

**ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
POSTGRADUATE PROGRAM IN INDUSTRIAL ENGINEERING**

**ALLEVIATING SCHEDULING PROBLEMS IN ANBESSA
CITY BUS SERVICE ENTERPRISE**

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DECLARATION

I here by declare that the work which is being presented in this thesis entitled “Alleviating Scheduling Problems in Anbessa City Bus Service Enterprise” is original work of my own, has not been presented for a degree of any other university and all the resources of materials used for the thesis have been duly acknowledged.

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ABSTRACT

The transport sector is a key element for the development of a country. Almost every item or human being participating in the national economy needs to be transported from one location to another. Thus a problem in the transport sector implies impediment of the development of the socio-economic status of the country.

It has become very common that globally emphasis is given to the transport sector. Hence, the modes of transport are diverse, efficient and effective in many countries. City Trains, city Buses, Midi Buses, Taxies, Express Cabs are among the transport means that facilitate city transport services. However, the existences of all these modes of transport dose not guarantee satisfactory transport service. The modes of transport shall address the customers by making themselves available at the time and place they are required. To keep the time and place of destination and departure of means of transport different measures are taken by different countries. Among these are; using different bus lanes on streets, and making appropriate scheduling and time tabling of the different modes of transport.

However, the case in our country, specifically, the capital city Addis Ababa, is different in that there is no city train service, the road ways are narrow and not well maintained, they are also un proportional to the number of vehicles available in the city, there is no bus lane, etc.

Moreover, the city bus service is the only public transport having a specific route of travel and governed by governmental development agency. The private transport sector is not controlled under a specified route and gives service based on the best advantage of the owner rather than the public. Consequently, the public is suffering from shortage of transport to make its daily activities. These factors have aggravated the problem of city transport in Addis Ababa.

The main objective of this thesis is to alleviate the problems of city transport described above through improving the scheduling system of Anbessa City Bus Service Enterprise. The paper gives emphasis on the way that the public gets the required transport service on the time and place which the customer specifies and on the continuity or dependability of the schedule

insuring this service. This is done by identifying the core problem of the public transport in relation to the city bus service through delay data collection, questionnaire distributed and interviews conducted to the customers.

Finally, appropriate method of data collections and trip time determination for making schedules, timely updating of the existing data for keeping the schedule dependable, consideration of all route disruption factors for sustainability of the feasibility of schedules are recommended.

The result of the study can improve the service delivered by the enterprise and shift the customers who are dissatisfied by the private transport sector to Anbessa buses increasing the market share of the enterprise in the city transport service. It will also improve the mobility of resources which is a key factor for improving the socioeconomic status of the city.

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LIST OF ABBREVIATIONS

ACBSE: Anbessa City Bus Service Enterprise

MIP: Mixed Integer Programming

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1. Introduction

1.1 Role of the Transport Sector

Transportation is known to be one of the most important sectors which play decisive role for the development of a country. In addition to the economic advantage, it contributes a lot in facilitating different activities of a nation.

The construction sector highly depends on delivery and removal of construction materials and their wastes, the industrial sector controls its profit on the wise schedule and implementation of the transportation system contained in its supply chain. Optimizing the transportation cost beginning from raw material supplier trucks through the ware houses and production site industrial vehicles up to the delivery transport systems to the end user has become base for competition to gain large market share in the industrial sector.

The role of transportation is not limited only to these. Shortage of access to transport and related infrastructure has been a major set back for easy health service delivery numbers of rural women have lost their life due to improper delivery, lots have lost their life on their way to medical centers due to lack of transportation service to reach during emergency.

Moreover, the main resource for development, human resource, shall be mobilized from one work place to the other and from home to work places and vice – versa. If the transport system is not sufficiently available or they are not available on a regular basis of a known arrival and departure time schedule the opportunity of projects, routine activities, government and non governmental plans and schedules will fall under risk. Work schedules will be extended now and then causing the overall development of the nation dragged. Specially, for countries like Ethiopia, which need rapid development to catch up with the global economy, the problems of the transportation sector shall be looked at thoroughly.

1.2 Public Transport in Ethiopia

The public transport problem in Ethiopia, specifically in the capital city Addis Ababa has currently reached its pick. Due to the economic status of the public, residents who have their own personal automobiles are very few.

Hence, the vast majority highly depends on public transports to move from home to work and back to home. According to the Addis Ababa Transport Authority Branch Office, studies made on modes of public transport in Addis Ababa City indicate that only 5% of the city dwellers use private automobile while 30% uses public transport like buses, taxis, midi buses, and other means of transports. The rest 65% of the city population is pedestrian.

However, it has become very common these days to see people suffering from shortage of public means of transport at rush hours. Taking the service of Addis Ababa city buses specifically, it has a very important role in the city transport system, since it is the only transport system providing service with relatively low fare. However, customers are always complaining the service given by this firm due to inconsistent arrival and departure time among others. This makes it necessary that the scheduling and other related complains be thoroughly investigated and solved.

In this paper an attempt will be made to alleviate the scheduling and related problems of Anbessa City Bus Service.

1.3 Need for Planning and Scheduling

Efficient resource planning, scheduling and allocation are essential for transportation companies willing to improve service quality and increase reactivity, particularly when cost is a primary factor. Companies need to assign the right resources to the right place at the right time, generating savings while ensuring that feasible schedules meet policies and regulations.

When the number of resources, regulations and polices increase, and costs become extremely high, it is impossible to efficiently schedule and allocate resources manually. Planning and scheduling (P&S) applications supported by simulation software help such companies to be more reactive, minimizing operational costs and guaranteeing legal, feasible schedules that guarantee schedule integrity, from long-term strategic planning to short-term tactical operations.

This helps to create a better efficient transportation plans that maximize cost efficiency and on-time service, load consolidation, route sequencing, scheduling and carrier determination. Route optimization reduces costs, meets service levels and assigns the right vehicle to the right stop at the right time. [21]

1.4 Problem Statement

Generally, there is problem of transportation service in Addis Ababa city. Majority of the residents of the city are low income group which can not even afford using public transport. This has made many residents to be dependent on Anbessa City Bus Service, which is the only public transport service in the city working with relatively lesser fare.

However, it is common to listen to complains from customers on the service rendered by Addis Ababa city Bus. This complains refer specifically to:

- Non uniform and very long waiting time of customers at bus stations.
- No public display of schedule for arrivals of buses at stations.
- Buses skipping stations while customers are waiting for them.
- Over loaded buses reducing the comfort of customers.

As a result of these problems, the productive labor and time of the people are wasted. Accordingly, the income that the people could have generated by using their precious time is lost. The economy of their family and the country at large is adversely affected.

On the other hand, Anbessa city bus loses considerable amount of money for not delivering the service to these customers.

1.5 Objectives of the Study

The goal of this study is to insight a way of managing city transport service scheduling and to contribute to the effort being made to minimize the problem of the public transport service.

The study also focuses on the general objectives of setting specific expected arrival and departure time for the bus stations so as to provide reliable or dependable schedules by which customers can find the bus of their choice at their preferred arrival and departure time and stations now and every time in the future.

The specific objectives are:

- Analyzing the statistical distribution of delay times of bus routes, bus failures, and number of customers.
- Determine dependable schedules of the bus routes
- Creating system to determine the number of buses required at each route.
- Recommend solutions for route disrupted by extraordinary traffic jams or/and bus failures.

1.6 Research Methodology

The methods followed for the research in this paper is:

- Collection of sufficient data about number of customers, time between failures of buses and delay times at each station and paths between stations of the bus routes at different clock times of the service hours.
- Analyze the statistical distribution of delay times and time between failures of the buses using Arena input analyzer.

- Data collection on customer satisfaction levels, i.e. interviews and questionnaire to be conducted to identify the required time between arrivals and departures of buses at each station.
- Modeling the delay time model and failure model of the bus routes based on the results of the data analysis.
- Through simulations of the delay time models, determining the dependable arrival and departure window times of buses at stations.

1.7 Application of Results of the Study

Anbessa City Bus Service Agency is the target company which is intended to benefit out of the results. However, the result of the study can be applied in any transport company, private or governmental, which is in need of the management of the services of transport vehicles in an area where there are any number of transport routes and number of customers waiting for the service at different stations and different times of the service hours.

The benefits of the results are of wide range and can be viewed from different directions. The most important benefits come out of the solution it provides for the low income customer of Anbessa City Bus. These customers will save the money they would lose by paying for expensive means of transport. They also save the time they would waste by waiting for the bus there by earning money for using the time for work. This improves the income of their family. They also improve the working environment and relations with colleagues and bosses due to timely presence at working places.

The nation at large will benefit from the increased productivity due to improved labour and time gained at work places. Moreover, Anbessa City Bus Service Enterprise will increase the income it collects from the improved number of customers gained by making its service available for more customers, and also customers previously lost due to in efficient service.

2. Literature Survey

2.1 Transportation Service and its Problems

2.1.1 Introduction

Transportation is an essential part of today's life. It has been an essential part of most societies of the past. One can hardly conceive of a future society in which it would not continue to be essential. The adequacy of its transportation system is a fair index of a country's economic development. [20]

Transportation can be considered the movement of people and goods and the facilities used for that purpose. The movement of people assumes first importance in the minds of many.

Especially, in urban areas transportation provides the connecting link between dwelling units and work opportunities. As much as 50 percent or more of all urban travel is likely to be work trips. [20] Shopping, entertainment, travel to and from school and a variety of other reasons for making trips depend on transportation to make corresponding land uses accessible to urban dwellers. The movement of peoples represents a vital transportation service that calls for the use of streets and highways, buses, and other forms of transit in the most efficient manner possible. Intercity travel for business and recreation takes place between all parts of the nation and the world.

The geographical location of natural resources determines the transport routes that give access to those resources and create economic utility, that is, time and place utility, by taking them from a location where they have little value to processing and consuming areas where their value is vastly increased.

2.1.2 Problems in the Transportation Industry

The planning and scheduling process is itself a problem area. The engineer can be usefully involved at all stages of transport development in planning, design, construction, and operation. So complex are the planning and scheduling problems it is no longer desirable for the engineer to work alone. He or she serves, rather, as one of a team, along with urban planners, sociologists, ecologists, architects, legal and financial experts, and with engineers from associated disciplines.

Devising a solution to meet an identified demand involves selecting a level and quality of service that will satisfy the demand within the limits of feasible funding. The level of service relates to the problem factors; capacity, frequency and accessibility of the service. Quality of service involves factors like; safety, dependability, comfort, privacy, speed and effects on the community and the environment. [20]

All the above stated transportation problem factors have their own contribution to poor transportation service. However, the scope of this paper is limited to analyzing the problem of *dependability* which exists as one of the primary problems in the service delivery of ACBSE.

i) Safety and Dependability:

Safety and dependability are so closely interrelated that there is difficulty in discussing one apart from the other. There is an implied obligation that persons and goods entrusted to a carrier reach their destination in the whole and un damaged state with which the journey began. There is a similar obligation that the journey or trip be performed with reasonable dispatch and dependability.

For schedule operation there is a question of how frequently and at what hours buses, trains, planes, or trucks should operate. Commuter service for example requires a

concentration of capacity and schedules during the morning and afternoon rush hours (7:00-9:00 a.m. ± and 4:00-6:00 p.m. ±)

There is a big problem here of matching frequency with demand. There is more waste when more service is provided than is needed or utilized. Insufficient service means an inadequate level of service. The problem involves the ability to finance sufficient equipment to provide the requisite number of vehicles. Speed then becomes a factor, not only running speed, but also the speed in getting a plane, train, car, or bus or truck through the terminal processes of loading, unloading, transferring, interchanging, and servicing so it will be ready for an other trip. That is, the rapidity of turn around. Slow turnaround time can mean poor utilization of equipment, too few trips per vehicle, and a greater capital outlay to provide needed equipment.

The needed frequency of service must be determined during the analysis of demand study data. A suitable frequency must be obtained by a study of the individual community or situation. This is one of the deliverables of this paper to be applied to Anbessa City Bus service being given in Addis Ababa city.

ii) Dependability and Arrival Reliability

Dependability refers to the safe, on-schedule movement and delivery of goods and passengers and freedom from delays and from loss and damage en route. [20] It is one of the most important characteristics a carrier can offer. Transport delays are costly both to the public and to the carriers. Delays to persons mean lost opportunities, contracts unsigned, appointments missed, deathbeds reached too late. A carrier with a poor record for dependability stands in a difficult competitive position. Many shippers place dependability first in selecting a carrier.

On time performance is a measure of dependability that can be obtained by a combination of adequately designed facilities and the tight operation of well maintained vehicles over equally well maintained roads and tracks. Equipments and route capacities as well as

signs and signals must be adequate to avoid congestion. An airport with an inadequate causes delays as aircraft await their turn to take off or land. Speed restrictions due to poorly maintained track have been a source of delay to trains, and the rebuilding of roads of the city has slowed down high way vehicles. Equipment failures have also played a role in bus delays. Good maintenance and high morale among well trained employees are prime ingredients in maintaining schedules. However, it is difficult to meet all these factors and that is why schedules and time tables should consider the stochastic nature of delays for better dependability.

2.2 Stochastic Delays in Transportation:

Most transport situations embody an element of chance and an element of order. For example, it is highly predictable that certain buses will run full during a peak period. But the actual number of people carried on any vehicle during a slack period is entirely a matter of chance. [5]

Again, the ideal orderly progression of events exemplified by a railway timetable is to be contrasted with the random variations encountered in all real life experience. It is important, however, to look for the underlying predictability of apparently order less systems.

If the time of occurrence of certain events is random but the total number of events occurring in a relatively long period of time is known, it is possible to assign a probability to the occurrence of a given number of events in a given (much shorter) time interval. This is given by different distributions depending on the cases involved. Because transport problems generally reduce to consideration of headways at a bottleneck which is usually fixed by breaking distance and is constant, the concept of Poisson arrivals and constant service times is considered the most convenient for traffic flow studies. [5] However, real data collection might indicate that the distributions of delay times on the road way and at station are not always of Poisson nature and constant respectively.

Hence, it becomes necessary to make time tables and schedules of the arrival and departure of city buses at all stations on the basis of stochastic delay time considerations for better and dependable schedule.

2.2.1 Factors of Stochastic Delays

Many factors unite to determine the time taken to cover a given distance. Weather, load, horsepower, station stops, etc. If one takes a large sample of train performance, from a train sheet for example, some trains may have made the trip in a minimum time. Other trips in less ideal conditions will have taken a longer time depending on the foregoing variables. Some of the elapsed time approaches the minimum others extend far beyond it.

The majority of times will concentrate around an average point. Since the variations in conditions and performances are largely accidental, when traffic becomes heavy, especially as a route's maximum capacity is approached, the problem of traffic interference becomes very important in creating delays and increasing minimum and average times per trip. It should be recalled that the fewer the load per vehicle the more vehicles will be used (in moving a given load) to cause traffic interference. Also the slower speeds of heavily moving vehicles may be an added source of interference and delay. [5]

i) Intersection:

A prime source of flow interruption is the intersection, especially the signalized intersection. Un signalized intersections either have a relatively low traffic volume or are protected over two directions of approach by stop signs on the minor approach giving, in effect, uninterrupted flow on the major approaches. Four way stops are used where prevailing volumes of traffic are normally are light or as a temporary expedient, prior to installation of lights.

ii) Vehicle Operator:

Transport must begin with the vehicle operator; the pilot, engineman, or driver of private automobiles, trucks, or buses. The operator is the maker of the decision – speed, distance between vehicles, selection of routes, and obedience to the rules and laws are all under his control. Operators greatly vary in skill, training, alertness and experience. Professional operators of trains, aircraft, buses, and ships receive extensive training in schools, on vehicle simulators, or through long apprentice-type service.

iii) Vehicle Performance:

Propulsive and resistive forces have impact on vehicle performance. As the load is increased, speed decreases and the minimum time per trip increases.

iv) Susceptibility to Weather:

Roadways are difficult to drive in rainy seasons or days. This is due to fog resulting in poor vision of the driver, poor friction on applying breaks, which in turn cause cautious driving to keep away from accidents etc. these reduces highway speeds or halts traffic entirely.

v) Route Obstructions:

Delays ensue when a route is obstructed whether purposefully (as when maintenance is being performed), by an accident or forces of nature. It is traditional with railways, and other busy lines a practical necessity to keep tracks open and trains running regardless of the cost or effort. A system of detour arrangements with other railroads keeps trains moving when tracks are completely blocked. The ubiquity of roads and highways makes detouring highway traffic a fairly simple matter.

There should be easy access to main highways and rail yards and away from rush hour traffic that might affect truck schedules.

vi) Station Stops and Spacing:

The effect of station halt time on average running time and door to door time is obvious. The longer the stop is the longer the time for a journey. The time to load or discharge passengers is a function both of vehicle and of station design.

Station spacing greatly affects running time, especially where stops are close together as with bus or rapid transit operation. A train or bus stopping at stations spaced half kilometer apart will have a maximum running speed achieved for only short part of that distance because of the time and space required for acceleration and deceleration. The average speed would be higher if the stops are one kilometer apart because more running can be made at maximum running speed. However, as the stations get further apart (or by simply closing every other station) the service provided is reduced. Patrons at the intermediate points would now have farther to travel to reach a station, and some of them would undoubtedly turn to alternative modes of travel.

In Addis Ababa city bus service, added to the existing scheduling problems, at many stations the bus stations are far from the taxi stations which is another complain by public transport users. This is because the users at the taxi stations found it difficult to take the city bus option running long distances before the bus halts and leaves the station in case it happens to be available at least when there is shortage of taxi service at rush-hours.

Another factor at stations could be the halt time at stations where the vehicle remains open increases so as to allow the greater number of patrons to get on or off, possibly dissipating the time gained by the faster running speed.

The closer spacing can be retained by skip stop operation with A and B buses whereby each bus stops at every other station. Another possibility has the bus at the end of the line

stop at every station for the first several stations (enough to fill the vehicle), then run express to the final destination. Another bus would start local pickup where the first had left off, then it too would express to its destination.

Station stop time depends on the number of passengers to be loaded or discharged. This, too, is a function of station spacing and also of bus headway. More riders accumulate when stations are farther apart, fewer when trains are frequent and headways short.

2.3 Researches on Transport Service Scheduling

In the transportation industry planning and scheduling problems abound. The variety in the problems is due to the many modes of transportation, e.g., shipping, airlines, and railroads. Each mode of transportation has its own set of characteristics. The equipment and resources involved i.e.

- (i) Ships and ports,
- (ii) Planes and airports, and
- (iii) Trains, tracks, and railway stations, have different cost characteristics, different levels of flexibilities, and different planning horizons. (Michael L. Pinedo, 2004, *“Planning and Scheduling in Manufacturing and Services”*)

A review is made on mathematical models of different modes of transport to make the comparison between analytical and simulation models easier. The first discussion focuses on oil tanker scheduling. The subsequent discussion considers aircraft routing and scheduling. In aircraft routing and scheduling the goal is to create a periodic (daily) timetable. In a certain sense this model is an extension of the model for oil tanker scheduling.

The integer programming formulation of the aircraft scheduling problem is very similar to the formulation described for the oil tanker scheduling problem; however, in the airline case there are additional constraints that enforce periodicity. The last section discusses

timetabling of trains. Track capacity constraints in railway operations specify that one train can pass another only at a station, and not in between stations.

2.3.1 Tanker Scheduling

Companies that own and operate tanker fleets typically make a distinction between two types of ships. One type of ship is company-owned and the other type of ship is chartered. The operating cost of a company-owned ship is different from the cost of a charter that is typically determined on the spot market.

A schedule for a ship defines a complete itinerary, listing in sequence the ports visited within the time horizon, the time of entry at each port and the cargoes loaded or delivered at each port. The objective typically is to minimize the total cost of transporting all cargoes. This total cost consists of a number of elements, namely the operating costs for the company-owned ships, the spot charter rates, the fuel costs, and the port charges. Port charges vary greatly between ports and within a given port charges typically vary proportionally with the deadweight of the ship.

$$\pi_i^l = \sum_{j=1}^n a_{ij}^l c_j^* - c_i^l$$

Denotes the “profit” (i.e., the amount of money that does not have to be paid on the spot market) by operating ship i according to schedule l .

Where:

c_i^l is the incremental cost of operating a company-owned ship i under schedule l versus keeping ship i idle over the entire planning horizon.

The cost c_j^* denotes the amount that has to be paid on the spot market to transport cargo j on a ship that is not company owned.

The Tanker Scheduling Problem can be formulated as follows:

$$\text{Maximize} \quad \sum_{i=1}^T \sum_{l \in S_i} p_l X_i^l$$

Subject to

$$\sum_{i=1}^T \sum_{l \in S_i} a_{ij}^l X_i^l \leq 1 \quad j = 1, \dots, n$$

$$\sum_{l \in S_i} X_i^l \leq 1 \quad i = 1, \dots, T$$

$$X_i^l \in \{0, 1\} \quad l \in S_i, \quad i = 1, \dots, T$$

The objective function specifies that the total profit has to be maximized. However, before the branch-and-bound procedure is applied, a collection of candidate schedules have to be generated for each ship in the fleet.

As stated before, such a schedule specifies an itinerary for a ship, listing the ports visited and the cargoes loaded or delivered at each port. The generation of an initial collection of candidate schedules has to be done by a separate ad-hoc heuristic that is especially designed for this purpose. The collection of candidate schedules should include enough schedules so that potentially optimal schedules are not ignored, but not so many that the set packing problem becomes intractable. Physical constraints such as ship capacity and speed, port depth and time windows limit the number of feasible candidate schedules considerably.

Since the problem is a maximization problem a good schedule generated by a clever heuristic (or a manual method) provides a lower bound for the value of the optimal solution.

The Tanker (ship) scheduling Case described by Michael L. Pinedo is similar in nature of the schedule characteristics desired for ACBSE in that a schedule for a ship defines a complete itinerary, listing in sequence the ports visited within the time horizon, the time of entry at each port and the cargoes loaded or delivered at each port. (Michael L. Pinedo,

2004,” *Planning and Scheduling in Manufacturing and Services*” pp 254, sec. 11.2, para.3, line3)

However, the objective of mathematical model of the tanker case typically is to minimize the total cost of transporting all cargoes which consists of a number of elements, namely the operating costs for the company-owned ships, the spot charter rates, the fuel costs, and the port charges which vary greatly between ports and within a given port proportionally with the deadweight of the ship.

On the other hand, the objective the writer is seeking to get under minimizing scheduling problem of ACBSE buses is focused at getting a dependable schedule for the customers of the buses which is potentially enabling the reneged and balked public transport users to come back.

The schedules in the tanker schedule case are rather collections of candidate schedules which have to be generated for each ship in the fleet. The generation of an initial collection of candidate schedules has to be done by a separate ad-hoc heuristic that is especially designed for this purpose instead of the mathematical model such as the one used to maximize the profit. (Michael L. Pinedo, 2004, pp 255-256).

However, there are certain things that the writer believes to consider from the tanker schedule case to minimize scheduling problem of ACBSE. Among these, the fact that collection of candidate schedules should include enough schedules so that potentially optimal schedules are not ignored is one.

Moreover, physical constraints such as ship capacity and speed, port depth and time windows are the analogies of the tanker schedule case which are applicable in the case of minimizing scheduling problem of Anbessa buses as bus capacity and speed, bus station area and turnaround access, arrival and departure time windows, respectively.

The quality of the heuristic (manual method) used to forward the candidate schedules in the tanker scheduling problem depends on the talent of the person who is working on it. (Michael L. Pinedo, 2004, pp 256), while there is no such a heuristic which is exposed for subjective judgment in case of the bus scheduling and it rather depends on the quality of data collected

In contrast to the transportation problems analyzed in the next two cases, schedules for tankers (oil, natural gas, bulk cargo in general) are usually not cyclic.

2.3.2 Aircraft Routing and Scheduling

A major problem faced by every airline is to construct a daily schedule for a heterogeneous aircraft fleet. A plane schedule consists of a sequence of flight legs that have to be flown by a plane with the exact times at which the legs must start and finish at the respective airports. The first part of the problem (determining the sequence of flight legs) is basically a routing problem, whereas the second part of the problem (determining the exact times) is a scheduling problem. The fleet schedule is important, since the total revenue of the airline can be estimated if the demand function of each leg is known.

Moreover, the fleet schedule also determines the total cost incurred by the airline, including the cost of fuel and the salaries of the crews. An airline typically has, from past experience and through marketing research, estimates of customer demands for specific flight legs (a flight leg is characterized by its point of origin, its departure time and its destination). It can be assumed that a minor shift in the departure time of the flight leg does not have an effect on the demand. So an airline has for each leg a (narrow) time window in which it can depart. An airline also has estimates for the revenue derived from a specific flight leg as a function of the type of plane utilized, and of the costs involved.

The daily aircraft routing and scheduling problem, for example, can be formulated given a heterogeneous aircraft fleet, a collection of flight legs that have to be flown in a one-day period with departure time windows, durations, and cost/revenues corresponding to

the aircraft type for each leg. A fleet schedule has to be generated that maximizes the airline's profits (possibly subject to certain additional constraints).

Some of the additional constraints that often have to be taken into account in an aircraft routing and scheduling problem are the number of available planes of each type, the restrictions on certain aircraft types at certain times and at certain airports, the required connections between flight legs (the so called "thrus") imposed by the airline and the limits on the daily service at certain airports.

Also, the collection of flight legs may have to be balanced, i.e., at each airport there must be, for each airplane type, as many arrivals as departures. One must further impose at each airport the availability of an equal number of aircraft of each type at the beginning and at the end of the day.

The total anticipated profit:

$$\prod_i^l = \sum_{j \in L_i} \prod_{ij} a_{ij}^l$$

Where, L_i , denotes the set of flight legs that can be flown by an aircraft of type i ,
 π_{ij} , the profit generated by covering flight leg j with an aircraft of type i
 S_i denotes the set of feasible schedules for an aircraft of type i , and, with each schedule $l \in S_i$
 a_{ij}^l is 1 if schedule l covers leg j and 0 otherwise.

So the total number of aircraft available is:

$$\sum_{i=1}^T m_i$$

Where, T denotes the number of different aircraft types, and m_i denotes the number of available aircraft of type i , $i = 1, \dots, T$.

The daily aircraft routing and scheduling problem can be formulated as follows:

$$\text{Maximize } \sum_{i=1}^T \sum_{l \in S_i} \prod_{i=1}^l x_i^l$$

Subject to

$$\sum_{i=1}^T \sum_{l \in S_i} a_{ij}^l x_i^l = 1 \quad j \in L$$

$$\sum_{l \in S_i} x_i^l = m_i \quad i=1, \dots, T$$

$$\sum_{l \in S_i} (d_{ip}^l - o_{ip}^l) x_i^l = 0 \quad i=1, \dots, T \quad p \in P_i$$

$$x_i^l \in \{0,1\} \quad i=1, \dots, l \in S_i$$

Where:

P , denotes the set of airports,

P_i be the subset of airports that have facilities to accommodate aircraft of type i .

The objective function specifies that the total anticipated profit has to be maximized. The first set of constraints implies that each flight leg has to be covered exactly once. (This set of constraints is somewhat similar to the first set of constraints in the formulation of the tanker scheduling problem.)

The second set of constraints specifies the maximum number of aircraft of each type that can be used. The third set of constraints corresponds to the flow conservation constraints at the beginning and at the end of the day at each airport for each aircraft type. The remaining constraints imply that all decision variables have to be binary 0 – 1.

The potential profit is:

$$\pi_i^l = \sum_{j \in Li} (\pi_{ij} - \alpha_j) a_{ij}^l - \beta_i - \sum_{p \in Pi} \gamma_{ip} (d_{ip}^l - o_{ip}^l)$$

Where:

π_{ij} , is the profit generated by flying leg j with an aircraft of type i ,

α_j , is the current cost incurred by operating leg j ,

β_i , is the current cost incurred by using an additional aircraft of type i , and

γ_{ip} , is the current cost incurred by allowing an imbalance of one airplane of type i at airport p .

Hence, the same justification is applied for the case of aircraft scheduling problem. The schedules for the flights are not the objectives of the mathematical models applied. The objective functions of the mathematical models are maximizing the profits to be generated by assigning different types of air crafts to different legs and different types of aircrafts to different candidate schedules. Hence, there is basically no relation among the objectives of the writer in making dependable schedules of city buses of ACBSE and the two cases mentioned above.

2.3.3 Train Timetabling

The most common train timetabling problem focuses on a single, one way track that links two major stations with a number of smaller stations in between. A train may or may not stop at a smaller station. Once the timetables for the trains in the corridors have been determined, it is relatively easy to find a suitable timetable for the trains on the other lines in the network.

For each train there is an ideal timetable, which is the most desirable timetable for that train. This ideal timetable is determined by analyzing passenger behavior and preferences. However, this timetable may be modified in order to satisfy track capacity constraints. It is possible to slow down a train and/or increase its stopping (dwelling) time

at a station. Moreover, one can modify the departure time of each train from its first station, or even cancel a train. The final solution of the timetabling problem is referred to as the actual timetable. An actual timetable specifies for train its departure time from its first station and its arrival time at its last station.

The timetable of each train is periodic, i.e., it is kept unchanged every period. The train timetabling problem involves determining the values of various sets of variables, namely the times of arrivals and departures of train i at all stations.

When a timetable is put together there are usually some predetermined arrival and departure times for certain trains at specific stations and some preferred arrival and departure times for other trains. There is a cost (or revenue loss) associated with deviating from these preferred arrival and departure times.

The general objective to be minimized in the train timetabling problem is:

$$\sum_{i \in T} \sum_{j=1}^L (c_{ij}^a (z_{ij}) + c_{i,j-1}^d (y_{ij}) + c_{ij}^T (z_{ij} - y_{ij})) + \sum_{i \in T} \sum_{j=1}^{L-1} c_{ij}^\delta ((y_{i,j+1} - z_{ij}))$$

Where,

z_{ij} , is the arrival time of train i at station j ,

$c_{ij}^a (z_{ij})$, is the cost function that specifies the revenue loss due to a deviation from this preferred arrival time.

The travel (trip) time of train i on link j , denoted by:

$$\tau_{ij} = z_{ij} - y_{ij} \quad j = 1, \dots, L,$$

and the stopping (dwelling) time at station j , denoted by:

$$\delta_{ij} = y_{i,j+1} - z_{ij} \quad j = 1, \dots, L - 1.$$

Deviation costs associated with each one of these quantities are,

$$c_{ij}^d, c_{ij}^r, c_{ij}^\delta,$$

Formulating the timetabling problem as a Mixed Integer Program (MIP) requires a set of 0 – 1 variable: Also, to make the formulation easier, two dummy (artificial) trains I' and I'' are included in set T . The timetabling problem can be formulated as the following mixed integer program.

Minimize

$$\sum_{i \in T} \sum_{j=1}^L (c_{ij}^a (Z_{ij}) + c_{i,j-1}^d (y_{ij}) + c_{ij}^T (z_{ij} - y_{ij})) + \sum_{i \in T} \sum_{j=1}^{L-1} c_{ij}^\delta ((y_{i,j+1} - z_{ij}))$$

Subject to

$$\begin{aligned} y_{ij} &\geq y_{ij}^{\min} & i \in T, & j = 1, \dots, L \\ y_{ij} &\leq y_{ij}^{\max} & i \in T, & j = 1, \dots, L \\ z_{ij} &\geq y_{ij}^{\min} & i \in T, & j = 1, \dots, L \\ z_{ij} &\leq y_{ij}^{\max} & i \in T, & j = 1, \dots, L \\ z_{ij} - y_{ij} &\geq \tau^{\min}_{ij} & i \in T, & j = 1, \dots, L \\ y_{i,j+1} - z_{ij} &\geq \delta^{\min}_{ij} & i \in T, & j = 1, \dots, L - 1 \\ y_{i,j+1} - y_{h,j+1} + (1 - x_{hij})M &\geq H^d_{hij} & i \in T, & j = 0, \dots, L - 1 \\ z_{ij} - z_{hj} + (1 - x_{hij})M &\geq H^a_{hij} & i \in T, & j = 1, \dots, L \\ \sum_{h \in \{T-i\}} x_{hij} &= 1 & i \in T, & j = 1, \dots, L \\ x_{hij} &\in \{0, 1\} \end{aligned}$$

The variables are subject to various sets of operational constraints. For example, train i needs at least a minimum time τ^{\min}_{ij} to traverse link j ; train I must stop at station j for a minimum amount of time δ^{\min}_{ij} to allow passengers to board. For reasons of safety and reliability minimum headways have to be maintained on each link. Let H^d_{hij} be the minimum headway required between the departures $y_{h,j+1}$ and $y_{i,j+1}$ of trains h and i from station j and let H^a_{hij} denote the minimum headways between the arrivals z_{hj} and z_{ij} of

trains h and i at station j (ensuring adequate headway between trains h and i when exiting link j).

Moreover, the (continuous) decision variable y_{ij} = the time train i enters link j (i.e., the time train i departs from station $j - 1$); z_{ij} = the time train i exits link j (i.e., the time train i arrives at station j). There may also be upper and lower bounds on all arrival and departure times.

The train time table case has many points similar to the case of city bus scheduling. One of these similarities is that in train time tabling problem the preferred arrival and departure time at all stations are to be determined. On the other hand there are dissimilarities in that the train is not subjected to significant uncertainty of delay times between stations. There is also track capacity constraint which inhibits one train to pass another between stations due to single track condition in which only one train can pass a point on the track at a time.

Determining the preferred arrival and departure time is an important issue for both the train and the city bus cases and it is one of the objectives for the latter. These preferred arrival and departure times are determined by analyzing passenger behavior and preferences. (Michael L. Pinedo, 2004, pp 278, par.2, line2-3). Hence, it can be obtained through questionnaire and data collection. Using this information the fine tuning of the most preferred departure time of the trip can be made. To arrive at this most preferred time the largest number of customers which are capable and prefer to board at each minute of the window departure time can be analyzed.

This analysis is to be made by first asking samples of customers about their maximum patient to wait for the bus (expressed in clock times) at the station of departure to catch the train and their assured arrival clock times. This helps in determining the cost coefficient of the preferred departure time (C_{ij-1}). This is done by the finding of the clock time, between the window departure time, at which the net maximum number of customers is achieved after customer balking, renegeing, and arrival capability conditions.

In addition to this, the cost coefficients for the remaining three terms of the objective function; preferred arrival time, the total trip time, and the delay time at station of the train can be determined in almost similar method. This condition can be formulated in the objective function of the mathematical programming for the train time table problem.

However, there are other elements which shall be determined and included in the constraints' list. These are six in number excluding the headway and other constraints. The minimum and maximum departure and arrival times, the minimum allowable trip and station delays which are listed independently in the formulation. This makes the mathematical formulation of the problem to include many inputs which makes it more difficult for the dispatching personnel to easily make the time table and make adjustments with the changing factors.

Moreover, solving the mathematical model for each and every link and for every trip made in the day long period of the trip multiplies the difficulties by requiring another time, knowledge, and effort which makes the task more difficult to be handled by dispatchers.

The objective of the scheduling or time tabling problem of the city bus or train can be done in an easier method which does not require lots of calculations to find cost coefficients, determine maximum and minimum constraints that the objective function is subjected to and tedious manipulation of the mathematical model problem solving.

For example, the arrival and departure time of a bus for currently existing customers can be best determined by collecting the opinion of the customers on their requirement of only the arrival or departure times. This data can be organized and analyzed easily manually or graphically described using software like Arena to observe the net maximum number of customers' preference of arrival or departure times. Once the customer preference on the arrival or departure requirement is identified, determining the corresponding departure or arrival time after travel does not require any more data except

the window time of the particular trip, which is a requirement for the mathematical model also, and does not require asking the customers' opinion.

It is to be remembered here that in the mathematical modeling method the preferred departure time deviation cost coefficient is to be calculated by taking data about the various customer preference of departure time. Moreover, the cost coefficients for the remaining three terms of the objective function; preferred arrival time, the total trip time, and the delay time at station of the train, need to be determined in almost similar method. This is because the objective of the mathematical model is cost minimization while the method of the writer is focused in an easy and flexible method of setting arrival and departure times as mentioned above.

In addition to this, the train time tabling case problem does not elaborate the time delay characteristics while in the case of the city bus, the delay characteristics is highly stochastic due to the mixed traffic system in which the road is shared among every type of vehicle that rides and drives in the city road. The earliest possible and the maximum latest arrival times achievable at each station of each trip of the buses is determined using input analyzer and step wise simulation capability characteristics of Arena software package.

This will be very important to the objective the writer is seeking for, since the customer is required to know the dependable arrival and departure time windows at which he/she can comfortably catch the bus and reach his/her get off station. Whereas, the train time tabling case mathematical programming model focuses, as an objective function, at the arrival and departure time which brings about the minimum cost (lost value due to customers balking and renegeing due to un met arrival and departure requirements) and ignores the dependability of that economically optimal arrival time and departure time achieved.

2.4 Analytic and Simulation Scheduling Techniques

2.4.1 Methods of Allowing for Uncertainty

The problem of allowing for uncertainty is reducible to the difficulty of finding a satisfactory way of aggregating the uncertainty associated with a series of individual estimates. It is clearly wrong to simply to use the high, the low, and the most likely estimates in turn. The probability that all the high or the low estimates will coincide is extremely remote. [4]

There are three main ways of carrying out this analysis. They attempt to express the effect of uncertainty in terms of probability distributions which show the extent to which different answers are likely.

i) Calculating the True Distribution

This is based on exhaustive analysis of all the possible outcomes of an event. It therefore requires a great deal of calculation and is only efficient in relatively simple cases. A problem involving the sum or product of m unknowns, each subjected to uncertainty and able to assume one of n possible values, requires n^m calculations, each representing a possible out come of the sum or product.

ii) Estimating the True Distributions from a Simulated Sample

The number of calculations involved in an exhaustive analysis increases rapidly once the evaluation involves more than two or three variables. A computer can clearly reduce the calculations to manageable proportions, but it is doubt-full whether the accuracy achieved is worth the loss of efficiency that the large number of calculations implies.

One solution to the problem of efficiency is to estimate the required probability distribution from a simulated sample which is based on the well established principle that the characteristics of large population of variables can be estimated from a relatively small random sample.

The simulated sample clearly reduces the number of calculations required. However, for large problems, a computer is still necessary. In practice, the true distribution is not known (there would be no point in generating a simulated sample if it was). It is usually considered large enough when the probability distribution does not change much if the sample size is further increased.

One of the great advantages of simulation is that it avoids the tedium of an exhaustive analysis without requiring any new mathematical skills on the part of the analyst. It involves the simple processes that are readily grasped and understood. A complex evaluation might nevertheless require the use of a computer. However the techniques involved in this kind of computer simulation are extremely and the programmer is usually able to rely on a number of system facilities to make the task even simpler.

iii) Estimating the True Distribution Using Mathematical Expectations

This method uses probability calculus. It calculates the mean and variance of each estimate and usually interprets their probability distributions in terms of normal curve. This assumption clearly introduces some bias into the estimation of the shape of the probability distribution. The actual shape of the distribution is based on an assumed symmetry which may not be valid. This is the first possible disadvantage of this method. A second advantage is that the method requires a minimal knowledge of probability calculus.

Apart from these difficulties the method suffers from the disadvantage of not providing detailed information about the shape of the probability distribution. The mixed methods represent an extremely attractive way of accounting for uncertainty, since they combine the best elements of all the three methods. The use of a mixed method nevertheless requires a fairly detailed knowledge of the potential bias inherent in the calculations before the evaluator can sensibly decide when to replace the probability calculus by one of the other two methods.

Generally, the mathematical models considered in the above three case problems are basically different in their objectives with respect to the schedule problem mitigation

methodology of Anbessa bus considered in this paper. However, some elements of the models of the tanker and train time tabling problem resemble the case due to the basic principles underlying in scheduling. The aircraft scheduling problem, however, doesn't discuss the schedules at all. It simply assumes the schedules to be done by some heuristics.

3. Overview of Anbessa City Bus Service Enterprise

3.1 Company Profile

3.1.1 History:

The today's Anbessa City Bus Service Enterprise started its operation in 1942 G.C when fascist Italy was driven out of Ethiopia. The then Ministry of works and Communication collected vehicles and spare parts used by the invader. With these resources and under the name of 'Public Transport' the service was launched to the public. In 1952 G.C it was reorganized as Share Company and started its service with ten buses colored green and yellow. These buses were dispatched in four routes each containing two buses. They are of different Models identified by Model 7A, A12, 3A, 3B, 6A, 6B, 7, 7B.

At this time the company had 120 workers including foreign nationals. It began service with single trip cost per person of 0.25 and 0.40 Ethiopian Birr for those who want the return trip. After 1959 G.C the tariff reduced 0.15 Birr for single and 0.25 for double trip. Other transport alternatives for the public existing at that time were named 'Kurkur' and the Cart locally called 'Gari' cost from 0.25-0.75 Birr according to the distance of travel.

In 1961 'Gari' was made to stop giving service in side the town. Beginning from 1960 G.C the 'Public Transport' increased its number of routes from four to fourteen and raised the number of buses at each route from two to three. This enabled the towns surrounding Addis Ababa; Holeta, Beseka, Burayu to be connected to the city with the service.

In 1964 G.C the company bought twenty more buses and retired all foreign managers and completely begun being led by Ethiopians. In 1965 G.C office and car washing service was established in a one storey building constructed in collaboration with 'Total', the fuel and oil provider of the company.

In 1967 G.C the population of the city was estimated more than 600,000 and 163 buses were added to give service. From 1968 – 1974 G.C a station was constructed to provide parking for the increasing number of buses in ‘Kolfe’ area. Bus stations were built in a way that provides shelter to the customers.

Beginning from the year 1974 G.C the company was transferred to government ownership and named as National Transport Corporation. Under this management it was made to administer 100 cross country and 50 additional city buses. To reduce the shortage of parking area and garage a twelve million birr agreement was signed to construct the ‘Yeka Depot’. The depot began its work in 1987 G.C.

After the fall of the military regime, in 1994 G.C it was reorganized as ‘Anbessa City Bus Service Enterprise’ with a capital of 14 million birr.

3.1.2 Current Service Status in Addis Ababa

The federal government of Ethiopia now owns the company, but its operations are financially supported by the city government. A subsidy is paid for each passenger carried. However, this subsidy is being progressively reduced and the city is committed to its eventual elimination which has declined from 26cents per passenger to 10 cents per passenger.

Anbessa has 449 DAF brand buses which are bought in the years 1988-1996 G.C. which have given services for more than five years, and most of the 260 Mercedes brand buses are out of major services due to long service years and spare part problems. Those old Mercedes buses are used for special services and school bus service.

Anbessa’s operations are managed from its three depots from Megenagna (Yeka), Mekanisa and Shegole. It operates in 93 routes most of which are radial routes to the central business and commercial areas of the city. The current bus routing and scheduling plan for Anbessa is prepared internally by the company. The fare charged for any journey has been the fare applicable to that route, and was not related to the distance traveled by

the passenger. In a recent service improvement action ACBSE began to use variations by zones. Currently ACBSE has begun variable fare for Buses covering the surrounding suburbs by changing their route number to city route on the return way to the city center to increase utilization by collecting the customers waiting for the service.

Currently the enterprise gives service to more than 650,000 – 700,000 passengers per day. And there are a total of 3,150 employees hired by the enterprise.

Major services of the enterprise constitute:

- General public bus transport
- Contract transport service
- Advertisement
- Mobile crane service
- School bus service
- Technical services

3.1.3 Capacity of the Service

Currently five hundred buses exist under the enterprise. Out of these, four hundred buses can be put in to service by completing the spare part and maintenance requirements. Due to shortage of spare parts and maintenance requirements only three hundred four are participating in the day to day service giving activities. However, their service level is equivalent to the service that could be delivered by only two hundred thirty seven buses.

3.2 Anbessa Maintenance Facility Organization

The maintenance given in the enterprise is divided into depots maintenance and field maintenance. The field maintenance are handled in each of the different 3 ketenas of transport service terminals which are located in Addis Ketma, Leghar, Menilik II Square. The field maintenance handles easy maintenance of the buses like changing & checking tire pressure. Simple check up and minor repair are also done on the ‘kela’s.

The depot maintenance is handled from three different centers located at Yeka, Shegole and Mekanisa depots. Major services given in the depots include Preventive maintenance & Scheduled Inspection. Each center handles both the scheduled preventive and breakdown maintenance of the buses boarding in the depots. The maintenance facilities gives service for the 462 DAF model buses and 64 Mercedes most of the later ones are out of service. The Yeka depots handles 249 buses of which 210 are DAF model and 19 are Mercedes, Shegole and Mekanisa handles 196 and 80 buses respectively.

The Yeka Depot being the biggest service centers constitute all body shop and full garage service other than the depot maintenance service.

4. Data Collection

4.1 Research Methodology

4.1.1 Questionnaire and Interview

The beginning step in the research methodology followed in this paper is verifying the existing scheduling problems of Anbessa city buses and other related problems through questionnaire distributed to the customers and the public and interviews made to the concerned bodies.

Once the existence of the problem is verified a system by which this problem can be mitigated shall be designed. This includes collection of data on delay times, number of customers and bus failures. Collection of sufficient data about number of customers, time between failures of buses and delay times at each station and paths between stations of the bus routes at different clock times of the service hours will have great contribution for effective and dependable schedule.

4.1.2 Delay Data

This includes the delay time data at each bus station, each path between the stations, and turnarounds of end of each trip. A sufficient amount of these data taken primarily to compare for compliance with the existing schedule obtained from the enterprise and thereby changing it in to text format word file to be fed to the Arena Input Analyzer. The input analyzer then processes the data to give the summary of each statistical distribution of the delay times per each delay cause of each particular traffic intensity period.

4.1.3 Number of Customers Data

The number of customers boarding on to the bus at each station and the corresponding customers getting off affect the net number of customers being served instantaneously in the buses. This data is important in the identification of the comfort of customers in the bus at different instances and also determination of the number of buses required at different times of the service hours. Hence, the data fed to the Arena Input Analyzer results in the parameters required to the modeling, simulation, and scheduling processes.

4.1.4 Bus Failure Data

The bus failure conditions are one of the factors affecting dependable schedules. Hence, a schedule with out the consideration of this factor is not expected to be reliable. Therefore, the data of failure of buses is collected and analyzed through Arena Input Analyzer to find out the statistical distribution of the failure rate and predict the next failure of the bus so as not to include that particular bus in the schedule at the time of its expected failure.

The out put of the analyzed data is used in the modeling and simulation of the failure model through which the failure is predicted. The flow chart of the design for mitigating the scheduling problem identified is shown in the figure 4.1 below.

Figure 4.1 Flowchart of the design for mitigating scheduling problem of Anbessa city buses

4.2 The Scope of the Study

Out of the ninety three bus routes, this study is focused on four selected routes which are believed to represent the rest geographically and characteristically. These routes are:

Route number 3: From Minilk Square (Georgis) through National Theater to Ayer Tena,

Route number 4: From Mercato through Gottera Interchange to Kality,

Route number 50: From Megenanga through Meskel Square to Total the old route 3 bus
Turnaround, and

Route number 52: From Mercato through Lagar to Gerji EEPCO.

Hence, observation of the existing schedules of these routes is made and data related to the schedules of these routes are also collected.

4.3 Data Related to Existing Method of Schedule Design

Interviews have been made to the concerned body of Anbessa City Bus Service and individuals who were hired to the enterprise on contract basis to perform the data collecting activity to be used as input for designing the schedules to the bus routes. The results of the interviews from both sides were compared and found to be supplementary to each other.

4.3.1 The Type of Data Collected:

According to the result of the interviews to data collectors, the type of data collected is delay times at non stopping time. Based on this, the time delay (stop time) at signalized intersections, stop time at bus stations, and turn around time at the end of a forward or backward trip was not included in the real time data collection process. However, a deterministic time delay data has been added for these delays in the process of determining the trip delay time. According to the enterprise deterministic time is set only for turnaround time.

4.3.2 The Consideration of Rush Hour Effect

In addition to this, the interview to data collectors indicate that the time delay data collection mostly didn't pay attention to the different traffic intensity clock times of the day at which the data should be collected. Hence, there are cases in which data collected at any one trip of the morning shift is taken to represent the whole morning shift and even the whole day or it is taken as the trip delay time representing the route in the design of the schedule of that particular route. The data collectors say they were trying to get data for a total of three trips at most and two trips at least to make an average trip time for each route. The average time obtained in this manner is supposed to be the trip time of that route. In other cases, three delay times are considered for each particular bus route taken at different traffic intensity or headway period. These delay times are minimum, average, and maximum trip delays and are considered in the schedule of the route as minimum, medium, and maximum headway period trip delay times.

4.3.3 Weekend Days Consideration

The results of interview to local dispatchers indicates ACBSE had made special consideration to schedules of Sundays by separately collecting data on Sundays. The enterprise made this consideration due to the fact that the delay times on Sundays are by much different from other week days.

4.3.4 Elements of the Existing Schedule

The schedule that Anbessa City Bus Enterprise is currently using is made on the basis of the data collected in the manner mentioned in the sections above. The earliest departure time of the buses of the morning shift is determined by the enterprise and the considered trip delay times are basically used to determine the arrival time. A fifteen minute tea break is included at the supposed mid time of the shift at the end of the trip around the mid shift time.

4.3.5 Sequencing of the Buses of Same Route

The schedule includes all the buses of each route. A route might contain from a minimum of one bus up to ten or more buses which might vary in quantity during service giving in relation to bus failures and maintenance problems. The enterprise describes the sequencing of buses of the same route to be scheduled basically to follow each other at equal interval times which results by dividing the average trip time to the number of the buses assigned to that particular route.

4.4 Data Related to Applicability of Existing Schedule

The scope of this study is limited to four bus routes and the observation of Applicability of the existing schedules of ACBSE is made at these routes. However, these routes are generally believed to represent the rest of the routes.

Table 4.1 Applicability of the existing scheduled number of trips

S.No	Route Nos Observed	Number of Buses Assigned	Scheduled Single No of Trips per day	Actual No of Trips Made	Percent Performed
1	4	5	60	38	63%
2	50	3	52	12	23%
3	3	10	133	114	85%
4	52	6	76	37	49%

In the four routes considered, the existing schedules are generally not appropriately applied. A wide range of applicability is also observed. The buses at these routes were observed to make a minimum of 23% and maximum of 85% of the number of trips they are supposed to make.

Moreover, in most cases the buses didn't meet the scheduled trip delay times. In fact, the actual trip delay time of the busses vary depending on delay factors. However, it is possible to make comparison among the actual trip delay times and the scheduled trip delay times. The resulting percentage is described in the table below in ranges of percentage indicating the maximum and minimum performance of the planed schedule.

Table 4.2 Applicability of the existing scheduled trip delay times

S.No	Route Nos Observed	Scheduled Trip Delay Time/ Actual Trip Delay time (%) Over the observed samples	
		No Of trips (%)	% implemented
1	4	81	60-90
		19	<60
2	50	27	100
		86	>80
		14	60-69
3	3	6	>90
		94	70-85
4	52	1	100
		29	73-75
		79	55-67

4.5 Real Delay Times and Number of Customers Data

On the four selected routes considered in this study a real data of all time delays constituting the trip delay time is collected and number of customers' boarding in to and getting off the bus was also collected at each bus stop to have a real figure of these facts.

These data, being real figures taken at the working hours of the buses, experience stochastic characteristics along different days on which the data was collected.

The delay times considered in the data collection are; turnaround times at each beginning and ending trips of buses, loading and unloading delay times at each station stops, and time elapsed by the buses while moving from one station to the other or temporarily obstructed by different factors. This helps as an input to the delay time model which in turn becomes in put for reliable scheduling as is indicated in the following chapters.

In addition to this the number of customers boarding into and getting off the bus is recorded at each station as an input to analyze the net load through Arena Software modeling environment. This helps ACBSE to be aware and consequently take measures of the comfort of customer travel conditions and over and under loading of the buses. (The data recorded are shown in Appendix A)

The data collection was made on all the routes considered in the study at all periods of the day from morning 6:15 A.M to evening 9:30 P.M at all days of the week of the months (Yekatit-Ginbot, 2001E.C).

4.6 Data Related to Customer Views and Required Arrival Times

4.6.1 Results of the Data Collected Through Questionnaire

Questionnaires were distributed to customers of Anbessa City Bus and others who use alternative means of city transport systems. The questionnaire primarily focuses on the customers' preference on arrival clock times at their destination station and on the reasons for their preference of Anbessa City Bus as their means of transport.

The questionnaire consists inquiries concerned about the total services given by Anbessa City Bus Enterprise in general and the particular services given at the routes selected for this study (route no. 3,4,50, and 52).

30 questionnaires were distributed to the respondents at each route giving a total of 120 out of which 94 are appropriately filled. The rest are returned unfilled. (The format of the questionnaire is indicated in Appendix B)

The responses of the respondents of the questionnaire distributed to the customers of Anbessa City Bus Services and other city dwellers using other means of city transport is summarized as follows.

4.6.1 Choice of Anbessa as a City Transport

Regarding the reason of preference of the respondents on Anbessa rather than other means of city transport system, 20% of the respondents said Anbessa City Bus is their choice because it does not take long time at bus stations relative to minibus taxis and midi buses giving city transport service currently. Where as the relative low fare of Anbessa is the main reason for 80% of the respondents to prefer this means of transport. Besides this reasons Anbessa is preferred for its service that covers long distances without any interruption. 90% of the respondents are impressed by this characteristic of Anbessa city bus services.

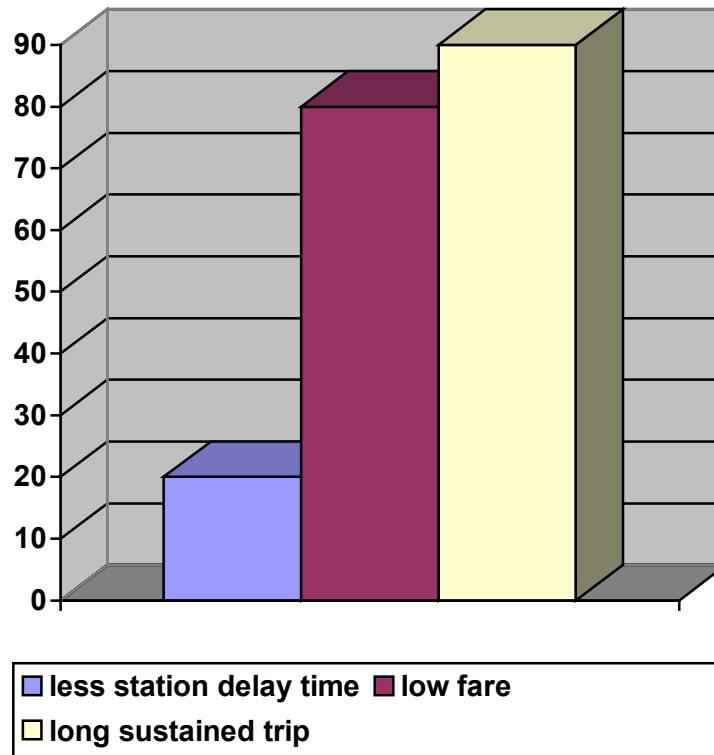


Figure 4.2 Reasons for choosing Anbessa Bus in percent of respondents

The part of the questionnaire that inquires the reason why the respondents do not use the Anbessa city bus service has different responses. 74% of the respondents which are not regular users of the service give reasons to the un known arrival and departure time of the buses for their not being regular users of the service. 15% say they can't afford the fare. 3% of the respondents say that Anbessa is not comfortable enough to make them regular users. The rest 8% say that the station locations of the city bus is far a part from taxi stations to make the choice of Anbessa buses in case of their accidental arrival.

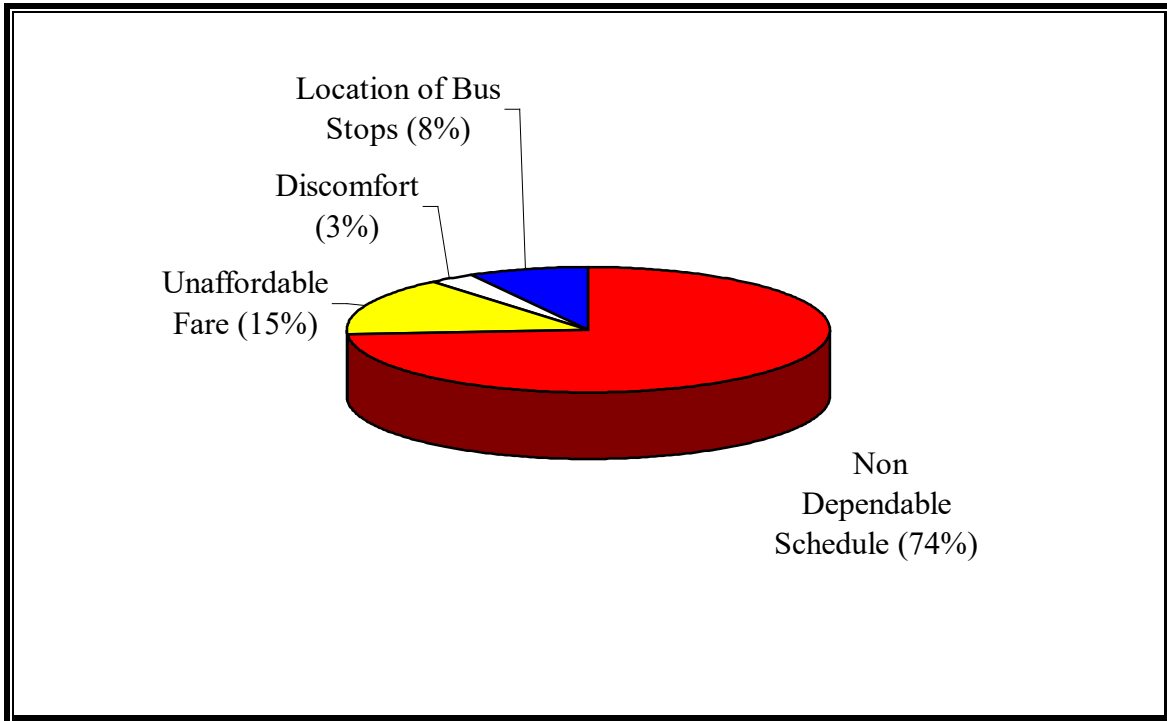


Figure 4.3 Percentage of Causes for not using Anbessa Bus

4.6.3 Dependability of the Services

48% of the respondents, say they wait up to one hour at stations for the arrival of the bus. The other 44% say that it took them from one hour up to two hours to get the bus. The rest 8% said it took them more than two and half hours.

An enquiry to know the patience of the customer was included in the questionnaire. 30% of the respondents say they are not able to wait a bus more than 45 minutes. The other 30% say that they are patient enough to wait up to an hour and half. 40% of the respondents are confident that they can wait up to two hours and not more than that.

A pain full problem customers are facing in the Anbessa city bus service is raised through the questionnaire. This issue is the skipping of stations by the buses while customers are waiting. 67% of them say they have encountered such conditions in a few occasions

while 22% say they meet this situation occasionally. 11% say they repeatedly faced this problem.

If the patience of the customer is tempted more than they bear it, 87% of the respondents go to other city transport service while 9% of them say they will report to the nearby control personnel of ACBSE. 4% of the respondents decide to choose going back home and walking.

According to the respondents, 62% of them use Anbessa to go to work and come back home while the rest 32 % use to go to school and come back home and also for multi purposes.

The part of the questionnaire concerned with the specific routes indicates that 92% of the respondents say poor availability of buses is the major problem on route number 4, while this issue is the problem of 84% of the respondents of route 50. Respondents of route 52 also gave emphasis to in availability as the major problem on the route by 78%.

Among other routes considered, respondents from route number 4 give additional emphasis on the problem of buses halting for long time with out giving service and problems of road construction by 47% and 26% respectively. On the other hand, respondents of route number 3 give additional attention to changing of route number of buses after reaching to their destination as another problem that shall be considered marked by 31% of them. Problem of comfort is mentioned by a maximum of 8% of the respondents of all the routes considered.

4.6.4 Financial Benefits of the Choice for Anbessa

The part of the enquiry requesting the financial saving achieved by the respondents for choosing Anbessa as means of transport shows an amount more than one birr is saved by 43% of the respondents while 54% of the respondents save up to two birr and fifty cents. The rest 3% of respondents say they save up to fifty cents, on route number 4.

On route number 52, 59% the respondents say they save three up to more than four birr by using Anbessa bus rather than other means of transport. This percentage is 47% in case of route number 3, and the saving amount is limited from two to three birr for 49% of the respondents. In route number 50 the major saving is one to two birr for 67% of the respondents and up to 25% of the respondents say they save up to fifty cents.

4.6.5 Preferred Arrival Times of Buses

Most of the customers, government or private enterprise hired, and some of the private business owners or private small and micro scale business workers have almost similar choice of arrival time at their working places. They also have similar choice of arrival time at their home back from work. However the degree of certainty they demand from transport systems increase for government and private enterprise hired workers including students at work or school entrance times.

The private workers show some degree of relaxation on their choice of arrival at work places by specifying window of arrival times. But they still have their red mark of arrival times not to be crossed although not meeting those marks causes less tension compared to hired workers.

Hence, the preferred arrival times at destination stations are 7 a.m., 7:30 a.m., and 8:00 a.m., (by 92% of respondents), while 9:00 a.m., and 6:30 a.m. by (6% and 3% of the respondents respectively). They also show their preference on their returning trip to home as soon as they get out of their working place and school, at 3:00 p.m., 3:30 p.m., 5:00 p.m., 5:30 p.m.,(according to 67% of the respondents) and 6:00 p.m.,6:30p.m., 7:00p.m., (7% of respondents), 7:30 p.m., 8:00 p.m., 8:30 p.m., (26% of respondents) in varying percentage from one route to the other and from one terminal to the other.

In routes numbers, 3, specially at (Giorgis terminal), 50, (Megenagna terminal), 52 and 4 in both forward and backward route, large number of customers are in demand of the

service as the college students generally close classes and private small scale traders close their works with in these time range.

To sum up the data collection, the existing schedule is found to be very optimistic as compared to the delay data collected currently for this study. Moreover, the interviews and questionnaire results verify that there is a problem of dependability, and clarity of schedules. Consequently, patrons are using Anbessa bus by chance and not by choice due to their un predictable arrival.

5. Data Analysis and Synthesis

5.1 Introduction

In the previous chapter the data of performance measure of the existing schedule of ACBSE is described in two parameters. The first parameter measures the percentage of implemented number of trips out of the scheduled number of trips of each route observed. The results under this parameter indicate that 45 % of the scheduled trips couldn't be implemented.

The other parameter measures the percentage of time delay of each trip performed with respect to the scheduled delay time of the respective trip. The result of this measure indicates that 93.5 % of the trip delay times were above the scheduled plan.

These performance data clearly indicate the problem of dependability of the existing schedule of ACBSE. Once the existence of the problem is identified, it becomes necessary to investigate what caused the problem.

Obviously, to investigate the problems related to a schedule, it is necessary to look in to the elements of the schedule. In the previous chapter the elements of the schedule of ACBSE, the types and the method of data collection have been discussed. In this section, it is necessary to discuss these elements in view of their influence to a schedule to be un reliable.

5.2 Analysis of the Existing Method of Schedule Design

Before going to the details of their influence, it is necessary to put a classification of the elements of the existing schedule. The elements of the existing schedule can be classified as the deterministic elements and the stochastic elements.

5.2.1 The Influence of the Deterministic Elements

The deterministic delay time data elements considered in ACBSE's currently existing schedule, as mentioned repeatedly include the turnaround time, station stop delay times, and delay times at signalized intersections. These elements are given a constant or deterministic delay time in the process of determining the trip delay times of the buses.

In fact, all deterministic data wouldn't put the dependability of a schedule at risk. However, a deterministic delay data which is fixed based on an optimistic approach obviously risks the dependability of the schedule. Most likely estimates also tend to put the dependability of schedules at risk although to a lesser extent compared to the optimistic estimates.

The observed fact on the ground has shown that all the deterministic elements of the existing schedule are optimistic.

5.2.2 The Influence of the Stochastic Element

The other element of the existing schedule, the stochastic element, is the delay time data concerned with the travel period of the buses including temporary stops which are not planned and happened due to obstruction.

ACBSE data collectors have taken stochastic data for this element of the schedule. However, as described in the previous chapter the quantity of data taken is very less than the quantity required to represent the facts. Data which does not sufficiently represent the facts expose the schedule to be made to be unreliable resulting in low dependability.

Hence, both the deterministic and stochastic elements of the existing schedule of ACBSE have contributed to the low dependability of the schedule.

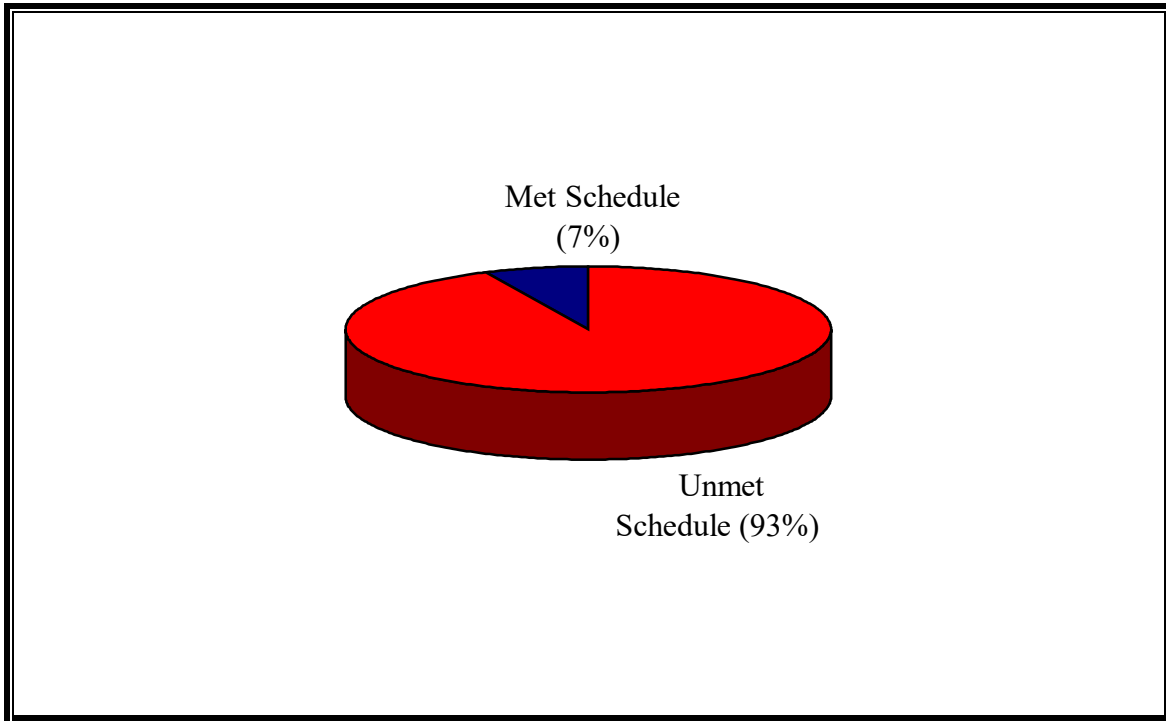


Figure 5.1 Synthesis of Percentage Application of the Existing Schedule

5.3 Analysis of the Data Collected for the Study

In the previous chapter the type and method of data collection made for the purpose of the study has been described. Now it is time to make analysis for those data. The data are of 3 types, delay data of delay causes of the trips made by the buses, number of customers catching and getting off the buses, and questionnaires distributed to the customers and city dwellers. In this section the analysis for the delay data is considered.

5.3.1 Classification of Traffic Intensity Periods

A classification of the traffic intensity period has been made for each route considered in the study. Basically, the classification is made on the basis of the actual trips made by the buses rather than the scheduled trip periods. The classification is required for ease of analysis which shall consider the behavior of delay nature in relation to traffic intensity and customer demand.

Hence, the data are analyzed across the same delay cause elements (same bus station stops, same travel ways, and same turning stations) and across the same traffic intensity clock time period of different days of the week (Monday through Sunday).

Input analyzer of the Arena software requires the input data of delays of the delay causing elements in a text format document. The delay data of all delay causing elements, for all the days, Monday to Sunday, for all of the four weeks of the month considered for data collection, at the first traffic intensity period, 6:15- 7:33 a.m. (say for example the delay data at Mercato beginning station which is elapsed to allow each customer to enter to the bus by receiving the individual fare and delivering the ticket), is entered in text format. The input analyzer automatically displays the graphical representation, the distribution type, minimum, maximum, mean, and other details of that particular data in put of the delay cause. The specific delay time distribution for each case and other relevant parameters are synthesized to give the required modeling, simulation, and flexible scheduling actions of the transport process. (The results of the analyzed data is shown in Appendix C)

In the following sections the determination of the traffic intensity period classification of each routes considered in this study is analyzed.

i) Route Number Four:

Based on the actual data collected in this specific route, the clock time ranging from, 6:15 – 7:30 a.m. take similar delay nature due to the currently existing traffic intensity nature on the route. This is decided based on the fact that all the trips made with in this time range took a maximum of 86 minutes and a minimum of 76 minutes. Moreover, from the data collected it is observed that as the clock time goes forward from this time range the traffic intensity is observed to increases fast.

This indicates the emergence of the following traffic intensity period. This traffic intensity period is characterized in terms of the delay time it takes on the buses. The trips

made at this traffic intensity period take from 96 minutes to 106 minutes. This intensity ranges from around 7:30 a.m. – 9:00 a.m. Similarly, the third intensity period follows after about 9:00 a.m. – 12:30 p.m. taking trip delays from 106 – 120 minutes, which is the highest traffic intensity period of the route.

The next intensity period is observed in the second shift or in the afternoon period. This intensity period is identical with the first one and takes the same travel delay time, 76-86 minutes. The clock time in which this intensity is observed is around the range from 12:30 p.m. – 3:00 p.m. the other intensity immediately follows this one with trip delay time from 86-100 minutes. This is observed in the range of clock time around 3:00 p.m.- 4:30 p.m. the next intensity appears in the clock time range from 4:30 p.m. – 5:30 p.m. with trip delay time from 86- 96 minutes. The last traffic intensity characterizes the first intensity period with all its trip delay conditions and ranges from 5:30 p.m. to 9:00 p.m. the following table summarizes the traffic intensity of the route.

Table 5.1 Traffic intensity periods of route number four

Traffic Intensity Period	Trip delay Range (minutes)	Clock time Range Periods Included
1	76-86	6:00 a.m.- 7:30 a.m.
		1:00 p.m.- 3:00 p.m.
		5:30p.m.- 9:30 p.m.
2	96-106	7:30 a.m.- 9:00 a.m.
3	106-119	9:00 a.m.- 1:00 p.m.
4	91- 101	3:00 p.m.- 5:30 p.m.

Having identified the different traffic intensity periods of the day of the route, it is possible now to make appropriate allocation of delay time for each trip within the route. When making this allocation pessimistic approach is applied to insure a better degree of dependability to the customers. Hence, the following schedules are made for the buses

which make the beginning trips of the route trips both from Mercato (4 Ψ) and Kality (4 U) with in each traffic intensity period. (The trip times shown in the schedules made consider all the time taken for a trip until the time the bus has to be ready for the next trip)

Table 5.2 Number of possible trips and schedules for the first buses of route number four

Sequences 4 U and 4 Ψ		
No of Trips	Beginning Trip	Ending Trip
1	6:15	7:33
2	7:33	9:19
Tea break	9:19	9:39
3	9:39	11:30
4	11:30	13:27
End of first shift		
5	13:30	14:56
6	14:56	16:32
Tea break	16:32	16:52
7	16:52	18:18
8	18:18	19:54
End of second shift		

ii) Route Number Fifty

A similar methodology of determining the classification of different traffic intensity periods is applied to this route as well. Route number fifty basically has a better applicable delay time assigned for the trips made by the buses. As indicated in table 4.2 in the previous chapter a 27% of 100 applicable trip delay time durations are observed. However, there is problem of excessive assignment of delay times in the existing

schedule of these 100% applicable trip delay durations where as there is under estimation over the other periods of traffic intensity which reduced the applicability of the schedules. Hence, in effect, the traffic intensity periods observed in this route are as described in the following table.

Table 5.3 Traffic intensity periods of route number fifty

Traffic Intensity Period	Trip delay Range (minutes)	Clock time Range Periods Included
1	50-55	6:00 a.m.- 8:00 a.m.
2	55-65	8:00 a.m.- 10:30 a.m.
3	65-80	10:30 a.m.- 1:00 p.m.
4	60-70	1:00 p.m. – 9:30 p.m.

After identifying the different traffic intensity periods of the day of the route, it is possible now to make appropriate allocation of delay time for each trip within the route.

When making this allocation pessimistic approach is applied to insure a better degree of dependability to the customers. Hence, the following schedules are made for the buses which make the beginning of the route trips both from Megenagna (50U) and Total terminal (50σ) with in each traffic intensity periods.

Table 5.4 Number of possible trips and schedules for the first buses of route number fifty

Sequences 50 <i>U</i> and 50 <i>σ</i>		
№ of Trips	Beginning Trip	Ending Trip
1	6:15	7:10
2	7:10	8:05
3	8:05	9:10
Tea break	9:10	9:30
4	9:30	10:35
5	10:35	11:55
6	11:55	13:45
End of first shift		
7	13:45	14:55
8	14:55	16:05
9	16:05	17:15
Tea break	17:15	17:35
10	17:35	18:45
11	18:45	19:55
12	19:55	21:05
End of the second shift		

In similar manner, the traffic intensities for route number three and route number fifty two and the resulting schedules for the beginning trips are designed as shown in the following consecutive tables.

Table 5.5 Traffic intensity periods of route number three

Traffic Intensity Period	Trip delay Range (minutes)	Clock time Range Periods Included
1	45-55	6:00 a.m.- 8:00 a.m.
		12:30 p.m.- 15:00 p.m.
		18:30p.m.- 21:30 p.m.
2	60-70	8:00 a.m.- 10:00 a.m.
3	55-65	10:00 a.m.- 12:30 p.m.
4	50-60	15:00 p.m.- 17:00 p.m.
5	65-75	17:00 p.m.-18:30 p.m.

Table 5.6 Number of possible trips and schedules for the first buses of route number three

Sequences 3 <i>U</i> and <i>Z</i>		
№ of Trips	Beginning Trip	Ending Trip
1	6:15 a.m.	7:10 a.m.
2	7:10 a.m.	8:05 a.m.
3	8:05 a.m.	9:15 a.m.
Tea break	9:15 a.m.	9:35 a.m.
4	9:35 a.m.	10:45 a.m.
5	10:45 a.m.	11:50 a.m.
6	11:50 a.m.	12:55 p.m.
End of first shift		
7	12:55	13:50
8	13:50	14:45
9	14:45	15:45
Tea break	15:45	16:05
10	16:05	17:05
11	17:05	18:20
12	18:20	19:15
13	19:15	20:10
End of the second shift		

Table 5.7 Traffic intensity periods of route number fifty two

Traffic Intensity Period	Trip delay Range (minutes)	Clock time Range Periods Included
1	70-80	6:00 a.m.- 8:00 a.m.
2	80-90	8:00 a.m.- 9:00 a.m.
3	65-75	9:00 a.m.- 15:00 p.m.
		18:00 p.m.-21:00 p.m.
4	75-85	15:00 p.m.- 17:00 p.m.
5	85-100	17:00 p.m.-18:00 p.m.

Table 5.8 Traffic intensity periods of route number fifty two

Sequences 52 <i>U</i> and 52 <i>W</i>		
№ of Trips	Beginning Trip	Ending Trip
1	6:15	7:35
2	7:35	9:05
3	9:05	10:20
Tea break	10:20	10:40
4	10:40	11:55
5	11:55	13:10
End of first shift		
6	13:10	14:25
7	14:25	15:50
Tea break	15:50	16:10
8	16:10	17:35
9	17:35	19:15
10	19:15	20:30
End of the second shift		

5.3.2 Day Based Differences of Traffic Intensity

The observation made on the trip delay data collected at different days of the weeks and different weeks of the month considered for the study indicate that there is no trend of delay time differences across neither the same week days of any of the four weeks nor the weeks of the month considered for the data collection. The delay data indicates a random increase or decrease (but not significant) from one day to the other and from one week to the other.

Saturday mornings generally exhibit a delay time characteristics of the week days. However, in the afternoon a less traffic intensity similar to the early mornings, noon, and late evenings is observed. On the other hand, Sundays generally exhibit less traffic intensity similar to the early mornings, noon, and late evenings throughout the day.

Hence, it could be thought that a better number of trips can be made on Saturday afternoons and Sundays than the week days. However, on the other hand, there is very less demand of the service at week ends. Hence, it would not be economical to increase the number of trips. It becomes more feasible if the arrival and departure time is specified and made public to the customers so that they seek the service in clustered demand period rather than an economic scattered demand which increases the cost of the enterprise.

This option wouldn't have significant effect on customer desires since the schedule is fixed and official to make the customers adapted to the schedule and plan their activities accordingly. It is also to be noted that the activities of the customers is identified generally to be more flexible in terms of time frame at week ends than the week days.

The number of customer data on week days and week ends is compared in the following table for all of the routes considered in this study.

Table 5.9 Comparison of number of customer data on week days and week ends for all of the routes considered in this study.

S. №	Route Numbers	Average Number of Customers on Weekdays	Average Number of Customers on Week ends	% Number of customers W.R.T. weekdays
1	3	123	70	57
2	4	92	68	74
3	50	63	41	65
4	52	108	59	55

As can be observed from the table on all the routes considered the average number of customers on week ends is much less than the average number of customers on week days.

5.3.3 Controlling the Load of the Buses and Comfort of the Customers

The actual data of customers boarding to and getting off the bus at each station is gathered for the buses considered under this study. This data collection is aimed at the analysis of over loading conditions of the buses. Hence, the Arena Software model for net number of customers is made for each route and the specific trip data suspected of exceeding the limit of allowable net number of customers is entered to the relevant route model.

The simulation of the model clearly indicates the net number of customers in the bus at any place and time of the trip at running mode and the maximum value is displayed also in the report. (The maximum limit of number of customers set by the manufacturer of the

buses is 101. However, ACBSE can set its own limit to this number based on Ethiopia's people economic psychological and social conditions to respect the comfort of its customers.)

Modeling the net number of customers in a bus involves two types of data analysis. The first type is that which refers to the boarding of customers in to the bus and includes; the time between arrivals of the customers at each bus stations of the routes, the number of customers per each arrival, and the maximum number of arrivals which are all filled in the fields available under the 'create module'.

The second type is that which refers to the getting off conditions of customers from the buses up on reaching their destination. Under this analysis, the statistical distribution by which customers are getting off the bus on reaching their destinations is analyzed by Arena input analyzer as in the case of delay time model and the resulting distribution is filled in the process module under the field 'delay'.

The time between arrivals of number of customers at each station, the number of customers per arrival, the maximum number of arrivals and the specific distribution of the rate of customers getting off the bus is synthesized to give the required modeling and simulation for easy identification of the net number of customers.

Knowing the net number of customers in the bus at any time enables the dispatching personnel to easily visualize the excess number of customers in the buses which require either schedule adjustment or additional bus to keep the comfort and satisfaction of the customers as well as retain and attract the renegeing and balking customers. Moreover, it helps to get data related to the load exposure of the buses which is important factor to determine the life of the buses.

The results of the simulation of the model on net number of customers for Route Number Three is discussed in the following chapter under section 6.4

5.4 Analysis of Customer Requirement Arrival times

In the previous chapter we have observed the data on customer preference of arrival times at their destination stations. It is now time to synthesize these preferences on the schedules of the buses. Hence, the schedules which allow the comfortable arrivals of the majority of customers to their destination are made to be applied to the buses following the first buses of each route which started earlier at morning 6:15 a.m. These schedules are indicated in the following tables.

5.5 Stochastic Delay Time Based Schedules

The route sequences $4 \mathbf{A}$ and $4 \mathbf{L}$ refer to the buses that immediately follow the routes $4 \mathbf{U}$ and $4 \mathbf{W}$ sequences respectively at the time interval indicated in the table below.

Table 5.10 Schedules of succeeding buses of route fifty

Sequence 4 Α and 4 Λ		
№ of Trips	Beginning Trip	Ending Trip
1	6:40	8:06
2	8:06	9:52
Tea break	9:52	10:07
3	10:07	12:06
4	12:06	14:05
End of first shift		
5	14:05	15:31
6	15:31	17:12
Tea break	17:12	17:32
7	17:32	18:58
8	18:58	20:24
End of second shift		

Similarly, the route sequence 4 **σ** and 4 **π** refer to the buses that immediately follow the route sequence 4 **Α** and 4 **Λ** at the time interval indicated in the table below.

Table 5.11 Schedules of succeeding buses of route four

Sequence 4 σ and 4 $\tilde{\sigma}$		
No of Trips	Beginning Trip	Ending Trip
1	7:00	8:26
2	8:26	10:12
Tea break	10:12	10:32
3	10:32	12:31
4	12:31	14:30
End of first shift		
5	14:30	15:56
6	15:56	17:37
Tea break	17:37	17:57
7	17:57	19:23
8	19:23	20:49
End of second shift		

Now we can clearly observe that the entire customer demanded arrival and departure times are basically met by the three sequences at each direction of dispatches (Mercato and Kality).

Generally, these schedules have made considerations of the rush hours of morning arrival times and the evening departure times which the majority of the customers demand focuses. Figure 5.2 and Figure 5.3 indicate the morning arrival and evening departure times respectively that could be met by applying the schedules designed for route number four according to the rush hour demand of customers requirement assessment made in this study.

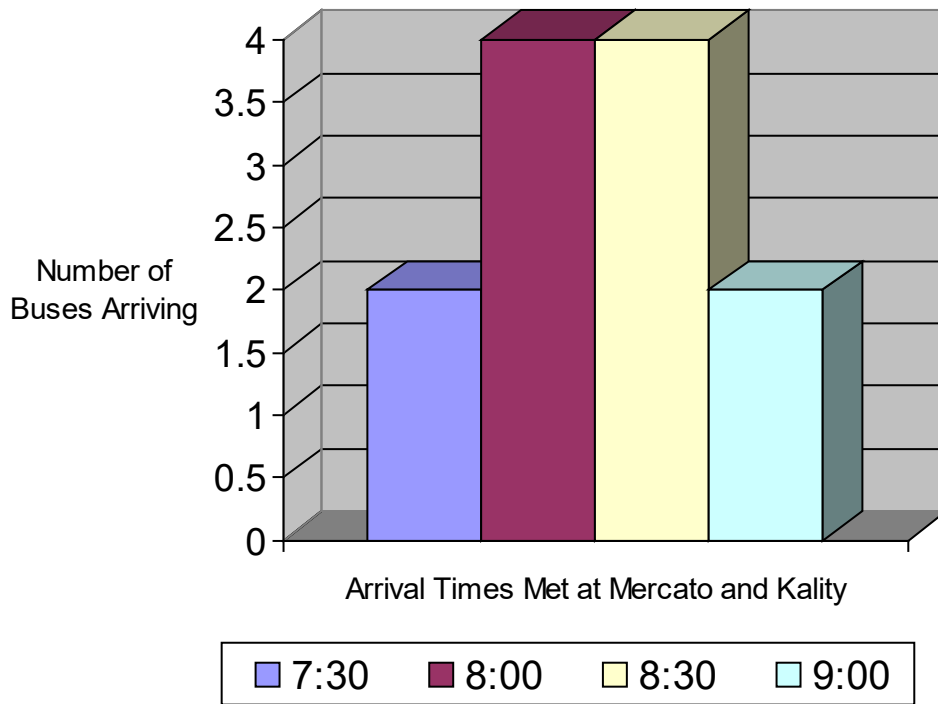


Figure 5.2 Arrival Time Coverage of Morning Rush Hours of Route Number Four

It is to be noted here that the number of buses indicated in the graphs is decided based on the currently allotted number of buses by the enterprise although they are not available at full capacity.

The fleet capacity is an important factor to implement schedules and to address all customers with similar arrival and departure requirement. More than one bus might be required for one particular arrival or departure time depending on the number of customers in demand. It is stated in the literature part of this paper how to address such demands by dispatching the buses at the same time.

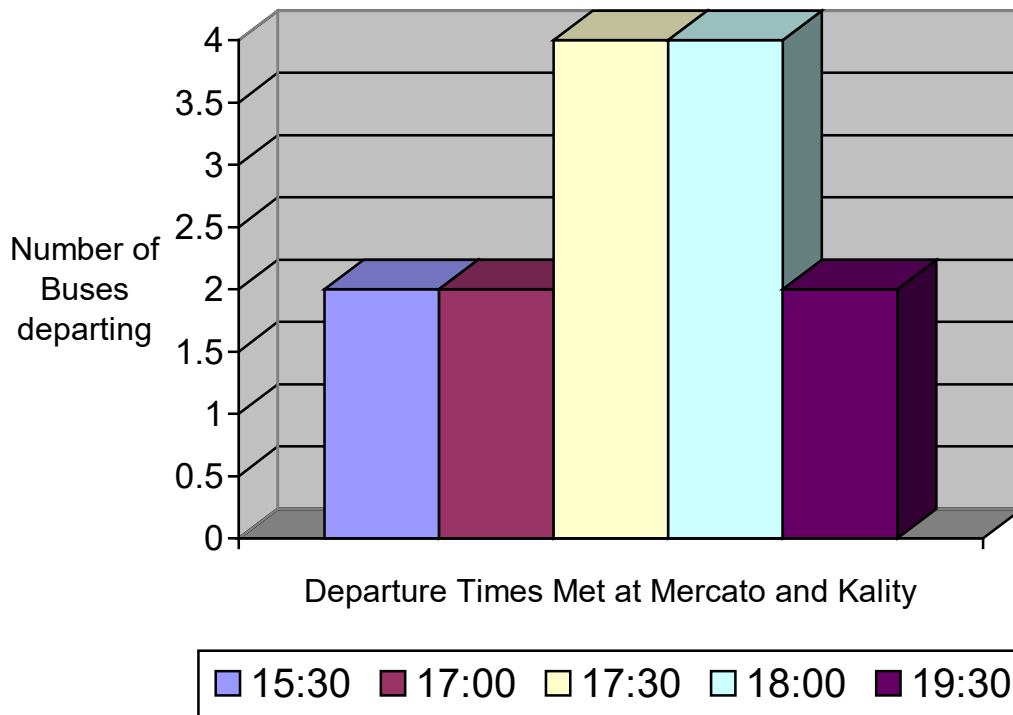


Figure 5.3 DepartureTime Coverage of Evening Rush Hours of Route Number Four

The route sequences 50λ and 50μ refer to the buses that immediately follow the routes $50 U$ and 50σ sequences respectively at the time interval indicated in table 5.12 below. The fourth sequence “ 50ω ” is basically not included in the existing schedule. However, its requirement is unquestionable to balance the trips in both directions and respond to customer demand as well.

These schedules of route number fifty also have made considerations of the rush hours of morning arrival times and the evening departure times which the majority of the customers demand focuses. Figure 5.4 and Figure 5.5 indicate the morning arrival and evening departure times respectively that could be met by applying the schedules designed for route number fifty according to the rush hour demand of customers requirement assessment made in this study.

Table 5.12 Schedules of succeeding buses of route fifty

50 \uparrow and 50 \downarrow		
№ of Trips	Beginning Trip	Ending Trip
1	6:40	7:35
2	7:35	8:30
3	8:30	9:35
Tea break	9:35	9:55
4	9:55	11:00
5	11:00	12:20
6	12:20	13:40
End of first shift		
7	13:40	14:50
8	14:50	16:00
9	16:00	17:05
Tea break	17:05	17:25
10	17:25	18:35
11	18:35	19:45
12	19:45	20:55
End of the second shift		

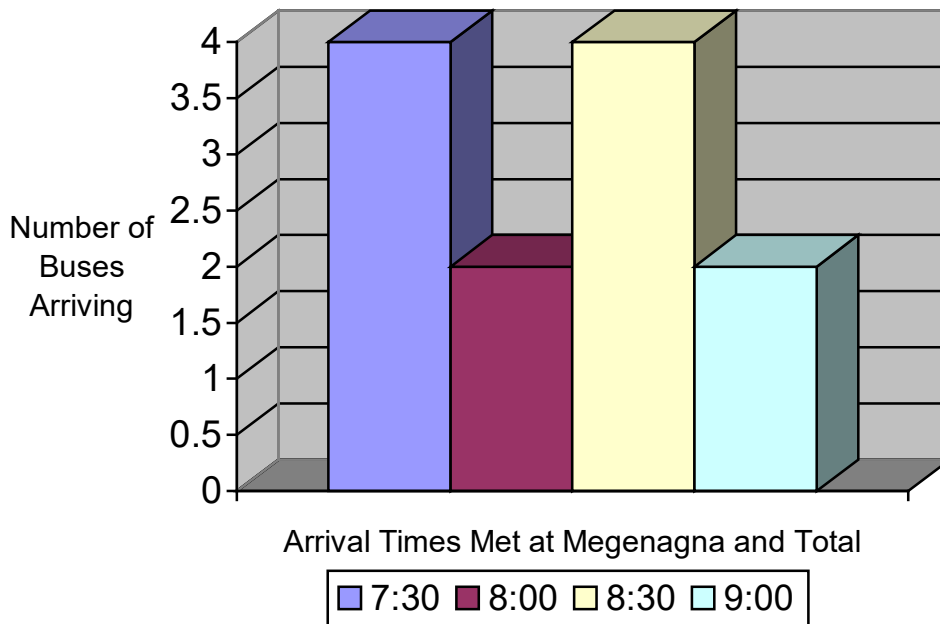


Figure 5.4 Arrival Time Coverage of Morning Rush Hours of Route Number Fifty

As can be observed in the above graph an attempt is made to increase the number of buses arriving at the peak of rush hours. However, since there is no sufficient number of buses to cover the route, one of the pick arrival times, 8:00 remains to have only two buses. Similar problem is observed in the evening rush hour departure times. The graph depicting the evening departure time coverage is shown in Figure 5.5 below.

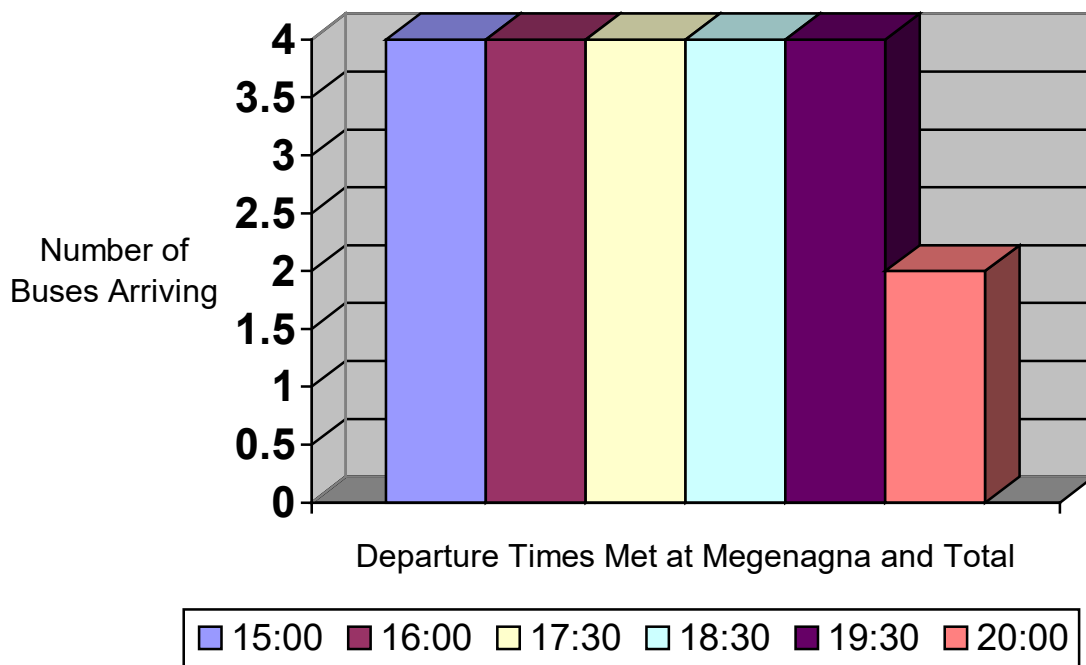


Figure 5.5 Departure Time Coverage of Evening Rush Hours of Route Number Fifty

The above graph is indicative about the relative shortage of buses at the peak hour; 20:00 at which workers and students are collected at stations in demand of transport. In fact the buses departing at around 19:45 can reach some of them at mid way stations.

The route sequences 3 \hat{A} and 3 \hat{B} refer to the buses that immediately follow the routes 3 U and 3 Z sequences respectively at the time interval indicated in table 5.13 below.

Table 5.13 Schedules of succeeding buses of route number three

Sequences 3 Λ and 3 $\tilde{\Lambda}$		
No of Trips	Beginning Trip	Ending Trip
1	6:30	7:25
2	7:25	8:20
3	8:20	9:30
Tea break	9:30	9:50
4	9:50	10:55
5	10:55	12:00
6	12:00	13:05
End of first shift		
7	13:05	14:00
8	14:00	14:55
9	14:55	15:55
Tea break	15:55	16:15
10	16:15	17:15
11	17:35	18:50
12	18:50	19:45
13	19:45	20:40
End of the second shift		

The route sequences 3 σ and 3 Φ refer to the buses that immediately follow the routes 3 Λ and 3 $\tilde{\Lambda}$ sequences respectively at the time interval indicated in table 5.14 below.

Table 5.14 Schedules of succeeding buses of route number three

Sequences 3 ω and 3 ϕ		
No of Trips	Beginning Trip	Ending Trip
1	6:35	7:30
2	7:30	8:25
3	8:25	9:35
Tea break	9:35	9:55
4	9:55	11:00
5	11:00	12:05
6	12:05	13:00
End of first shift		
7	13:00	13:55
8	14:50	15:50
9	15:50	16:50
Tea break	16:50	17:10
10	17:10	18:25
11	18:25	19:20
12	19:35	20:30
13	20:30	21:25
End of the second shift		

The route sequences 3 ω and 3 η refer to the buses that immediately follow the routes 3 ω and 3 ϕ sequences respectively at the time interval indicated in table 5.15 below.

Table 5.15 Schedules of succeeding buses of route number three

Sequences 3 ω and 3 Ω		
№ of Trips	Beginning Trip	Ending Trip
1	6:45	7:40
2	7:40	8:50
3	8:50	10:00
Tea break	10:00	10:20
4	10:20	11:25
5	11:25	12:30
6	12:30	13:25
End of first shift		
7	13:25	14:20
8	14:20	15:15
9	15:15	16:15
Tea break	16:15	16:35
10	16:35	17:50
11	17:50	19:05
12	19:05	20:00
13	20:00	20:55
End of the second shift		

The rush hour coverage of buses in case of route number three is much better than the other routes. However, this dose not guarantee its sufficiency compared to the demand existing in that route. The following figures; Figure 5.6 and Figure 5.7 depict the morning and evening rush hour coverage conditions respectively.

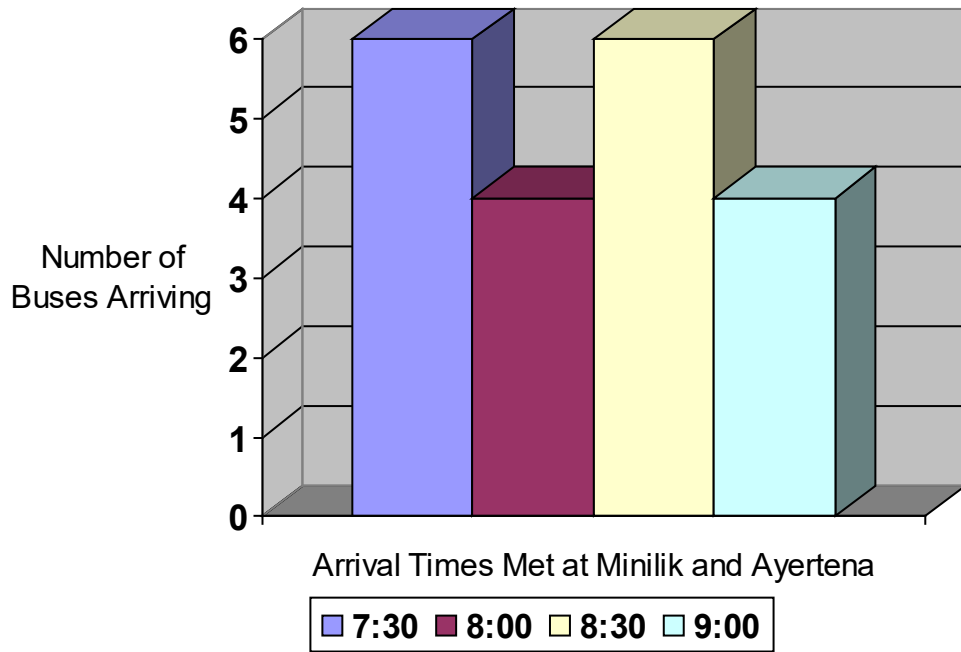


Figure 5.6 Arrival Time Coverage of Morning Rush Hours of Route Number Three

The above graph indicates the peak hour; 8:30 has better coverage within the available capacity which is the necessary condition. The evening coverage is indicated in Figure 5.7 below.

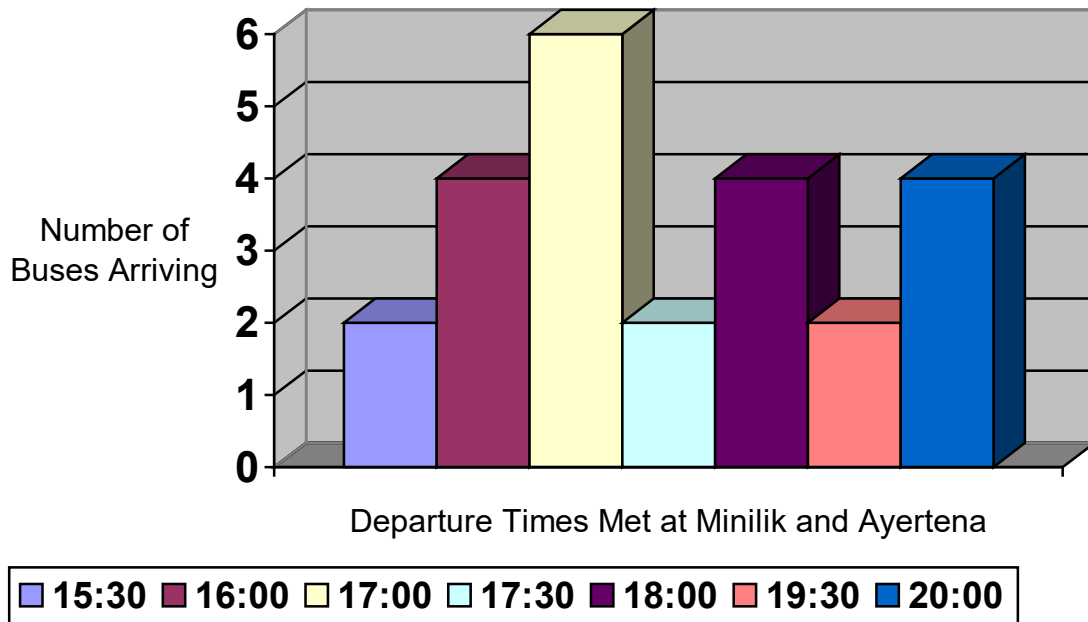


Figure 5.7 DipartureTime Coverage of Evening Rush Hours of Route Number Three

The above figure indicates the coverage that could be achieved without loss of any time. However, the peak hours are not sufficiently covered while the slack hours are provided with better coverage. Hence, a requirement of balancing the coverage arises at this point. To balance the coverage it is necessary to make minor adjustment on the schedule with minimum cost of time to achieve better customer service and financial benefit. Therefore, such adjustments of time at the two sequence schedules; 300 and 304 of fifteen minutes and at the other two sequence schedules; 301 and 302 of twenty minutes delay results in the required coverage we are looking for as indicated in the following figure.

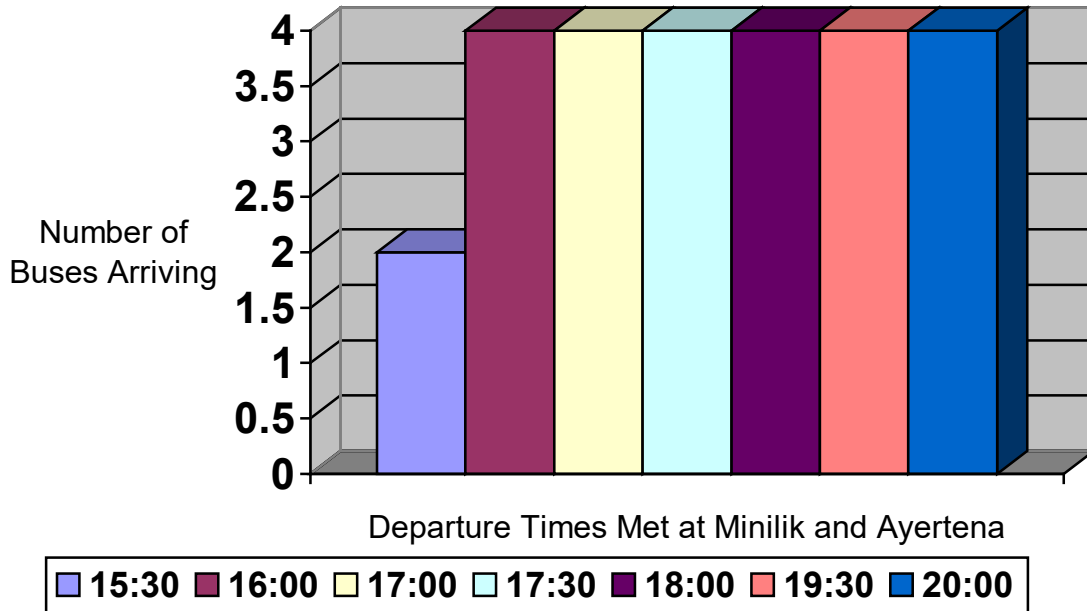


Figure 5.8 DipartureTime Coverage of Evening Rush Hours of Route Number Three(balanced)

It is again to be noted that the coverage can be further improved with improved fleet size for the route.

Similarly, the schedules for sequences of route number fifty two are indicated in the tables below. The route sequences 52 Λ and 52 \mathcal{L} refer to the buses that immediately follow the routes 52 \mathcal{U} and 52 \mathcal{W} sequences respectively at the time interval indicated in table 5.16 below.

Table 5.16 Schedules of succeeding buses of route number Fifty two

Sequences 52 А and 52 Б		
№ of Trips	Beginning Trip	Ending Trip
1	6:45	8:05
2	8:05	9:35
3	9:35	10:50
Tea break	10:50	11:10
4	11:10	12:25
5	12:25	13:40
End of first shift		
6	13:40	14:55
7	14:55	16:20
Tea break	16:20	16:40
8	16:40	18:05
9	18:05	19:20
10	19:20	20:35
End of the second shift		

The route sequences 52 **В** and 52 **Г** refer to the buses that immediately follow the routes 52 **А** and 52 **Б** sequences respectively at the time interval indicated in table 5.17 below.

Table 5.17 Schedules of succeeding buses of route number Fifty two

Sequences 52 σ and 52 η		
No of Trips	Beginning Trip	Ending Trip
1	7:00	8:20
2	8:20	9:50
3	9:50	11:05
Tea break	11:05	11:25
4	11:25	12:40
5	12:40	13:55
End of first shift		
6	13:55	15:10
7	15:10	16:35
Tea break	16:35	16:55
8	16:55	18:35
9	18:35	19:50
10	19:50	21:05
End of the second shift		

The arrival time coverage for the morning shift of the route is indicated in figure 5.9 below.

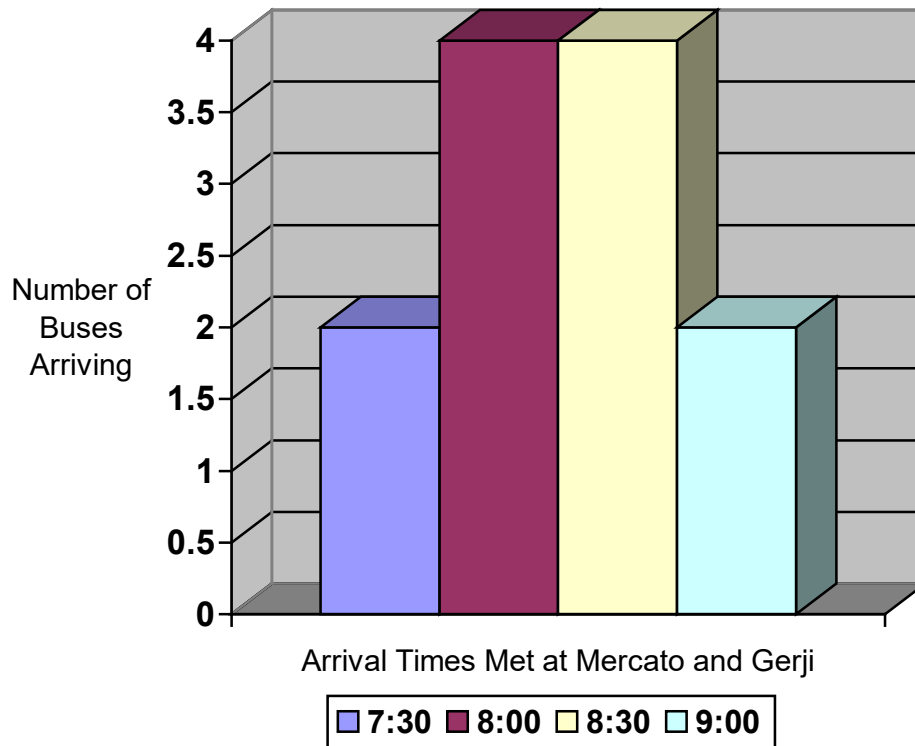


Figure 5.9 Arrival Time Coverage of Morning Rush Hours of Route Number Fifty two

As can be observed from the graphs, the evening coverage of this route seems to be less satisfactory compared to the morning one. This might be attributed to three main factors. The first reason is that the evening shift is exposed to diversified customer departure time requirement which is not the characteristics of the morning shift as such. The second reason is that the fleet size of the route is very limited to satisfy this diversified need.

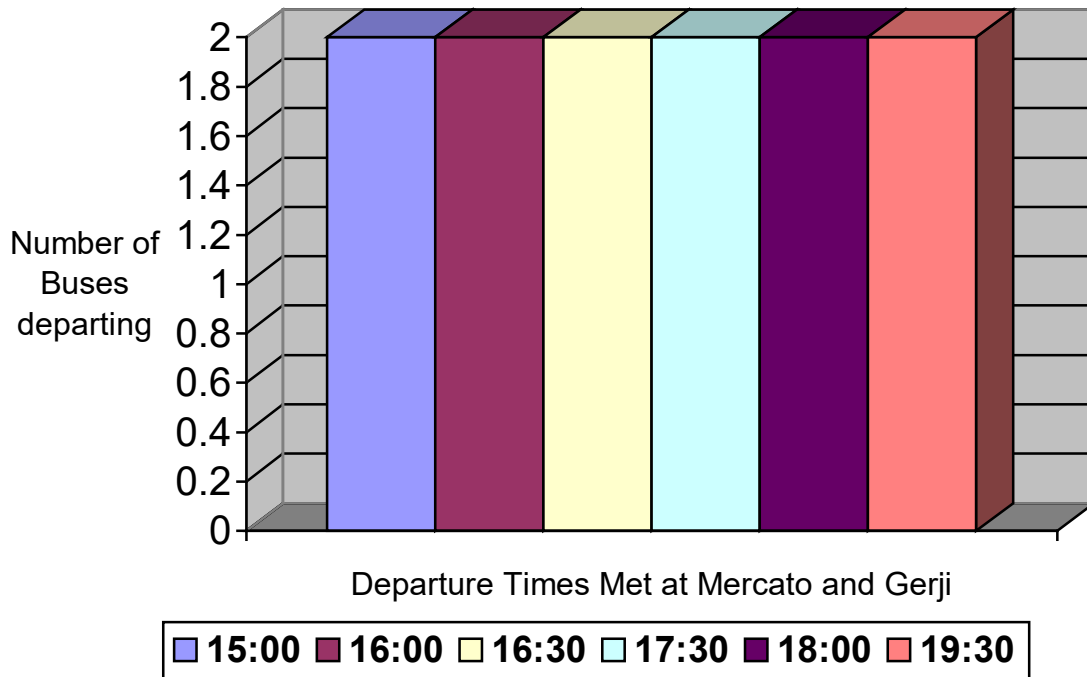


Figure 5.10 DipartureTime Coverage of Evening Rush Hours of Route Number Fifty two

Moreover, the trip delay time is so long, up to more than an hour and half, that minor time delay for adjusting the departure time as in the case of route number three is impossible. Hence, this problem can be solved by operating on the controllable variable that is increasing the fleet size of the route.

5.6 Determining the Statistical Distribution of Delay Times

The delay time data for each delay cause is analyzed through Arena Input Analyzer. The Input Analyzer gives the statistical distribution, mean, maximum, and minimum values of the data input. These out puts of the analysis by the software are used in the modeling process of the routes. The sample results of the data analysis of Arena software is indicated in Appendix C.

6. Modeling, Simulation and Results

6.1 Delay Time Model

After the data are analyzed and the distributions identified for each delay cause and traffic intensity period, each delay cause is modeled by using Arena modeling environment. Then for each delay cause the identified distribution is assigned through the access provided by the software to feed data in the ‘delay’ and ‘leave’ modules dialog boxes under the field ‘delay time’. This enables the model to run during simulation according to the statistical distribution assigned to each module.

6.1.1 Modules and Data Requirement

The modeling includes the create module which enables the creation of document entities which are representing the schedule papers to assign buses for the various trips to be made. These are converted to the physically assigned buses having different colors, based on the different sequences they represent in that specific route, as they pass through the assign module. The buses then move to their beginning stations to perform their daily task. The modules following the create modules are the leave modules named by the bus station areas and representing the delay time required for customers boarding into and getting off the bus. Following the leave modules are the delay modules named by half letters of the previous station names and half letters of the following station names and also area names of turning stations and tea break times. The delay modules represent the path delay time between stations, turnaround delay times while the buses take turns to begin the return trip, and parking delay times which happen during tea breaks and lunch time shift changes.

These combined appropriately result in complete representation of trip delay times model of the Anbessa city buses. The model is supported by clock time and date referring to the simulation of the models.

6.1.2 Types of the Delay Time Models

Three types of model are made on each route to appropriately utilize the model for scheduling and time tabling purposes. The first model, which can also be named as the pessimistic model, makes use of the maximum delay times observed at each of the delay causing factors like; loading and unloading delay, delay to cover the distance between stations, and turning time delays. This model is required to determine the latest possible arrival and departure time that could be achieved by the bus at each station. The second model, which can also be named as the optimistic model, makes use of the minimum delay times observed at each of the delay causing factors. This model is required to determine the earliest possible arrival and departure time that could be achieved by the bus at each station. The third model uses the direct stochastic delay time distribution obtained from the input analyzer. This model helps to visualize the real representation of the analyzed data through the simulation itself and the results of the simulations.

6.1.3 Benefits of the Delay Time Model

The delay time model is primarily helpful to easily determine for the dispatch personnel the arrival and departure clock times of the buses at each and every bus station with out any laborious calculations. This is possible through the step wise simulation of the models of the pessimistic as well as the optimistic which shows the time clock at every step of the move of the bus made.

This results in the window time in which every bus is expected to arrive or depart each of the stations. When this arrival and departure time is displayed for the customers it becomes a promise between the enterprise and the customers to be implemented by the enterprise and to be accustomed to the customers according to the dependability it offers through time.

The stochastic model is also important to visualize customer concentration and bottleneck areas of the route to seek for relevant solutions. Moreover, when conditions on the

ground change either positively in relation to delay cause factors, like broadening and repairing of the roads, improving of interchanges and intersections, or negatively like route obstruction due to road maintenance taking place and un balanced increase of vehicles resulting in aggravated traffic jams, delay data analysis can be made on these specific areas and fed to the model to be simulated to adjusted the schedules accordingly. The Arena modeling environment for the delay time model is indicated in the following figure. In the model presented the above portion indicates the forward trip while the lower portion indicates the return trip. In the module name description of the back ward or the return trip, at the end of each module name, the letter 'b' is added to mean 'back trip' to avoid redundancy of naming modules. (Since the model is too long to present in A4 paper the representation below is partial and informative about the whole)

Figure 6.1 Model for trip delay time of Anbessa bus routes (Route Number Four)

6.2 The Model for Net Number of Customers in the Bus

This model also begins with create modules representing the origins of the customers at each bus stations and is followed by the process module which represents the in side environment of the buses. That means the net number of customers in the bus resulting from boarding and getting off at each station.

The number of customers inside the bus is displayed clearly under the process module so that the dispatcher or any concerned body can observe the net number of customers to take measures like ordering additional bus on the relevant route in case of excess number of customers in side the bus. The dispose module follows the process module representing the destination stations at which customers get off.

6.2.1 Modules and Data Requirement

In the create module, the number of customers obtained through data collection is entered in the dialog box under the fields, 'maximum arrivals'. Since it is assumed that the customers boarding in to the bus enter at each second of the bus stop time, a constant time value of one second is entered under the field 'the time between arrivals'. It is also assumed that one person arrives at each arrival times and this is filled under the field 'entities per arrival'.

Under the process module dialog box, the rate of customer arrivals to their destination which is obtained by the process of the input analyzer is entered in the field 'expression'. This represents the rate at which the customers leave the bus when they reach at their destination. The numerical indicator under the process module indicates clearly the net number of customers in the bus at any time and station during the simulation period and the maximum number is also indicated under the final results of the simulations.

6.2.2 Benefits of the Model

The Net Number of Customers Model is primarily required to identify the sufficiency of the service given by the enterprise in terms of comfort of customers and availability of the service at the required place and time.

When a complaint of comfort or availability is raised from the customer, an assessment of the complaint shall be verified by taking data of customers boarding and getting off at each stations of the route. The data collected shall be entered into the Net Number of Customers Model of the concerned route and simulated to verify that the bus has exceeded the limit set by the enterprise.

The exceeded limit as well as the physical observation at the site of data collection made to estimate the reneging customers for in ability to board due to full customers in the bus or fear of discomfort due to excess number of customers are inputs for the decision to be made by the dispatchers. The dispatchers can observe options of mitigating such problems through narrowing the time gap of the preceding or/and the following bus or ordering additional bus from other routes of relatively less number of customers.

The problem observed might be found to be happening ones in a week or in a longer time intervals like in months and in some cases a year. Such incidents happen when there are public monthly or yearly holidays. In this case the above possible solutions might hold. However, when the cause of the problem is fundamental like increased population and mobility of the route area additional buses might be feasible for the specific route. The model of the route considered is shown in the figure 6.2 below.

Figure 6.2 Model for net number of customers of Anbessa Bus (Route Number Three)

6.3 Results of Simulations

The three models discussed earlier are tested by applying the real data collected on the routes considered for this study. The results of the simulations of the models are discussed under this section.

6.3.1 The Delay Time Model

As discussed in the previous sections the primary objective of the delay time model is to identify the arrival and departure clock times of each station with much little effort than it would be if it was done manually. This makes it easy to the enterprise to post the dependable arrival and departure time of its buses at each station where the customers are waiting for the service.

The delay time models for route number four are simulated step wise to determine the window times with in which the buses will be available at the respective stations for the customers waiting. The results for the major stations used by the customers in forward and return trip of the morning shift of the three buses scheduled for the route (4U : 4A : 4M) are shown below.

MERCATO STATION

Route Number Four Bus Station Arrival and Departure Schedule

Morning

FORWARD TRIP

(4U) 12:05-12:15

(4A) 12:30-12:40

(4M) 12:50-1:00

RETURN TRIP

(4U) 2:46-3:18

(4A) 3:10-3:43

(4M) 3:35-4:03

ABINET STATION

Route Number Four Bus Arrival Schedule

Morning

(4U) 12:21-12:23	(4U) 2:38-3:10
(4Λ) 12:46-12:48	(4Λ) 3:03-3:35
(4σσ) 1:06-1:08	(4σσ) 3:28-3:55

BALCHA STATION

Route Number Four Bus Arrival Schedule

Morning

(4U) 12:25-12:28	(4U) 2:31-3:02
(4Λ) 12:50-12:53	(4Λ) 2:57-3:27
(4σσ) 1:10-1:13	(4σσ) 3:21-3:47

MEXICO STATION

Route Number Four Bus Arrival Schedule

Morning

(4U) 12:27-12:30	(4U) 2:30-3:00
(4Λ) 12:52-12:55	(4Λ) 2:56-3:25
(4σσ) 1:12-1:15	(4σσ) 3:20-3:45

KERA STATION

Route Number Four Bus Arrival Schedule

Morning

(4U) 12:35-12:39

(4U) 2:21-2:49

(4Λ) 1:00-1:05

(4Λ) 2:46-3:14

(4σ) 1:20-1:24

(4σ) 3:11-3:34

GOTTERA STATION

Route Number Four Bus Arrival Schedule

Morning

(4U) 12:39-12:43

(4U) 2:09-2:31

(4Λ) 1:04-1:08

(4Λ) 2:34-2:56

(4σ) 1:24-1:28

(4σ) 2:58-3:16

SARIS STATION

Route Number Four Bus Arrival and Departure Schedule

Morning

(4U) 12:50-12:56

(4U) 1:56-2:13

(4Λ) 1:15-1:21

(4Λ) 2:21-2:38

(4σ) 1:35-1:41

(4σ) 2:46-2:58

KALITY STATION

Route Number Four Bus Arrival and Departure Schedule

Morning

(4U) 1:08-1:24

(4U) 1:33-1:41

(4A) 1:33-1:49

(4A) 1:58-2:07

(4B) 2:18-2:09

(4B) 2:23-2:27

From the above results it can be observed that the window time gap grows as the distance moved increases. This is quite natural since the delaying factors accumulate as more distance is covered. However, from the data collected it is observed that about 99% of the customers catch the bus before Gottera Station both in the forward and return trip.

Hence, the window time that most customers are expected to wait for the bus is about four minutes for the forward trip and about 20-22 minutes for the return trip. The larger window time in the case of the return trip is attributed to the largest delay factor along this route; the road construction project activities of Gottera Interchange and the Gotteraris road. In addition to this, during the return trip the bus passes through the clock time of the morning rush hour as can be observed in the window times of the three buses at Gottera station (2:09 am -3:16 am).

Beside the previously mentioned uses, the Arena simulation results help to easily observe and compare the contribution of the cost elements to the total cost. Hence, it becomes convenient to work on the cost factors so as to reduce them. The value added costs (transporting cost), non value added (brake time and shift changing time costs), waiting costs (turning, loading, and unloading costs), and transfer costs (the cost for going to the depots at the end of the second shift and going to the dispatching center at the beginning of the morning shift), of the buses are the cost elements which the simulation results can possibly show.

The simulation also helps to observe and compare the work loads of the buses of same route. The results of the simulation indicate which bus is to spent more time at work and which bus has shorter working time. This enables to make the basis for leveling the work loads of the drivers and cashiers as well as the buses themselves. An attempt is made in this study to test the above capabilities of the simulation. Hence, the simulation results of one year time of the cost elements and the utilization of buses for route number four is indicated under Appendix F.

6.3.2 The Net Number of Customers Model

The primary objective of this model, as described in the previous sections, is to inform the dispatcher or any other concerned body about the instantaneous net number of customers in the bus so as to get the information about the comfort of customers and over loading under loading conditions. However, there are also other considerable out puts of the simulation. This includes; the maximum, minimum and average, amount of time spent by the customers in side the bus in each of the trips considered. Similarly, the maximum and average number of customers who received the transport services is displayed as a result of the simulations. These figures along with the maximum and average time taken by the customers in side the bus will be indicative about the average load the bus is exposed per each trip.

The other important out put of the simulation is the average and maximum utilization of the buses considered per each trip. This is very important figure which describes the resource utilization and leads to efforts to be made for improved utilization.

It is observed that route number three is the route with more number of buses (10) assigned among the routes considered in this study as well as with more number of net customers per bus observed. A maximum net number of customers of 167 is recorded repeatedly in the morning rush hour 7:00 am- 10:00 am, and the afternoon rush hour 5:00 pm-6:00 pm, and 8:00 pm-9:00 pm. The resource utilization of the buses of this route is steel low with 45%.

On the other hand, route number 50 is the route with less number of buses allocated (3) and also with the least net number of customers observed (a maximum of 59). Route number 52 and 4 are observed to have a maximum net number of customers of 152 and 119 respectively. Moreover the utilization of the bus is 41% for route number 52 and 34% for route number 4. The simulation results for route number 3 are shown under Appendix G.

6.3.3 The Failure Model

The failure model is required to forecast the next failure of the bus considered so as to take precautionary measures by making early repair or excluding the bus from dispatch as the forecasted time approaches before sudden break down. This enables to reduce route disruption caused by sudden break down. The dispatcher needs to have the information about the condition of the buses under the dispatching depot.

In the failure model a DAF model bus with side number 6370 is considered for the analysis. A one year maintenance file of this bus is taken and fed into the Arena input analyzer to get the statistical distribution followed by the uptime and the down time of the bus. The Arena input analyzer result shows the statistical distribution of uptime between failures to be $11.5 + 29 * \text{BETA}(1.5, 1.2)$ in days, and the statistical distribution of down time between uptimes of POIS (19) in days.

These distributions in turn are fed to the failure model of route number 50 to simulate and forecast the failure times of the bus considered for one year from the last failure. This gave the required expected dates of failures through the simulation, and the average, minimum, maximum, and accumulated time spent per customer due to sudden failure of the bus. The average number of customers loosing the service due to the same cause is the other out put of the results of the simulation.

The last date the bus considered had completed its repair was March, 7th 2009. Since then, its expected failure date is forecasted for the coming one year. According to the simulation results the following 15 occasions of failure are expected to happen in the next one year service period of the bus on route 50.

Date of Expected Failure	Date of Expected Finishing Repair
March 30 th , 2009	April 1 st , 2009
April 17 th , 2009	April 18 th , 2009
May 19 th , 2009	May 20 th , 2009
June 16 th , 2009	June 17 th , 2009
July 3 rd , 2009	July 4 th , 2009
July 18 th , 2009	July 27 th , 2009
August 24 th , 2009	August 28 th , 2009
September 12 th , 2009	September 13 th , 2009
October 3 rd , 2009	October 6 th , 2009
October 31 st , 2009	November 1 st , 2009
November 19 th , 2009	November 21 st , 2009
December 7 th , 2009	December 8 th , 2009
December 30 th , 2009	January 1 st , 2010
January 19 th , 2010	January 25 th , 2010
February 28 th , 2010	March 1 st , 2010

Hence, the dispatcher is expected to observe on this forecast data to decide when this bus has to be included in the dispatch list. The simulation result report concerning the time spent and number of customers who lost the service due to the possible sudden failure of this bus when the forecast result is not considered is shown under Appendix H.

7. Mitigation of Schedule Disruption

7.1 Introduction

Whatever the proposed schedule is the best possible, one can not be hundred percent sure of the happenings of extraordinary events which are difficult or impossible to forecast. Accidents of different nature which result in short or long time closure of parts of the road in the route are among the factors that disrupt schedules. Moreover, unpredicted failure of buses has been observed creating great influence on implementation of schedules. Hence, schedules without consideration of such factors can not guarantee dependable service.

7.2 Minimizing Sudden Failure of Buses

Every equipment or machine including vehicles and their spare parts has service life, and preventive maintenance period. Appropriate record of the lives of spare parts and on time replacement of the worn out spares, the planning and implementation of the preventive maintenance of the buses and their spare parts, largely reduces the incidents of sudden failure.

7.2.1 Maintenance Problems in ACBSE

The current situation in ACBSE indicates problems of the maintenance services. About one hundred buses are out of service. Nearly ninety four buses are idle due to shortage of spare parts and appropriate maintenance. According to the information from the enterprise this is due to financial problem faced. The company also says its revenue is not sufficient to finance the regular spare part demand and maintenance expenses. The service equivalent to that of sixty seven buses is lost each day due to scheduling problems, sudden failure of the buses and other reasons.

Hence, attention is required to improve the service currently delivered to the public. These problems can be improved by increasing dependability of the service through dependable schedules which are displayed to the public as indicated in the previous chapters. This paves the way of increasing the revenue through increased number of customers attracted by the dependable service. This in turn improves the financial capacity of the enterprise to alleviate the maintenance and spare part expense problems.

7.2.2 Alleviating Sudden Failure Problems

Once the maintenance and spare part problems are solved the next thing becomes handling the maintenance and replacing the spares appropriately. This involves appropriately recording the life of spares, meeting the preventive maintenance programs, and replacing spares before failure. The life of spares, the failure pattern of vehicles, or the frequency at which they shall get maintenance is usually specified by manufacturers or obtained by keeping records of failures and analyzing the pattern.

The failure pattern of parts or the buses can be modeled using Arena software modeling facility. The model for failure characteristics of a bus is made by collecting the failure history of the bus from the Yeka maintenance depot of ACBSE.

Such modeling of buses enables to forecast the future possible failure of buses so that the relevant action is taken before the buses join the dispatching. This minimizes the failure of buses while giving service to the customers. Hence, this improves the dependability of the service given by ACBSE. A similar study of the nature of failure of buses in terms of cause of failure can be made. This enables to take preventive measures on the causes by forecasting the failures beforehand. (The bus failure model is shown in Appendix D)

Since the detailed maintenance depot enhancement model scenarios are dealt with by ato Bisirat Engidawork in his thesis work of last year 2000(E.C), a reference can be made on it regarding the maintenance improvement requirements.

7.3 Detour

7.3.1 Influence of Road Construction and Maintenance

Maintenance and construction of roads under the bus route line might happen at different areas in the city. These conditions usually obstruct the scheduled trips of the city buses and reduce the dependability of the schedules.

In the observation made in this study part of the road containing route number four was under the road construction projects of Gottera interchange and saris road. There was no measure taken to detour the route to improve performance of the schedule. Hence, the existing schedule has been exposed to aggravated dependability problems more than the one observed in other routes that did not involve road construction or /and maintenance.

However, since maintenance and construction of roads are common activities of a growing city and dependability of public transport systems on the other hand are important elements of the growth factor, a system shall be implemented to avoid the negative impact of road obstruction due to maintenance and construction of roads.

Therefore, alternative paths shall be planned and publicized for the customers to avoid the unnecessary time spent on long queues waiting for the slow movement of the traffic in obstructed roads. Obstructed roads spend the precious time of the work force (customers) and underutilize the capacity of the buses.

7.3.2 Effect of Possible Detour on the Road from Gottera to Kality Ring Road Roundabout

The Gottera interchange – saris road construction project intersects the Anbessa city bus route number four at Gottera interchange and departs it at the ring road kality turnabout. However, there is an alternative road way, which is the part of the ring road, to by pass the road under construction.

The data collected on the path under construction indicates that the minimum time spent in this part of the path is about 12 minute in the early morning and late evening periods. The maximum time spent is about 35 minutes and is achieved in the range of time clock 10:00 am - 12:30 am.

On the other hand, the alternative path takes almost similar time delay as the early morning, noon, and late evening cases of the road under construction, which is about 11 minutes. This indicates that there is a great benefit by applying the detour option. About 24 minutes is saved in terms of time in addition to the social, economical, and psychological benefits among others. The customer satisfaction maintained irrespective of the construction activities in that area is valuable.

It is to be remembered that there are customers who want to get off in the forward trip (to wards Kality) and others expecting to catch the bus on the return trip (to wards Gottera) at the stations under the construction site. Similarly, there are also customers which would prefer the detour path. However, the data shows the number of customers in the bus waiting to reach their destination is much more than the number of customers whose destination and departure is at the stations with in the road maintenance region. The average number calculated in percentage of the disadvantaged customers to that who are benefiting out of the detour ranges between 6-8 %. Hence, the majority of the customers require the detour in this case.

The detour measure shall be made by announcing to the public to get the service on the alternative path. (The model concerned with the detour alternative is indicated in Appendix E)

7.4 Dispatching Communication

The other schedule disruption mitigation system is using means of communication. ACBSE have been using radio communication system to alleviate problems of schedule implementation. The dispatchers of the enterprise have been using this system to report sudden failure of buses, and other issues related to dispatching and scheduling. However, this means of communication is no more used these days. The concerned bodies of the enterprise say that there is lack of capacity for maintenance of the communication radios.

7.4.1 Cases of Communication Requirement

There are many cases in which the radio communication is helpful to keep planned schedules of trips. If buses fail in an expected incident or unpredictable accidents, standby buses shall be called on to quickly replace the service and reduce the effect of schedule disruption. Moreover, some times buses are observed to head to wards traffic congestion and join the jam. This could have been solved if the control personnel use radio communication to inform the dispatchers to use temporary alternative routes to by pass the congested part of the route.

7.4.2 Expected Services in Case of Route Obstruction

The control personnel shall make their maximum effort to replace the service disrupted by route obstruction causes by helping the customers to take other alternatives of Anbessa buses in the near by alternative path and even returning the fare the customers have paid for the service to help them take other means of transport to reach on time to at their destinations. The measures to be taken might vary depending on the intensity of the obstruction and the skill and ethics of the control personnel available at the problem site.

The enterprise has buses reserved for stand by purpose. However, the observation made indicates that the buses missed for maintenance reason are not always replaced to cover the service gap created due to this cause.

8. Conclusions and Recommendation

8.1 Conclusions

The physical observations made, the result of questionnaires distributed, and the interviews made indicate clearly that the problems informally heard from customers of Anbessa; long waiting time, skipping stations, overcrowded buses, are prevalent.

Moreover, real delay time data and number of customer collected verify that the allotted time for delay causes in the currently existing schedule is mostly optimistic and the crowd in side the buses causes discomfort for the customers.

They also indicated that the data collected by the data collectors of the enterprise on delay causes are not taken exhaustively pertaining to the factors affecting delay time like; dry and rainy season, different traffic intensity periods of the day, week days and week ends, effect of the forward trip traffic and the return trip traffic. Insufficiency of all the relevant data is the reason for the difficulty in finding the maximum and the minimum attainable delay times. Deterministic delay time data collection system in cases of some of the delay factors like turnaround delay time has contributed for wrong estimation of delay times.

Arrival and departure time of buses are found to be mostly not according to schedule. In most cases trips are cancelled for reason of insufficient time allotted for the previous trip which forces the consuming of the following trip time.

Since there are different numbers of customers boarding and getting off the bus at different stations it had been difficult to estimate the maximum net number of people in a bus at certain instant of time. This had made it difficult to accurately and economically determine the number of buses required per each route.

Route obstruction factors like maintenance and construction of roads, public religious holidays which are increasing traffic intensity are not considered in the currently existing schedules. In addition to this, communication equipments like radio are not in use in cases of detour requirements and sudden failure of buses to mitigate route obstruction and schedule disruption.

This paper concludes the necessity of consideration of all the factors affecting the final results of delay data and number of customers' data collection. It addresses the value of covering the rainy and dry season, the slack and rush hours, public and religious holidays in the data collection. To insure dependable service, updating the schedules based on feed backs on the performances and taking pessimistic side of the data collected is shown to be vital.

This paper also introduced application of the delay time models for the success of satisfactory customer service. This model is critical not only for insuring dependable service but also for easily making the schedules public to increase the awareness of the patrons and increase the market share of the city transport service.

Number of customers' model is also introduced to enable the analysis of overloading, comfort of customers, and make complete determination of fleet size of buses.

The bus failure model is another model considered in this paper to support dependable scheduling. This is applied to forecast the future failures of buses. The maintenance service is a major focus area to safeguard the dependable schedule introduced through this paper. Hence, the dispatching of buses is made to consider the forecast of the failure models. Detour alternatives along with radio communications in cases of route obstructions help to complete the dependability of Anbessa city bus service.

8.2 Recommendations

- The city government shall give priority to the improvement of the service of Anbessa bus to alleviate city transport service taking advantages of the opportunities of its accessibility, capacity to serve many customers at a time, and contribution to reduce traffic intensity.
- Deterministic delay time consideration for scheduling purpose shall be avoided to eliminate extreme optimism and pessimism which adversely affects dependable and economic scheduling.
- Delay time and number of customers' data shall be taken sufficiently until the statistical distribution of the data appears to be not changing any more.
- The most pessimistic delay time and number of customers' data shall be considered for making dependable schedule with which more customers are satisfied.
- The data collected shall be updated when ever there is an indication of a change in the dependability of the schedule to cope up with the changing conditions.
- Customer opinion shall be collected and updated whenever needed to determine the arrival and departure times' requirement.
- Arrival and departure times at stations shall be clearly posted at the relevant bus stops for customer information and transparency.

- Software supports are recommended for automation of arrival and departure time calculations, forecasting maximum expected net number of customers in a bus, and other long term and short term planning and improvement of the service.

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