocated in case of a small delay or temporary speed restriction.

It does not make for good public relations when trains arrive at the outskirts of a city 10 minutes early and the passengers have to cool their heels in a stationary train knowing that they are only a few minutes travel time from their destination. Allowance time should be strictly limited and eliminated altogether when possible. It should not be used as an excuse for bad timekeeping.

Therefore allowance time is very important in effectiveness of railway timetable.

4.4.1.8. (Route) Driving time

Route driving time is a time needed from the origin station to the end station without any delay. A route is a path between two given end stations. Each route has a distance and a travel time associated with it. In any route there may be intermediate stations between the two stations. A trip is a train unit on a certain route with distinct departure and arrival time.

Route driving time is calculated by route distance divided by speed of the train.

$$\text{driving time} = \frac{r}{sp} \frac{d}{o t}$$

This is without any delay consideration only assuming the distance that the train covers and the constant speed of the train without any change.

4.5. Mathematical Model Development

Before go to the mathematical model development of this study; let's see the others model development experience.

4.5.1. Cyclic Railway Timetabling Model

Most of the European countries use cyclic railway timetable in their railway system. Mathematical model for cyclic railway timetabling is clearly shown below.

$a_n^t \in \{0, \dots, T-1\}$ The arrival time of train t at node n .

$d_n^t \in \{0, \dots, T-1\}$ The departure time of train t from node n . [2,26]

Passengers who want to change at a station from train t to train t' give us a very nice example of a time window constraint. Let us say they are given between 2 and 4 minutes to change trains. Then the time window constraint can be formulated as

$$d_{t'} - a_t \in [2,4]_T$$

as train t' should depart ($d_{t'}$) between 2 and 4 minutes after train t arrives (a_t). The subscript $[2;4]_T$ represents the periodicity. An equivalent formulation of this equation is

$$d_{t'} = (a_t + x) \bmod T, \quad x \in [2; 4]:$$

The general mathematical model can be expressed as follows

$$t_j = (t_i + x) \bmod T; \quad x \in [l_{ij}; u_{ij}];$$

Where $T \in \mathbb{Z}$ is the period within which the timetable repeats itself, and $l_{ij}; u_{ij} \in \mathbb{Z}$ are the lower bounds and the upper bounds on the time windows.

We assume $0 < u_{ij} - l_{ij} < T$.

Here, i and j are the events, which are either the arrival or departure of a train at a certain station, and t_i and t_j are the event time decision variables. [3]

These all mathematical models are only related to the periodic railway timetabling problems which most European countries use. But model of railway timetable can be non-periodic and also mixed timetable but regarding to the mixed timetable has no more reference regarding to the modeling problem.

This study tries to solve the problem of mixed railway timetable by modeling a common mathematical model for any type of railway timetable.

Then to develop the mathematical model of the railway timetabling using the requirements is easy now because the timetable requirements are once identified. When a train moves from one station to another station; the following equation shown in the figure 4.3 must apply for any type of train (passenger or freight) and for any type of infrastructure (single or double track) which is used to generate any type of railway timetable (periodic or non-periodic).

$$\begin{aligned}
 1. \quad & a \quad t_{i+1} = d \quad t_i + d \quad t_i + d \quad t_i \\
 2. \quad & d \quad t_{i+1} = s \quad t_i \\
 & \quad \quad \quad = a \quad t_i + d \quad t_i \\
 3. \quad & d \quad t_{i+1} = \frac{r \quad d}{s} \\
 4. \quad & d \quad t_{i+1} = m \quad t_i + d \quad t_i + tr \quad t_i + \\
 & c \quad t_i \quad t_i + he \quad t_i + s \quad h_i \quad t_i + \\
 & a_i \quad t_i
 \end{aligned}$$

Figure 4.3: moving train equations

When a train starts to move from one station to another station as shown in the figure 4.4 below; it is possible to find the departure and arriving time of this train in each and every station and sub stations. For detail see the following equations.

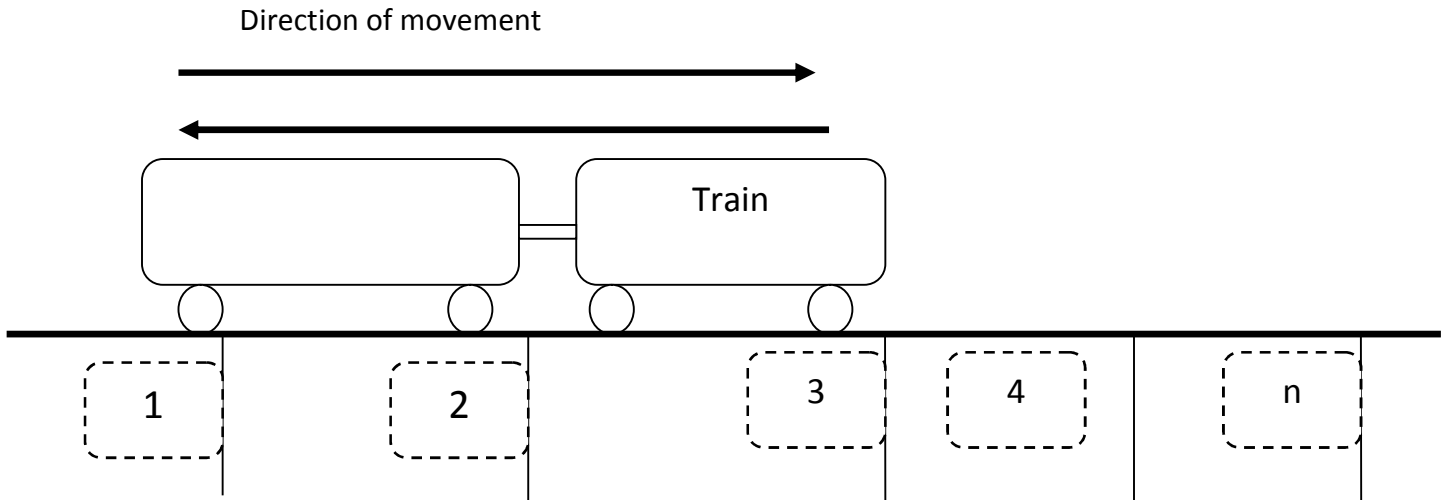


Figure 4.4: train in movement

Where: 1; 2; ...n – Number of stations

Now to find the arrival and departure time of the train in each station from any direction and in any infrastructure is shown as follows.

$$\begin{aligned}
 a_{t2} &= d_{t1} + d_{t(1t2)} + d_{t(1t2)} \\
 d_{t1} &= s_t
 \end{aligned}$$

Finding arriving & departing time from station 1 to 2
& s_t =starting time=given

$$\begin{aligned}
 a_{t3} &= d_{t2} + d_{t(2t3)} + d_{t(2t3)} \\
 d_{t2} &= a_{t2} + d_{t2}
 \end{aligned}$$

Finding arriving & departing time from station 2 to 3
& d_{t2} =dwell time at 2

$$\begin{aligned}
 a_{t4} &= d_{t3} + d_{t(3t4)} + d_{t(3t4)} \\
 d_{t3} &= a_{t3} + d_{t3}
 \end{aligned}$$

Finding arriving & departing time from station 3 to 4
& d_{t3} =dwell time at 3

$$\begin{aligned}
 a_{t5} &= d_{t4} + d_{t(4t5)} + d_{t(4t5)} \\
 d_{t4} &= a_{t4} + d_{t4}
 \end{aligned}$$

Finding arriving & departing time from station 4 to 5
& d_{t4} = dwell time at 4

$$\begin{aligned}
 a_{t6} &= d_{t5} + d_{t(5t6)} + d_{t(5t6)} \\
 d_{t5} &= a_{t5} + d_{t5}
 \end{aligned}$$

Finding arriving & departing time from station 5 to 6
& d_{t5} = dwell time at 5

$$\begin{aligned}
 a_{t7} &= d_{t6} + d_{t(6t7)} + d_{t(6t7)} \\
 d_{t6} &= a_{t6} + d_{t6}
 \end{aligned}$$

Finding arriving & departing time from station 6 to 7
& d_{t6} = dwell time at 6

Finally it is possible to summarize as follows, which fits for all equations and can calculate the arrival and departure of a train from any direction of route in any station using the following equation.

$$\begin{aligned}
 a_{t(n+1)} &= d_t + d_{t(nt\ n+1)} + d_{t(nt\ n+1)} \\
 d_t &= a_t + d_{tn}
 \end{aligned}$$

From station n to n+1 and
 d_t = dwell time at n
n-- Represents station
 $n \geq 1, n \in \mathbb{Z}$

Figure4.5: mathematical model of train movement

Where:

$$de_{t(n+1)} = m_{t(n+1)} + dw_{t(n+1)} + t_{t(n+1)} + c_{t(n+1)} + h_{t(n+1)} + sw_{t(n+1)} + al_{t(n+1)}$$

$$dr_{t(n+1)} = \frac{r_{d(n+1)}}{s}$$

Table 4.1: Parameters and variables used in the mathematical formulations

Symbol	Definition
ar_t	Arriving time in any stations or substations
d_t	Departing time from any station or substation
dr_t	Driving time from one route to another route
de_t	Delay time between starting and end stations or substation
s_t	Starting time from any station or substation
dw_t	Dwell time in station or substation
m_t	Maintenance time of a train
al_t	Allowance time during train movement
sw_t	Switching time during switching
h_t	Headway time between two trains
t_t	Transferring time during transferring passengers or goods
C_t	Connecting train time during adding or removing of cargos
r_d	Route distance
s	Train speed

4.6. Programming language Selection

The programming is developed by the PHP. PHP is a powerful server-side scripting language for creating dynamic and interactive websites. The main motivation for this choice was the developer's experience on other programming language was a graphic and was not easy understood for customer and in the other hand there was a lack of experience in these types of languages. Then this is important to introduce such programming languages which are helpful to design any program especially programs depend on timetable.

PHP is a hypertext preprocessor which is used to develop any dynamic program, and also interrelates and works together with others.

Then this paper uses programming languages like PHP, HTML, MYSQL, CSS and APACH which are helpful in constructing any program especially in timetabling. Details on these methods are given in [18], [19], [20], [21], and [22].

PHP creates an output of any type like a text in the form of a table which is clear and easily understood for any reader or customer. The flow chart of the program shows at figure 4.7 below.

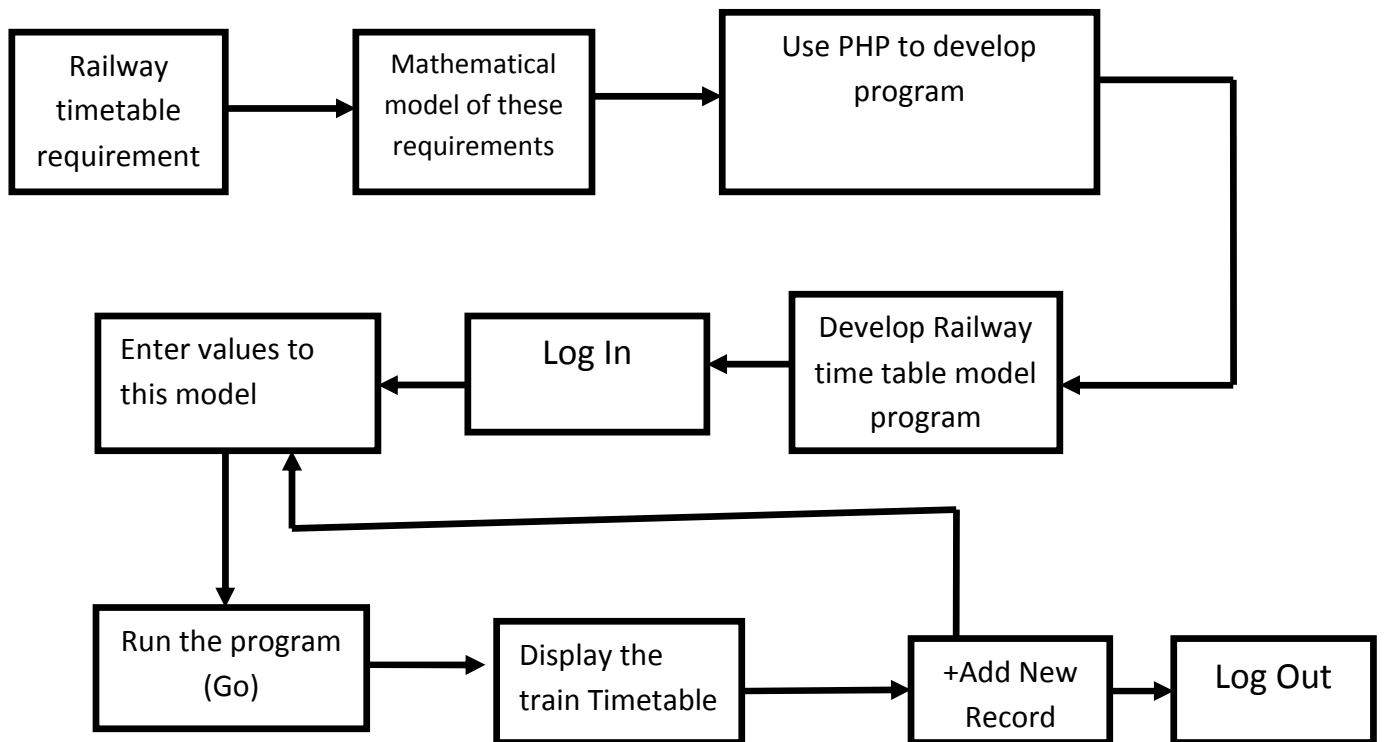


Figure 4.7: Timetable program flowchart

There is no experience in this type of programming language in other researchers to solve the problem of generating effective railway timetable. Most of others experience is on different algorithms and MATLAB which is a graphic form. Details on these type of methods are in [2,3,9,12,15].

4.6.1. Entities to the program

The program is a flexible which is common to any country and can enter any values. The program contains different entities shown in the following table

Table 4.2. type of entities

Type of entities	Value	Measurement	
Train code/name	Any valu	-	
Train route direction	>>	-	
Route distance	>>	Meter	
Train speed	>>	m/s	
Transfer time	>>	Hr:m:s	
Maintenance time	>>	Hr:m:s	
Headway time	>>	Hr:m:s	
Connecting time	>>	Hr:m:s	
Allowance time	>>	Hr:m:s	
Dwell time	>>	Hr:m:s	
Swiching time	>>	Hr:m:s	
Starting time	>>	Hr:m:s	
Arriving time	>>	Hr:m:s	

The final out put of the program timetable contains Train code/name , Route from , Route to , Depature time and Arrivale time as shown in following table 4.3 below.

Table 4.3. final timetable entities

Train code/name	Route from	Route to	Depature time	Arrivale time
0001ERC	Ayat1	torhayloch	12:30:00	01:10:00

4.7.Result of the study

4.7.1. Railway timetable generation program

From the railway timetable model development; a railway timetable generation program is developed as shown below in the figure 4.8 using PHP programming language. This is a result of the program which is developed in the notepad or other programming application.

In this program anyone can put any value, any type of route and any type of train. Then the timetable display as shown in the table 4.4 below after entering to the program page using log in showing in figure 4.8.

In this railway timetable generation program after entering all the input value to the program shown below; then finally by pressing the **“GO”** button and then the timetable will display as shown in table 4.4 below and then click **“+Add New Record”** to enter new input values.

This program is the solution to the railway timetable generation problem which is a flexible program to enter any value to this program model. Railway timetable generation model is the headache for any railway infrastructure managers because railway timetable requirement have different value from country to country even from station to station because it depends on passenger flow, type of infrastructure, type of train construction, type of train length, type of skilled human power, type of facilities in the organization. Due to these factors the railway timetable requirement values are different. Then a common programming model like this study must be needed to solve the problem of this difference in railway timetable requirement value.

Therefore; this program model solves the problem of the railway timetable generation problem effectively.

Username

Password

Remember Me

Figure 4.8: log in menu

Requirement

Transport Information

T-Code Route To:

Distance (meter)

Speed (m/s)

Starting Time

Requirements

Transfer Time	<input type="text" value="hr"/>	<input type="text" value="m"/>	<input type="text" value="s"/>	Connecting Time	<input type="text"/>	<input type="text"/>	<input type="text"/>
Maintainance Time	<input type="text"/>	<input type="text"/>	<input type="text"/>	Dwell Time	<input type="text"/>	<input type="text"/>	<input type="text"/>
Head Time	<input type="text"/>	<input type="text"/>	<input type="text"/>	Switching Time	<input type="text"/>	<input type="text"/>	<input type="text"/>
Allowance Time	<input type="text"/>	<input type="text"/>	<input type="text"/>				

Figure 4.9A: A railway timetable generation modelprogram (before entering value)

Home Transportation

Requirement

Transport Information

T-Code: 003ERC Route: kality To: stadium
 Distance (meter): 200000 Speed (m/s): 23

Starting Time: 12 30 0

Requirements

Transfer Time	<u>0</u>	<u>13</u>	<u>0</u>	Connecting Time	<u>0</u>	<u>5</u>	<u>0</u>
Maintainance Time	<u>0</u>	<u>5</u>	<u>0</u>	Dwell Time	<u>0</u>	<u>45</u>	<u>0</u>
Head Time	<u>0</u>	<u>6</u>	<u>0</u>	Switching Time	<u>0</u>	<u>3</u>	<u>0</u>
Allowance Time	<u>0</u>	<u>5</u>	<u>0</u>				

Figure 4.9B: A railway timetable generation modelprogram (after entering value)

4.7.2. Final railway timetable display

By entering the values of the railway timetable requirements (like dwell time, headway time, driving time etc.) and locations as input to the program as shown the figure 4.8, it displays the results of departure time, arriving time, the train code or name, the starting station and the end station as shown in the tables 4.2 below.

This table can show all the individual timetables once or can display only as we selected. Any one also can search any route or train as his interest.

Table 4.4A: The final output of train timetable (shows only 10)

March, 2014

Go

+ Add New Record

Show 10 entries

Search:

T-Code	Route From	Route To	Departure Time	Arrival Time	Entry Date	Action
0010ERC	awsh	welidya	2:15:0	2:55:56	2014-05-12 09:00:48	Delete
0011ERC	kality	leghar	8:12:0	3:49:47	2014-05-12 11:58:54	Delete
0012ERC	addis ababa	awash	8:30:0	12:20:54	2014-05-12 12:02:34	Delete
0013ERC	stadium	kality	5:15:5	6:14:57	2014-05-14 11:58:17	Delete
001ERC	ayat1	kality	1:30:0	2:38:1	2014-05-09 02:12:12	Delete
001ERC	djibuti	saris	4:30:0	8:45:55	2014-05-09 04:28:22	Delete
001erc	stadium	ayat2	12:30:0	3:1:30	2014-05-16 03:32:35	Delete
001ERC	ayat1	ayat2	12:30:0	4:55:45	2014-05-26 03:56:58	Delete
002ERC	torhyloch	stadium	2:30:0	3:10:29	2014-05-25 09:18:08	Delete
003ERC	djibuti	addis ababa	1:30:0	5:46:40	2014-05-09 04:09:09	Delete

Time Table

Showing 1 to 10 of 26 entries

First
Previous
1
2
3
Next
Last

Table 4.4B: The final output of train timetable (showing all)

March, 2014

Go

+ Add New Record

Show All entries
Search:

T-Code	Route From	Route To	Departure Time	Arrival Time	Entry Date	Action
00ERC7	adama	debreziet	2:23:3	4:56:4	2014-05-10 11:00:10	Delete
00ERC	stadium	ayat2	1:15:0	3:10:32	2014-05-09 04:23:49	Delete
009ERC	ayat1	stadium	2:15:0	4:43:52	2014-05-10 01:22:29	Delete
008ERC	mekile	welidya	11:30:0	1:3:49	2014-05-10 11:16:46	Delete
006ERC	megenagna	torhayloch	5:15:0	6:25:30	2014-05-09 04:30:59	Delete
005ERC	ayat1	saris	12:15:0	1:57:20	2014-05-09 04:20:07	Delete
005ERC	stadium	kality	12:30:0	2:19:53	2014-05-09 04:25:58	Delete
004ERC	georgis	saris	4:30:0	5:42:34	2014-05-09 02:21:11	Delete
003ERC	djibuti	addis ababa	1:30:0	5:46:40	2014-05-09 04:09:09	Delete
003ERC	ayat1	saris	2:30:0	6:44:55	2014-05-18 07:19:49	Delete
002ERC	torhyloch	stadium	2:30:0	3:10:29	2014-05-25 09:18:08	Delete
001ERC	ayat1	kality	1:30:0	2:39:1	2014-05-09 02:12:12	Delete
001ERC	djibuti	saris	4:30:0	8:45:55	2014-05-09 04:28:22	Delete
001erc	stadium	ayat2	12:30:0	3:1:30	2014-05-16 03:32:35	Delete
001ERC	ayat1	ayat2	12:30:0	4:55:45	2014-05-26 03:56:58	Delete
0013ERC	stadium	kality	5:15:5	6:14:57	2014-05-14 11:58:17	Delete
0012ERC	addis ababa	awash	8:30:0	12:20:54	2014-05-12 12:02:34	Delete
0011ERC	kality	leghar	8:12:0	3:49:47	2014-05-12 11:58:54	Delete

Table 4.4C: The final output of train timetable (finding table using search)

Time table Program Log out

Home Transportation search this site...

Show entries Search:

T-Code	Route From	Route To	Departure Time	Arrival Time	Entry Date	Action
0011ERC	kality	legbar	8:12:0	3:49:47	2014-05-12 11:58:54	Delete
0013ERC	stadium	kality	5:15:5	6:14:57	2014-05-14 11:58:17	Delete
001ERC	ayat1	kality	1:30:0	2:39:1	2014-05-09 02:12:12	Delete
003ERC	kality	stadium	12:30:0	4:16:55	2014-07-30 03:34:45	Delete
005ERC	stadium	kality	12:30:0	2:19:53	2014-05-09 04:25:58	Delete

Time Table

Showing 1 to 5 of 5 entries (filtered from 19 total entries)

CHAPTER FIVE

Conclusion and Recommendation

5.1. Conclusion

The problem of a railway timetable generation is still hard to define clearly. The main reasons are differences of railway systems of different countries. Even if the problem is analyzed with the requirements of only one country, it is still too vague to define it formally.

In this paper, PHP have been proposed to developing a program used to solve the problem of railway timetabling generation in a railway system which is common for all type of train and any type of infrastructures. The program develops based on the railway timetable requirements. The final conclusion of this study comes mainly on these threesteps in order to generate railway timetable. In the first step, identifying railway timetable requirements must carried out. In the second step; the mathematical model development must be carried out while in the third step, program must be created which is used to generate a timetable.

This research attempts design of effective railway timetable generation program to give the train exact departure and arrival time by giving the values of the railway timetable requirements. In this thesis the railway timetable requirements are the pillars to construct railway timetable generation program. Then the railway timetable requirements are Maintenance time; Driving time; Dwell time; Passenger transfers time; Switching time; Headway times; Allowance time; Route distance; Train speed; Route direction or movement (from-to) and Train (cargo) connecting (disconnecting) time.

Then in this thesis identifying the railway timetable requirements or factors is the core idea. After that a mathematical model is developed in order to become easy and simple to develop a programming model. Once the mathematical model is developed the program is developed using PHP programming language. This programming language makes the railway timetable design easy.

The result of this program now gives the timetable as train origin and destination route, train code, name or number as the interest of the organization, departure and arrival time of the train.

5.2. Recommendation for the Future work

It is important to note that this thesis focus on the generation of railway timetable design which is common for all type of infrastructure and type of train construction. This railway timetable generation program uses only when a value of the railway timetable requirements are given and when enters the value of these requirements the program gives us the railway timetable program by displaying the train code; the train route origin and destination; departure and arrival of the train which is visible for any one.

Then more research is still necessary to develop more powerful design of railway timetable generation program models of train timetable in complex networks in order to improve the reliability, efficiency and strength of railway operations.

The main recommendation for the future work of this thesis will be:-

1. Field study on the railway timetable factors or requirements to find the exact time of each requirement after the new Ethiopian nation-wide railway line will be functional.
2. Study about railway timetable factors to look for additional factors which will be helpful to increase effectiveness of railway timetable in order to stop unwanted delays completely.

6. Reference

- [1]. Yehualaeshet Jemere(MSc. CEng), (2012), Addis Ababa Light Rail Transit Project; Chief Officer, Construction and Project Execution Department, Ethiopian Railways Corporation; Ethiopia.
- [2].LeonW.P.Peeters, (2003), Cyclic Railway Timetable Optimization, Erasmus Research Institute of Management (ERIM):Erasmus University Rotterdam, ISBN 90-5892-042-9, Netherland.
- [3].Carole Gieseemann, (2000), Periodic Timetable Generation:Seminar on Algorithms and Models for Railway Optimization, University of Constance.
- [4].HuiminNNiu and xuesongzhou, optimizing urban Rail timetable under time dependent demand and oversaturated conditions, school of traffic , transportation and department of civil and Environmental Engineering: university of Utah,saltLakecity, UT 84112-056 Lanzhou Jiao tong university,Lanzhou,730070,china.
- [5].Rob M.p.Goverde, (2005), punctuality of railway operations and timetable stability analysis, Netherland.
- [6].Birre Nystrom, (2008), Aspects of Improving Punctuality, Department of Civil, Mining and Environmental Engineering ,Lulea University of Technology ,Sweden.
- [7].Andrea Darien,2008,Improving real-time train dispatching models, Algorithms and applications, Delft University of technology, Netherlands.
- [8].Pedro Alexander, 2008, Railway Traffic Management, institute of superior technology.
- [9].OlovLindfeldt, 2010, Railway operation analysis, Evaluation of quality, infrastructure and timetable on single and double-track lines with analytical models and simulation: Department of Transport and Economics, Stockholm.
- [10]. Dr.-Ing. Thomas Albrecht, 2006, Dresden University of Technology, Railway timetable and Traffic: Analysis, Modeling & Simulation, Eurail press.

- [11]. Ingo A. Hansen; 2009, Railway Network Timetabling and Dynamic Traffic Management ,2nd International Conference on Recent Advances in Railway Engineering, Iran university of science and Technology, Tehran.
- [12]. CUI Yanping, YANG Wentaoand ZHANG Yan, 2013, A Method for Generating the Timetable of Double-track Railway Line, Transportation and Economics Institute China Academy of Railway Sciences, Published by Atlantis Press, Paris, France.
- [13]. MOR Kaspi, 2010, Service Oriented Train Timetabling, Tel Aviv University The IBY and Aladar Fleischman Faculty of Engineering The Zandman-Slaner School of Graduate Studies, TEL AVIV.
- [14]. Prof. Dr. Martin Grottschel, 2009, Models For the Train Timetabling Problem, Technischen University, pp19-20, Berlin.
- [15].MichielAdriaanOdjik, 1998, Railway timetable Generation, Delft University, Delft University press, The Netherlands.
- [16].Sabrina Herrigel, 2012, Hierarchical Decomposition Methods for Periodic Railway Timetabling Problems, Institute for Transport Planning and Systems, ETH Zurich.
- [17]. KeivanGhoseiriandFahimehMorshedsolouk, 2006, School of Railway Engineering, Iran University of Science and Technology, Iran.
- [18].<http://www.html.net>
- [19].<http://www.Php.net>
- [20].<http://creativecommons.org>
- [21].<http://myphpform.com/php-form-tutorial.php>
- [22].Andy Harris,2003, PHP/MySQL programming for the absolute beginner, Premier Press, a division of Course Technology, United states of America.
- [23]. Leo Kroon, Dennis Huisman and GaborMaroti, 2007, Railway Timetabling from an operations Research perspective, Erasmus University Rotterdam, NL-3000 DR Rotterdam, The Netherlands .

[24].Jyh-CherngJONG and En-Fu CHANG; 2011; Investigation and Estimation of Train Dwell Time for Timetable Planning; 9th world congress on railway research:Sinotech Engineering Consultants, Inc., Taipei, Taiwan.

[25].Chi-Kang LEE (Professor); 1997; The Minimum Headwayofa RAIL Transit Line; Department of Transportation and Communication Management National Cheng Kung University; TAIWAN.

[26]. Peter Brucker & Thomas Kampmeyer, (2003), Tabu Search Algorithms for Cyclic Machine Scheduling Problems: The Fifth Metaheuristics International Conference, University at Osnabruck, Fachbereich Mathematik/Informatik 49069 Osnabruck, and Germany.

[27].www.railway-technical.com/train-maint.shtml

Railway systems, technologies and operations across the world;Railway Technical Web Pages1998 – 2014

[28]http://en.wikipedia.org/wiki/Railroad_switch.

Railroad switches From Wikipedia, the free encyclopedia, 2014.

[29]. Peter W.M. van Nederpelt and Piet J.H. Daas,2012,49 Factors that Influence the Quality of Secondary Data Sources, Paper Quality and Risk Management, Statistics Netherlands, 2492 JP The Hague.

8. Appendixes

Appendixes A: Abbreviations

APCAutomatic Passenger Counting

CSS Cascading Style Sheets

ERC Ethiopian Railways Corporation

HTML Hyper Text Markup Language

PESP Periodic Event Scheduling Problem

PHP Hypertext Pre-processor

SQL Structured Query Language

WAMP Windows Apache MySQL PHP

Appendix B: Cited Maps and Figures

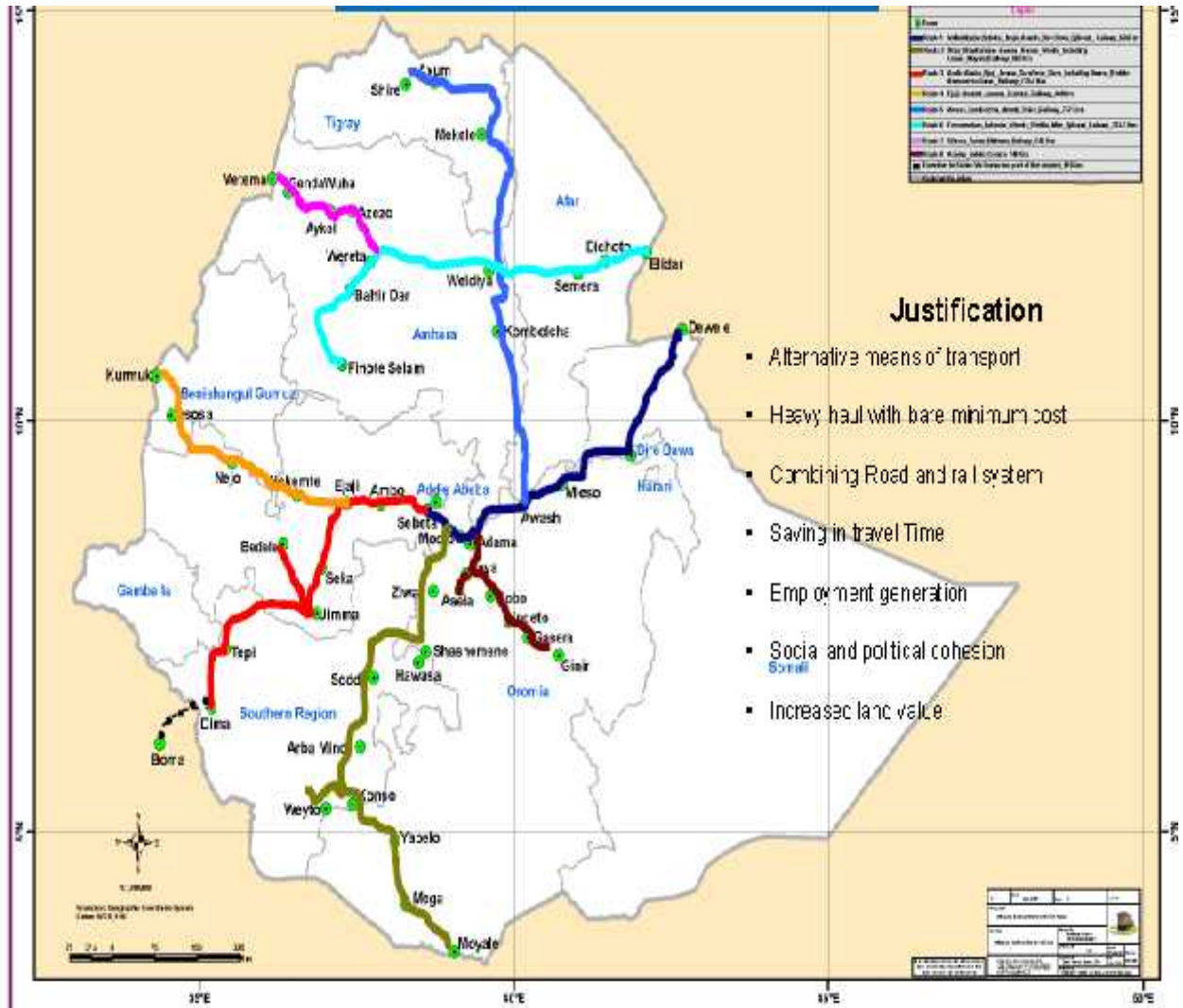


Figure B-1: Ethiopian national railway network [ERC, 2012]

የአዲስ አበባ ብብር ፕሮጀት

Addis Ababa Light Rail Transit (LRT) [ERC / USE/NO]

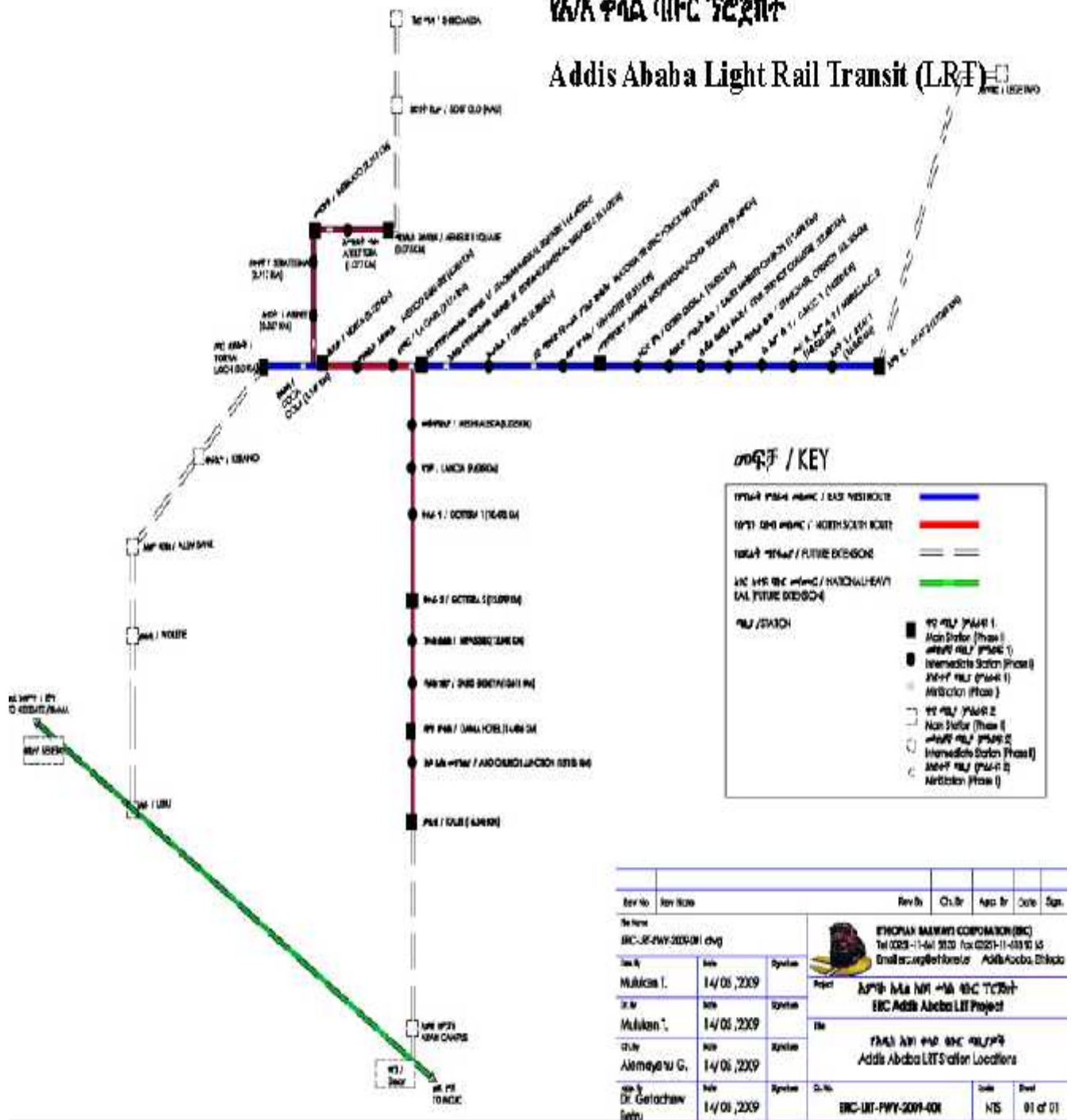


Figure B-3: Addis Ababa Light Rail Transit [ERC, 2012]

DECLARATION

I hereby declare that the work which is being presented in this thesis entitled **“DESIGN OF EFFECTIVE RAILWAY TIMETABLE GENERATION IN ETHIOPIA”** is original work of my own, has not been presented for a degree in any other university; and that all sources of material used for the thesis have been duly acknowledged.

TekleAbadiTekle

(Candidate)

Signature

Date

Submitted to: Addis Ababa University, Addis Ababa Institute of Technology

August; 2014