DEVELOPMENT OF OPTIMAL BUS SCHEDULE FOR BOSSO AND GIDAN-KWANO CAMPUSES, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA USING GENETIC ALGORITHM

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MEng/SIPET/2018/8223

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THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ENGINEERING IN CIVIL ENGINEERING (HIGHWAY AND TRANSPORTATION ENGINEERING)

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ABSTRACT

The poor academic performance of students also traced to inadequate hostels to accommodate students in the main campus making large number of them to stay at Bosso campus. Adequate CCTV data (travel demand and travel time) of student inter-campus movement were used for optimal development of the university Bus transit management. Using Genetic Algorithms (GA), the following results were obtained. 19 number of 18 (154 trips), 11 of 35 (44 trips) and 15 of 60 (34 trips) sitting capacity buses with respective travel time of 40, 50 and 60 minutes are required at the current traffic and road conditions. This led to generating four (4) different optimal Bus scheduled representing Bosso and GK for both lecture and examination seasons with their corresponding net cost for the Bus management. At every fifteen (15) minutes, a set of Bus(es) were made to depart with the maximum possible number of passengers to ensured no delay in transiting between the campuses. By imploring these scheduled, a net total of N185,000 would be obtained during lecture season per day to effectively transport 2562 students and the amount would increase by 289% during examination season.

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ABBREVIATIONS, GLOSSARIES AND SYMBOLS

GA Genetic Algorithms

CCTV Closed Circuit Television

LP Linear Programming

GK Gidan Kwano

ITIF Information Technology and Innovation Foundation

ITS Intelligent Transportation Systems

ATMS Advanced transportation management systems

APTS Advanced public transportation systems

V2II Vehicle-To-Infrastructure Integration

V2V Vehicle-To-Vehicle

ATIS Advanced Travelers Information System

TND Transit network design

FS Frequency setting

TNT Transit network timetabling

VSP Vehicle scheduling problem

DSP Driver scheduling problem

DRP Driver rostering problem

GIS Geographical Information System

MILP Mixed integer linear programming

APC Automatic passenger counting

ADC Automatic Data Collection

AVL Automatic vehicle location

FUTM Federal University of Technology Minna

PSO Particle swarm optimization

BBO Biogeographic based optimization

GSA	Gravitational search algorithm
POA	Pastoralist optimization algorithm
TOCs	Traffic Operation Centers
VMS	Variable Message Signs
ETC	Electronic Toll Collection
ERP	Electronic Road Pricing
VMT	Vehicle Miles Travelled
CICAS	Cooperative Intersection Collision Avoidance Systems
ISA	Intelligent Speed Adaptation
TOCs	Traffic Operations Centers
FS	Frequency Settings
BRT	Bus Rapid Transit
DED	Detail Engineering Design

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Transportation is the movement of people, goods and services from one location to another. This movement can be achieved through different modes such as; land, air and water Transportation (Kolo, 2019). However, for the purpose of this research, emphasis will be on land mode of transportation.

Land transportation in any form is the most used mode because of its various advantages and ease of operation. The land use mode of transportation can be subdivided into rail, cable, road and others. Various categories of mechanically operated machines make use of the road for ease of movement and safety. They includes; cars, trucks, buses, tricycle and motorcycles.

The world population is on the rise. This has also resulted in people searching for easy means of carrying out their daily activities with less stress on time. However, over the years, people and government has seen that the most effective way of meeting travel demand is to embrace timely and comfortable public transport. The transit demand is a concern not only to the country, but to the students moving between the campuses of Federal University of technology, Minna.

Growing traffic problems are a major concern for the countries all over the world. Almost every country of the world whether developing or developed are facing the problem in the management of transportation facilities (Singh and Gupta, 2013). In Nigeria, at Federal University of Technology, Minna to be precise, transportation demand is growing at a much faster rate as the staff and students' population is on the rise. This is a genuine problem because it is almost impossible to march the transport infrastructure rate with the traffic population growth rate.

The university population of both staff and students has increased by 525.25% over the last 6 years (FUTM Annual Report, 2020) and the vehicles transporting the student are nearly constant. In view of that, it is difficult to focuses on developing the optimal use of the available buses rather than purchasing new buses. A number of technologies are now invented to solve different transport related problems in optimizing available buses; such invention includes Information Technology and Innovation Foundation (ITIF) under which Intelligent Transportation System (ITS) is coined.

According to Ezell, (2010) Intelligent Transportation System (ITS) as a relatively new branch of Transportation Engineering which studies and implies new technologies to solve the different traffic and Transportation problems. ITSs are being used and developed all over the world for the optimum use of the available Transportation infrastructure. It is an integrated system which helps in managing and monitoring traffic flow, reducing congestion, providing best route to the travelers, saving lives, time and money. I.T.S is aimed at improving the safety and efficiency of the transportation system. ITS have sub branches dealing with different aspect of traffic safety and management.

Line capacity is simply the number of vehicles that can be transported on a route at a given period of time. It is obtained as the products of line frequency and vehicle capacity (Cats and Gluck, 2019). Line frequency is the number of times a vehicle leaves and arrive a station (origin/destination).

Different transit data collection methods are available for frequency setting problem ranging from the manual counting (observation) but with the emergence of Automatic

Data Collection (ADC) technology such as Automatic Vehicle Location (AVL) installed on a bus to track the location of the bus, Automatic Passenger Counting (APC) which gives the number of passengers by receiving "On or Off counts" or sometimes "On and Off counts" using sensors installed near the doors and Global positioning system (GPS). However, for the purpose of this research, manual method of counting is adopted and used to calibrate the Closed Circuit Television (CCTV) data collection. These data collected was then used for Bus time table and scheduling.

According to Wihartiko *et al.* (2017), Bus timetable is the information by transportation provider for the passenger to give a service certainty time in term of departure/arrival bus schedule. Bus transportation service provider which usually use timetable in giving the schedule information to the customer is the road based mass transit (Bus Rapid Transit/BRT), shuttle bus and any other scheduled bus service transportation.

The consequences of using timetable are to ensure the buses are deployed on scheduled. As a result, service providers must be able to determine the number of optimum bus departure/frequency from the place of origin to the destination (optimal trip number) so that a timetable is made in accordance with passenger demand conditions and existed constraints, with regard to passenger service. It means in the off-peak time, the amount of trip will be less compared with the amount of trip during rush hour and vice versa. If it's not be calculated well, when the trips frequency is too small, there will be accumulation of passengers (unserved passenger) or vice versa, when the trips frequency is too much, it will waste the operating costs.

Genetic algorithms are type of evolutionary algorithms that are inspired by the process of natural selection and genetics. Unlike heuristics algorithms, it is metaheuristics algorithm that is capable of solving many types of problem that cannot be solved using other conventional algorithms. It is a population based algorithm because it sends large initial population to obtain solutions to a given problem. Another advantage of GA it is stochastic, capable of given different solution types per run unlike deterministic algorithm.

Different optimization models are available for developing bus Time Table such as; particle swarm optimization (PSO), Biogeographic based optimization (BBO), Gravitational search algorithm (GSA) and pastoralist optimization algorithm (POA). For the purpose of this research; a linear programming model would be developed and solved using a Genetic Algorithm.

1.2 Statement of the Research Problem

Transportation challenges experienced in most Nigerian urban centers include traffic congestion, inadequate provision of carriers for commuters in quantity and timeliness, poor traffic management, poor conditions of roads, attitudinal behavior of drivers among others (Adeleke *et al.*, 2013).

According to Wihartiko *et al.* (2017) if the number of bus trips were more frequent than the optimal condition, it would make a high operating cost for bus operator; conversely, if the number of trip was less than optimal condition, it would make a bad quality service for passengers.

The increasing urban population plays a pivotal role in the growing travel demand, which in turn causes the transport crisis in Indian cities (Cyril, 2019). The bus system of the university has been inadequate (to travel demand) and uneconomical (to bus management) in traversing between the two campuses through Bosso - Kpakungu - Gidan-kwano line.

Despite some students leaving their various houses at early hour of the day, they still experience unplanned delay and sometimes denied boarding at the bus parks (origin).In addition to the above, stresses due to long waiting time seriously affect students. This is a consequence of improper time table. Therefore, this research is aimed at developing an optimal bus time table and scheduling to reduce the waiting time, minimizing the operation cost and maximizing the output.

1.3 Aim and Objectives of the Study

1.3.1 Aim of the study

This research is aimed at developing optimal Bus schedule for Bosso and Gidan-Kwano campuses Federal University of Technology, Minna using Genetic algorithms.

1.3.2 Objectives of the study

To achieve the research aim, the following objectives were set out:

i) Determination of travel demand at an interval of 15-minute on a daily basis for Bosso and GK campuses.

ii) Formulation of linear programming model (LP) with constraints.

iii) Generating optimal Bus schedule by using Genetic Algorithm (GA) to solve the formulated LP model.

1.4 Justification of the Study

At the end of this research, the user cost in terms of the high travel time, uncertain delay and varying transport fare due to changes in available fleet size would be considered. The operational cost which includes the cost of maintenance, fuel cost and driver's remuneration would also be minimized. With the developed Bus time table, the service demand of the buses will march to a reasonable extent the available transport facilities (buses). In addition, knowing buses arrival and departure period, students can leave their respective houses to the Bus Park and board their buses with little or no delay.

1.5 Scope of the Study

In any frequency optimization problems, there are many factors taking into consideration such as fleet size, travel demand, overcrowding and travel time uncertainty. This research is limited to only travel time uncertainty and travel demand. Observation or manual method was used, bus manager and drivers were also interviewed and CCTV data were collected. The videos from cameras were turned to data by physical counting. However, a programming code can be written to automatically generate the data with the dataset available to train the program. A mathematical model formulation involving linear programming (LP) was used to optimize the fitness function and generating the optimal Time Table using a stochastic, meteheuristics and probalistics algorithm (GA).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Transportation and its Means

Everybody travels whether to work, play, shop, business or schools. All raw materials must be conveyed from the land to a place of manufacture or usage, and all goods must be moved from the factory to the market place and from the staffs to the consumer. Transport is the means by which these activities occur; it is the cement that binds together communities and their activities. Meeting these needs has been, and continues to be the transport task (O' Flaherty, 2006).

Transportation is the movement of people, animals and goods from one location to another. The modes of transportation include air, rail, rail, road and water. The field can be divided into infrastructure, vehicles and operations. Transport infrastructure consists of the fixed installation including roads, railways, airways, waterways and terminals such as airports, railways stations, bus stations and sea ports. Vehicles travelling on these networks may include automobile, bicycle, buses, trains, trucks.

2.2 Characteristics of Transportation Modes

Transportation mode (Modal splits) is a solution that makes use of a particular type of vehicle, infrastructure and operation (Kolo, 2019). The transport of a person or cargo may involve one of mode or several of the modes with latter case being called intermodal or multimodal transport. According to Tuzkay (2019), the characteristics of transportation mode are:

2.2.1 Land transportation

2.2.1.1 Rail transportation

Rail transport is used for heavy and bulky loads over long hauls without paying great charges. Some of the advantages are consistency, low-cost guarantee and greater reliability and are not influence by the weather and traffic condition. The main disadvantages are inflexibility and particular route between fixed terminals. Also, they do not stop at intermediate points and there are some damages result from fueling, maintenance and cleaning.

2.2.2 Road transportation

The most commonly used mode for door-to-door transportation is the road transportation. Its core benefits are the flexibility and ability to reach hardy places. The disadvantages are high maintenance, fuel expenses and weight limitations. In addition, it causes air, water and soil pollution (Oluwole, 2019).

2.2.3 Water transportation

Rail and road modes are limited to land use, but, an important part of international trade is carried out by sea transport. Sea transportation contains three basic kinds which are river and canals, coastal shipping’s and ocean transport. The main advantages of sea transportation are the ability to transport large amount of bulk freights, liquids and containerized freight by ships. Also, there are no obligations or transit-passing transactions between the starting and arrival points; however, the damage risk is high, transit times are long and there is a boundary and to find appropriate ports is hard. Also, tank cleaning and fueling are harmful for water.

2.2.4 Air transportation

Air transportation is the most proper mode when slow speed is unacceptable. However, aircraft operations cause noise, and waste disposal problems.

For the purpose of this research, road transportation which provides door-to-door services is used. The passengers are transported between the campuses with three basic means which includes; motor cycle, bicycle and tricycle.

2.3 Transportation System

Transportation determines companies' competitiveness and has several negative effects on cities, creating a necessity to make great efforts in management processes. The later explains the need for advanced information systems that lead to transport optimization at all levels, both for commercial and passenger transport. An inadequate transportation system generates high costs and low customer service levels, which ultimately produces a negative economic impact for both (Juliann *et al.*, 2013).

City growth generates an increase of traffic due to a higher movement of vehicles for the transport of people and the distribution of goods. This makes mobility problems more evident and more complex every day. The problem of increased transport not only creates congestion problems, but also affects the economy, environment, health and competitiveness of cities and business. A collapsed transport system in a city means an economic problem since vehicles lose their ability to move easily; then their purpose, which is to move goods or people, is not developed properly, leading to higher transport costs, and affecting businesses and cities' economy. The environmental impact is evident, since vehicles will have longer waiting times in heavy traffic locations or their trips will be made at a lower speed, creating higher fuel consumption, which produces more carbon (iv) oxide (CO_2) and pollution.

Besides, traffic jams make people impatient, and this is reflected in the use of horns, creating noise pollution. As for health, CO_2 emissions and pollution from fuel burning generate respiratory problems In terms of competitiveness; companies and cities perform logistics operations less efficiently due to traffic, which involves higher costs and lower service levels, resulting in the mentioned competitiveness loss. Internationally, there are strategies aimed at mitigating the negative impact of freight transport in cities (Benjalloun *et al.*, 2010). According to Crainic and Kim (2007) and Arango *et al*, (2011), city logistics strategies must be linked to an information system that allows an efficient administration process, aiming at the capture, processing, transmission, and management of that information. This has led to the development of specialized computer tools for transport management, such as the Intelligent Transportation Systems (ITS) and to the integration of administrative tools for operation management and decision making.

2.4 Information Technology and Innovation Foundation (ITIF)

Information technology (IT) has transformed many industries, from education to health care to government, and is now in the early stages of transforming transportation systems. While many think improving a country's transportation system solely means building new roads or repairing aging infrastructures, the future of transportation lies not only in concrete and steel, but also increasingly in using IT. IT enables elements within the transportation system vehicles, roads, traffic lights, message and signs to become intelligent by embedding them with microchips and sensors and empowering them to communicate with each other through wireless technologies.

In the leading nations in the world, ITSs bring significant improvement in transportation system performance, including reduced congestion and increased safety and traveler convenience. Unfortunately, the United States lags the global leaders, particularly Japan, Singapore, and South Korea in ITS deployment. For the most part, this has been the result of two key factors: a continued lack of adequate funding for ITS and the lack of the right organizational system to drive ITS in the United States, particularly the lack of a federally led approach, as opposed to the "every state on its own approach" that has prevailed to date (Ezell, 2010).

2.5 Intelligent Transportation Systems (ITS)

Intelligent Transportation Systems (ITS) applies advanced technologies of electronics, communications, computers, control and sensing and detecting in all kinds of transportation system in order to improve safety, efficiency and service, and traffic situation through transmitting real-time information; Summary of ITS categories is illustrated in the Table 2.1

Table 2.1: Summary of Categories of ITS Applications and their Specific Applications

ITS Application Category	Specific ITS Applications
Advanced Transportation Management Systems (ATMS)	The specific ITS application of ATMS are Traffic Operation Centers (TOCs), Adaptive Traffic Signal Control, Dynamic Message Signs or Variable Message Signs (VMS)
ITS-Enabled Transportation Pricing systems.	Electronic Toll Collection (ETC), Congestion Pricing/Electronic Road Pricing (ERP), Vehicle Miles Travelled (VMT) Usage Fees and Variable Parking Fees
Advanced Public Transport Systems	Real Time Status for Public Transit System (Rail, Bus and Subways for example), Automatic Vehicle Location (AVL), and Electronic Fare Payment (e.g. Smart Cards)
Vehicle-to –Infrastructure Integration (VII) and Vehicle-to-Vehicle Integration (V2V)	Cooperative Intersection Collision Avoidance Systems (CICAS) and Intelligent Speed Adaptation (ISA)
Advanced Travelers Information System (ATIS)	Real-time Traffic Information Provision Route Guidance/Navigation Systems Parking Information Roadside Weather Information Systems

(Source: Ezell, 2010)

2.5.2 Importance of ITS

Many think improving a country's transportation system solely means building new roads or repairing aging infrastructure. But the future of transportation lies not only in concrete and steel, but also in the implementation of technology, specifically a network of sensors, microchips, and communication devices that collect and disseminate information about the functioning of the transportation system. Transportation systems are really about networks, and much of the value of a network is contained in its information: For example, whether a traffic signal "knows" there is traffic waiting to pass through an intersection; whether a vehicle is drifting out of its lane; whether two vehicles are likely to collide at an intersection; whether roadway is congested with traffic; what the true cost of operating a roadway is.

What intelligent transportation systems do is empower actors in the transportation system from commuters, to highway and transit network operators, even down to the actual traffic lights themselves with actionable information (or, intelligence) to make better-informed decisions, whether it's choosing which route to take; when to travel; whether to mode-shift (take mass transit instead of driving); how to optimize traffic signals; where to build new roadways; what the true cost of roadways are and how best to price their use; or how to hold providers of transportation services accountable for results. The big opportunity at hand is to bring information to bear on transportation networks, transforming them into truly intelligent transportation systems (Ezell, 2010).

2.5.3 Benefits of intelligent transportation system

Applying information technology to a country's transportation network delivers five key classes of benefits:

2.5.2.1 Increasing Driver and Pedestrian Safety

Intelligent transportation systems can deliver important safety benefits. There are 1.2 million fatalities annually on the world's roadways. In 2007, a traffic accident occurred every five seconds in the United States (totaling over 6 million accidents), with a traffic fatality occurring every 13 minutes, killing 41,059 Americans and causing approximately 2.6 million injuries. (In 2008, 5.8 million crashes led to 37,261 fatalities). 29 European Union countries experienced a similar number of accidents and fatalities, with 42,943 deaths on European Union roadways in 2006.30 Japan experienced 887,000 traffic accidents in 2006, injuring 1.1 million victims and causing 6,300 fatalities. (Karkkainen *et al.*, 2004). In fact, ITSs are leading to a fundamental rethinking of vehicle safety.

Over the past 50 years, most of the developments in transportation safety such as the mandatory installation and use of seat belts in the 1970s and the installation of airbags in the 1980swere designed to protect passengers in the event of a crash. ITSs improve the performance of a country's transportation system by maximizing the capacity of existing infrastructure, reducing to some degree the need to build additional highway capacity.

2.5.2.2 Improve the operational performance of the transportation network

ITSs improve the performance of a country's transportation network by maximizing the capacity of existing infrastructures, reducing the need to build additional highway capacity. Maximizing capacity is crucial because, in almost all countries, increases in vehicle miles traveled dramatically outstrips increases in roadway capacity(and in many countries there is either little more room to build, little political will to build, or both). For example, from 1980 to 2006 in the United States, the total number of miles traveled by automobiles increased97 percent, but over the same time the total number of highway lane miles grew just 4.4 percent, meaning that over twice the traffic in the United States has been traveling on essentially the same roadway capacity.

FHWA (2012), a number of ITS applications contribute to enhancing the operational performance of transportation networks. For example, traffic signal light optimization can improve traffic flow significantly, reducing stops by as much as 40 percent, cutting gas consumption by 10 percent, cutting emissions by 22 percent, and reducing travel time by 25 percent (CVIS, 2012). Applying real-time traffic data could improve traffic signal efficiency by 10 percent, saving 1.1 million gallons of gas a day nationally and cutting daily carbon dioxide emissions by 9,600European Union countries experience 7,500 kilometers of traffic jams every day on their roads, with ten percent of the EU's road network affected by congestion. In fact, 24 percent of Europeans' driving time is spent in traffic congestion, at a yearly cost of one percent of the European Union's GDP.47 Australia annually suffers $12.5 billion in costs due to urban congestion. In Japan, congestion costs the nation3.5 billion man-hours, worth almost ¥11 trillion ($109 billion) each year. Deploying intelligent transportation systems has been shown to have a significant and direct impact on reducing congestion.

2.5.2.3 Enhancing mobility and convenience

ITS enhance driver mobility and convenience by:

1) Decreasing congestion and maximizing the operational efficiency of the transportation system, as described previously, and

2) Providing motorists and mass transit users with real-time traveler information and enhanced route selection and navigation capability.

In fact, perhaps the most familiar intelligent transportation systems are telemetric-based applications such as satellite-based vehicle navigation or other services that deliver real-time traffic information to drivers either in-vehicle or before departing as they plan for their trip. These services help drivers identify and take the most efficient, trouble-free routes and help preclude motorists from getting lost.

2.5.2.4 Deliver environmental benefits

ITSs are positioned to deliver environmental benefits by reducing congestion, by enabling traffic to flow more smoothly, by coaching motorists how to drive most efficiently, and by reducing the need to build additional roadways through maximizing the capacity of existing ones. Vehicle transportation is a major cause of greenhouse gas emissions. In England, the transport sector contributes about one-quarter of the country's CO_2 emissions, 93 percent of which comes from road transport. In France, transport represents 31 percent of final energy consumption and 26.4 percent of greenhouse gas emissions. Transportation accounts for 25 percent of worldwide greenhouse gas emissions and 33 percent in the United States. Traffic congestion causes an outsized amount of CO_2 emissions.

Vehicles traveling at 60 kmph (37 mph) emit 40 percent less carbon emissions than vehicles traveling at 20 kmph (12 mph) and vehicles traveling at 40 kmph (25 mph) emit 20 percent less emissions than the 20 kmph baseline. In Japan, Germany, and increasingly the United States, enthusiasts upload records of their driving behavior from vehicles to Web sites where they compete with others to be the most efficient driver. Thus, intelligent transportation systems that decrease congestion and improve traffic flow ameliorate environmental impact considerably. To be sure, by decreasing congestion and enabling traffic to flow more smoothly, intelligent transportation systems may cause some degree of induced demand, encouraging more drivers to take to the roads due to improved traffic conditions. But while ITS causes some induced demand, overall it is poised to deliver net environmental benefits.

2.5.2.5 Boosting productivity, economic and employment growth

Intelligent transportation systems boost productivity and expand economic and employment growth. By improving the performance of a nation's transportation system, thus ensuring that people and products reach their appointed destinations as quickly and efficiently as possible, ITS can enhance the productivity of a nation's workers and businesses and boost a nation's economic competitiveness. Many transportation agencies already use ITSs effectively to reduce traffic congestion and it's nearly $200 billion estimated annual impact on economic productivity and the environment. David and Gregory (2008) stated that the estimated effects of congestion pricing on freight and found commercial services industries would be net beneficiaries (Ezell, 2010).

A number of countries, including South Korea, Germany, and Japan, view intelligent transportation systems as a key industrial sector, capable of generating considerable export-led economic and employment growth. Scott, (2009) the U.S. Department of Transportation has estimated that the field of ITSs could create almost 600,000 new jobs over the next 20 years. A 2009 ITIF study found that a £5 billion investment in intelligent transportation systems in the United Kingdom would support approximately 188,500 new or retained jobs for one year. Stalley and moore, (2009) nations that lead in ITS deployment are also likely to be international leaders in ITS job creation and to create economic export and competitiveness advantage for themselves.

2.6 Intelligent Transportation Systems Application

2.6.1 Advanced transportation management systems (ATMS)

Advanced Transportation Management Systems (ATMS) include ITS applications that focus on traffic control devices, such as traffic signals, ramp metering, and the dynamic (or “variable”) message signs on highways that provide drivers real-time messaging about traffic or highway status. Traffic Operations Centers (TOCs), centralized traffic management centers run by cities and states worldwide, rely on information technologies to connect sensors and roadside equipment, vehicle probes, cameras, message signs, and other devices together to create an integrated view of traffic flow and to detect accidents, dangerous weather events, or other roadway hazards. Adaptive traffic signal control refers to dynamically managed, intelligent traffic signal timing. Many countries’ traffic lights, including the vast majority of the close to 300,000 signalized intersections in the United States, use static, outdated timing plans based on data collected years or decades before (NTOC, 2007).

In fact, an estimated 5 to 10 percent of the congestion on major American roadways amounting to 295 million vehicle hours is attributed to bad signal timing. David (2008) giving traffic signals the ability to detect the presence of waiting vehicles, or giving vehicles the ability to communicate that information to a traffic signal, perhaps through DSRC-enabled communication (assuming both the vehicle and traffic signal are DSRC-equipped), could enable improved timing of traffic signals, thereby enhancing traffic flow and reducing congestion. Another advanced transportation management system that can yield significant traffic management benefits is ramp metering. Ramp meters are traffic signals on freeway entrance ramps that break up clusters of vehicles entering the freeway, which reduces the disruptions to freeway flow that vehicle clusters cause and makes merging safer. About 20 U.S. metropolitan areas use ramp metering in some form.

2.6.2 Advanced public transportation systems (APTS)

Advanced Public Transportation Systems (APTS) include applications such as automatic vehicle location (AVL), which enable transit vehicles, whether bus or rail, to report their current location, making it possible for traffic operations managers to construct a real-time view of the status of all assets in the public transportation system. APTS help to make public transport a more attractive option for commuters by giving them enhanced visibility into the arrival and departure status (and overall timeliness) of buses and trains. This category also includes electronic fare payment systems for public transportation systems, such as Suica in Japan or T-Money in South Korea, which enable transit users to pay fares contactless from their smart cards or mobile phones using near field communications technology. I.F (2009) Advanced public transportation systems, particularly providing “next bus” or “next train information, are increasingly common worldwide, from Washington, DC, to Paris, Tokyo, Seoul, and elsewhere.

2.6.3 ITS-Enabled transportation pricing systems

ITS have a central role to play in funding countries’ transportation systems. The most common application is electronic toll collection (ETC), also commonly known internationally as “road user charging,” through which drivers can pay tolls automatically via a DSRC-enabled on-board device or tag placed on the windshield (such as E-Z Pass in the United States). The most sophisticated countries, including Australia and Japan, have implemented a single national ETC standard, obviating the need, as in the United States, to carry multiple toll collection tags on cross-country trips because various highway operators’ ETC systems lack interoperability. This particularly has been a problem for the European Union, although the European

Committee for Standardization is working to resolve this challenge (and has made considerable progress).

Atkinson and Castro, (2009) ITS have a central role to play in financing countries' transportation systems. Stockholm's congestion pricing scheme yielded immediate results, reducing traffic by 20 percent in the first month alone as many commuters opted for public transportation. Shilley and Stalley (2008), High-Occupancy Toll (HOT) lanes reserved for buses and other high occupancy vehicles but that can be made available to single occupant vehicles upon payment of a toll are another ITS-enabled mechanism to combat traffic congestion. The number of vehicles using the reserved lanes can be controlled through variable pricing (via electronic toll collection) to maintain free-flowing traffic at all times, even during rush hours, which increases overall traffic flow on a given segment of road.

2.6.4 Vehicle-To-Infrastructure integration (VII) and Vehicle-To-Vehicle (V2V) integration

Vehicle-to-infrastructure integration is the archetype for a comprehensively integrated intelligent transportation system. In the United States, the objective of the VII Initiative as of January 2009 rebranded as IntelliDrive has been to deploy and enable a com-munications infrastructure that supports vehicle-to-infrastructure, as well as vehicle-to-vehicle, communications for a variety of vehicle safety applications and transportation operations. IntelliDrive envisions that DSRC-enabled tags or sensors, if widely deployed in vehicles, highways, and in roadside or intersection equipment, would enable the core elements of the transportation system to intelligently communicate with one another, delivering a wide range of benefits.

According to Ezell, (2010), IntelliDrive is a system which could either warn the driver to slow down or be designed to automatically slow the vehicle through automatic intervention. France is currently testing deployment of an ISA system that would automatically slow fast-moving vehicles in extreme weather conditions, such as blizzards or icing. The province of Victoria, Australia, is testing a system in which trains could remotely and autonomously break vehicles attempting to cross their path at railway intersections (Terry, 2008).

2.6.5 Advanced travelers information system (ATIS)

Booz and Hamilton (1998), Advanced Traveler Information includes static and real-time information on traffic conditions, and schedules, road and weather conditions, special events, and tourist information. It went further to explain that this information are collected and disseminated using telecommunication and computer devices. Advanced traveler information system has been found to be of immense advantage to the transportation industry. Many societies have adopted its use for the reason that it goes a long way to enhance most if not all the challenges involved in transportation. The information provided by it will help travelers make the best of choices when deciding on which route to use, the most economical transport company or means to use.

Rutherford *et al.* (2005), agreed with this when it said ‘it is generally believed that advanced traveler information systems (ATIS) are among the most cost-effective investments that a transportation agency can make. The goal of these strategies is to provide travelers with information that will facilitate their decisions concerning route choice, departure time, trip delay or elimination, and mode of transportation. Agencies usually employ a variety of ATIS methods to reach different travelers’.

Real time information provided by Advanced Travelers Information System (ATIS) via communication gadgets and technologies helps travelers to be aware of the road conditions ahead of them. This will help shorten their perception-reaction time for any road condition as they may have already made a decision on how to handle the situation when encountered during the trip right away from the moment they got the information. This will on the long run reduce the level of accidents on the highway if the motorists put the provided information into consideration as they drive and also take adequate precaution.

Eran *et al.* (2012) in agreement with the above statement affirmed that Advanced Traveler Information Systems (ATIS) are designed to assist travelers in making better travel choices by providing information regarding the available travel alternatives. Without information, travelers' choices are based mainly on experiential information that is based on knowledge gained from past experiences. It also went further to say "ATIS enable her users, in addition to experience, to base their choices on descriptive, prescriptive and even feedback information.

Descriptive information usually consists of information about real time prevailing conditions such as current or predicted travel times while Prescriptive information usually suggests to the travelers the 'best' alternative for example the route with the shortest travel time. As an integral part of ITS, Advanced Traveler Information System (ATIS) assists travelers with planning, perception, analysis and decision-making to improve convenience, safety and efficiency of travel (Dong *et al*., 2010).

2.7 Data Collection

2.7.1 Data collection techniques

Transit-data-collection techniques required for operations planning can be divided into three categories: (i) manual-based methods, (ii) automated-based methods, and (iii) AVL-based methods (AVL automated vehicle location). Fundamentally, there are only two types of methods, manual and automated. However, AVL or AVM (automated vehicle monitoring) systems give more accurate information, especially in time and space, than do other item-specific automated methods and, therefore, can be looked at as a separate category. Five primary techniques for collecting transit data may be identified: point check, ride check, deadhead check, passenger survey and population surveys.

2.7.1.1 Point check

Point check is usually described as counts and measurements performed by a checker stationed at a transit stop. The stop selected is virtually the maximum (peak) load point, at which the transit vehicle departing this stop has, on average, the maximum on-board load across all route segments. A route segment is defined as a section of the route between two adjacent stops. For each vehicle passing the stop, the point check usually contains load counts, arrival and departure times, and vehicle and route identifications.

Other point-check locations than the peak stop are more (multiple) peak points, end points and strategic points. Multiple point checks accommodate situations in which there are simultaneously several peak points and a situation of long routes and branching routes, in which a branching route is one that stretches along the base route and adds a certain branch. End point checks accommodate running-time measurements and, if applicable, record fare box readings. Strategic point checks are useful for item-specific checks, such as at major transfer points (measuring transfer time and successful vehicle meetings), major activity centers (observing passenger behavior in selecting a competitor mode), and new neighborhoods (measuring changes in passenger demand).

2.7.1.2 Ride check

Ride check refers to counts and measurements performed by either a checker riding the transit vehicle along the entire route or an automated instrument (hence, replacing the human checker). The ride check contains mainly on and off passenger counts, from which one can derive the on-board passenger load for each route segment, arrival and departure times for each stop, and sometimes item-specific surveys or measurements (vehicle running speed, boarding by fare category, gender of passengers and baggage size), and record fare box readings.

The common automated instrument for ride checks, called APC (automated passenger counter), can perform the main ride-check tasks. It cannot, however, replace the checker in counting boarding by fare category and in surveying passengers. A special ride check is one performed by the operator (driver). It usually involves the interaction of the driver and a fare box, with the driver inserting into the machine information related to fare category and O-D per passenger. The action, however, increases the time spent at the stop.

However, data may also be collected by installing a CCTV shown in Plate I at strategic location and later exporting the video from the camera which in turns can be generated by manually or physical counting or writing a computer code to automatically generate the data. This research will be adopting a CCTV form of data collection from past records. Data itself is divided into different classes according to their quality.

Plate I: A closed circuit television (CCTV)

2.7.2 Levels of data quality

One solution to the quality of data issue is to develop a quality standard for all data used in the system. This standard could develop four levels of data:

2.7.2.1 Unacceptable data: Data that may be used for some other purpose, such as fleet management or maintenance that has a potential impact on travel, but is not accurate or timely enough for use in a 511 system.

2.7.2.2 Good data: Data that is minimally acceptable for use in a 511 system. Incident information is an excellent example of good data. Incident information has value for a particular duration of time. If the incident information is a few minutes out of date, the data still has value to the system.

2.7.2.3 Better data: Data that provides accurate and timely information regarding the status of the transportation system. Sensor data that reflects the real-time status of the transportation network could be an example of better data.

2.7.2.4 Best data: Data that provides accurate and timely information regarding the status of the transportation system, has significant value over time, and gives an indication regarding the future conditions of the transportation network.

2.8 Transit Network Planning

The planning process spans every decision that should be taken before the operation of the system, and is known as the Transit Network Planning problem denoted as TNP. Due to its complexity, TNP is divided into tactical, strategically and operational decisions (Ceder, 2007).

2.8.1 Tactical planning decisions

Tactical decisions associated to the TNP are related to improving the level of service and reducing the operational costs. In this planning horizon, which is normally few months, the fleet size and characteristics is fixed. In addition, most lines and the origin-destination demand matrix are considered given. In this context, the remaining questions are:

(i) The frequency and fleet (number and type of vehicles) assigned to different lines in each period.

(ii) The timetables for low frequency lines and

(iii) The design of operational strategies to be considered during the execution.

2.8.1.1 Frequency setting problem

In the previous section, we address the TND problem which usually defines preliminary frequencies. However, the operation of a transport system is dynamic, and so the service policies must be adjusted to the demand behavior and system performance, that is, it is necessary to make changes in the network design, frequencies, and fare structure, among other things. The Frequency Setting problem (denoted as FS) determines the number of trips for a given set of lines, L to provide a high level of service in a planning period. Since frequency changes influence the passengers' perception of the level of service it may lead to an increment or decrement of the system usage. Early works on Frequency Setting when we assume a fixed demand-line assignment was based on analytic models (Newell, 1971; Salzborn, 1972; Scheele, 1980; Han and Wilson, 1982) or heuristic solution methods (Furth and Wilson, 1981). These seminal approaches were later extended including uncertainty in the demand observed in each line or other considerations.

Hadas and Shnaiderman (2012), address the minimization of a total cost based on empty seats and not-served demand. Li *et al.* (2013) also consider stochastic parameters such as demand, arrival times, boarding/alighting times, and travel times. The authors define a stochastic optimization approach to find the optimal frequency that minimizes the sum of the expected value of the company profit and the waiting time costs for passengers. The authors develop a GA to solve the problem and compare their approach with traditional Frequency Setting models of (Newell, 1971) and (Ceder, 1984). The authors state that the headways obtained are usually larger than those using the approach by Newell (1971) and shorter than those using (Ceder, 1984). They claim that these moderate headways provide a better balance between the bus operational costs and the passengers' satisfaction. Verbas and Mahmassani (2013) and (2015), extend the model presented by Furth and Wilson (1981).

Considering demand variation along time and line route. The authors re-define a line as a set of ''line patterns''-consisting of subset of stops of the normal line-for which a frequency must be set in order to properly satisfy demand patterns in specific time intervals. The variation of demand is modeled by assuming temporal and spatial heterogeneity of ridership elasticity with respect to frequencies. The problem is formulated with a non-linear program which minimizes the weighted sum of ridership and waits time savings over all stops, lines, and time intervals subject to constraints such as budget, fleet size, headway bounds for each line pattern, and bounds for load factors. Verbas and Mahmassani (2013) test the model on an example in order to analyze the impact of the constraints. Numerical results show that increasing the fleet size may lead to reduce operational costs since vehicles may be assigned to low-cost, high-ridership line patterns. Verbas and Mahmassani (2015) test the model on large instances in order to analyze the impact of temporal/spatial demand elasticity's and the author's state that demands is not temporally stable.

a) Bi-level approaches for the frequency setting

Constantin and Florian (1995), define the upper-level as determining the frequencies which minimize the total travel and waiting times while at the lower-level a transit assignment problem is modeled. Then, they develop a projected sub-gradient algorithm to solve instances based on the transit networks of Stockholm, Sweden; Winnipeg, Canada; and Portland, OR, U.S. dell'Olio *et al.* (2012), address the problem of determining the vehicle capacity and the needed frequency in order to satisfy a given demand. The upper-level considers the optimization of the sum of user and operator costs while the lower-level represents transit assignment decisions.

To solve the optimization problem, the authors propose an iterative heuristic approach consisting of three steps iteration: (i) generate an initial set of frequencies; (ii) solve the transit assignment model using commercial software; and (iii) implement the Hooke-Jeeves algorithm to find new frequencies and determine vehicle capacities. The numerical results of implementing the proposed approach in a sub-network in Santander, Spain quantify the benefits from using a heterogeneous fleet.

Demand uncertainty incorporates a new element into the FS problem since passengers may not board the first arriving bus even though the aggregated frequency is enough to carry all passengers. Yoo *et al.* (2010), propose a formulation that minimizes the total travel time of passengers subject to fleet size constraints and considering users' route choices. The upper-level determines the bus frequencies while the lower-level solves a transit assignment problem assuming uncertain passenger arrivals at bus stops. To solve the proposed problem, the authors implement a heuristic algorithm consisting of two procedures:

(i) GA to compute potential frequencies and

(ii) Label-marking method that assigns the demand to the current network configuration according to the minimization of the total expected cost.

The proposed solution approach is tested on the transit network of Dalia, China. Numerical results show that it is possible to reduce travel times by 6% compared with the current operation of the system. Moreover, the authors compare the operation of four private companies under two scenarios: (i) an integrated system, that is; companies sharing vehicles; and (ii) independent operation. Numerical results show a 13% reduction of the total travel time in the integrated case.

Yoo *et al.* (2010) present a FS model based on a non-cooperative Stackelberg game. The upper-level maximizes the demand, subject to fleet size and frequency constraints. At the lower-level a capacity-constrained stochastic user equilibrium assignment model is solved considering variable demand and transfer delays. To solve the proposed formulation the authors develop an iterative procedure consisting of two stages:

(i) Solving the lower-level for a given frequency

(ii) Determining new frequencies using a gradient projection method.

Huang *et al.* (2013) present a FS problem with uncertain demand to minimize the weighted sum of the operating costs and travel times variance. In this study, the upper-level determines the frequencies while the lower-level computes the mean and variance of the passenger flow through each link of the transit network. Verbas and Mahmassani (2015) propose a bi-level solution method which: (i) determines frequencies at the upper-level maximizing waiting time savings considering constraints such as budget, fleet size, vehicle load, and headway policy; and (ii) runs a simulation algorithm at the lower-level modeling the demand response to the new Frequency Setting.

b) Frequency settings to coordinate different transport modes

Coordination of different lines or transport modes is rarely considered in FS problems, even when coordination affects costs that are imparted to transit operators as well as its users (Sun and Hickman, 2004). In this matter, Shrivastava and Dhingra (2002) develop a non-linear integer formulation for the FS of feeder lines connecting trunk lines (with given schedules) in order to minimize transfer times at connection stops and the operational cost.

Assumptions of the problem are fixed demand and bounds for transfer waiting times, fleet size, and load factors. Since the problem is intractable by commercial software, the authors develop a GA taking into account the load factor as a quality measure. The proposed algorithm is tested on the transit network of Mumbai, India and numerical results show that there is a trade-off between the load factor and transfer waiting time. The later GA is also implemented by Verma and Dhingra (2006) and Shrivastava and O'Mahony (2009), in sequential approaches that heuristically generate lines and then coordinate them.

More recently, Sivakumaran *et al.* (2012), propose a continuous approximation approach which determines the frequency of feeder lines minimizing the weighted sum of wait times at feeder stops, their transfer wait at the trunk stop, and the feeder operating cost. The demand is modeled through a time-independent density function which varies gradually along distance. The authors finds out that by dispatching feeder vehicles in coordination with the given trunk schedule, total user cost can significantly diminish while little or no extra cost is imparted to the operator of the feeder lines. Moreover, they extend the analysis to jointly determine the headways for trunk and feeder lines. In this case, it is shown that schedule coordination can often be Pareto improving which benefits both users and operators.

Wu *et al.* (2014) propose a non-linear formulation for the FS with static demand in order to coordinate feeder bus lines with trunk lines in BRT corridors. The model considers vehicles' capacity and frequencies' bound. The objective is to minimize the weighted sum of users' and operators' cost includes waiting time, transfer cots, in-vehicle waiting time, drivers' wages, vehicle operation, and vehicle maintenance. To solve the problem, the authors develop a GA and test it on two kinds of scenarios: (i) coordination of all-stop BRT and bus; (ii) coordination of all-stop BRT, limited-stop BRT, and Bus.

2.8.1.2 Transit network time tabling problem

There are two types of transit systems operation: (i) frequency-based operation where a frequency f (buses/hour) should be met with hopefully a regular service, that is; buses are expected to pass every 60 minutes; and (ii) timetable-based operation where specific departure and arrival times for selected stops are set for all trips. Commonly, the TND and FS problems assume a frequency-based operation where it is possible to estimate the waiting times, fleet size, and waiting times at transfers stops in terms of the lines' frequencies. However, the timetable-based operation arise from the need of consider specific operation characteristics such as satisfy known demand patterns, synchronize different bus lines, and maximize the number of well-timed transfers.

a) Transit network time tabling to meet specific demand patterns

The efficiency of timetables is strongly related to passenger demand, which may be highly variable during the day and even within short planning periods. Examples of how to create timetables with balanced passenger loads are shown by Ceder (2007), where the rate of passenger arrivals is assumed to be constant (based on data recollection) in small planning periods and departure times are generated through analytic procedures. It is unusual to address load and headway evenness in a timetabling problem.

However, Ceder *et al.,* (2013) proposed to minimize the deviation from the desired passenger load while trying to maintain even headways using buses with different sizes. A handicap is the determination of the headway to be used in the timetable. Hence, the authors develop a heuristic approach to determining the desired headway to satisfy the demand based on the following three strategies: (i) maximizing the size of the bus; (ii) minimizing the size of the bus; and (iii) selecting the bus whose capacity is closer to the average passenger load. Moreover, the desired headway is used in a heuristic algorithm to determine the timetable.

b) Transit network time tabling to minimize waiting times

Passenger transfers are present in all transport systems. Then, the minimization of waiting time costs at transfer stops may be a reasonable objective for the TNT. For example, Klemt and Stemme (1988) propose a quadratic semi-assignment formulation for the TNT minimizing transfer waiting times in order to schedule a given number of trips. The authors develop a constructive process in which trips are scheduled one at a time with consideration to transfer synchronization. Later, Domschke (1989) designed B&B, local search, and SA algorithms that outperform the solutions obtained by Klemt and Stemme (1988).

Chakroborty *et al.* (1995) present a non-linear mathematical formulation for the TNT minimizing the total waiting time (including transfers). Constraints of the problem are fleet size, arrival time bounds, maximum headway value, and maximum transfer times. The authors develop a Genetic Algorithm (GA) which is tested on examples of the problem obtaining high quality feasible solutions in short time. TNP is also commonly divided into the following sub problems:

2.8.2 Transit network problems

2.8.2.1 Transit network design (TND): Defines the lines layouts and associated operational characteristics such as rolling stock types and space between stops in order to optimize specific objective functions such as the minimization of the weighted sum of operators' and users' costs. Notice that in this strategic process, frequencies must also be preliminarily set, but they are later adjusted in the Frequency Setting problem.

2.8.2.2 Frequency setting (FS): Characterizes the periods of operation based on demand patterns (morning peak, morning nonpeak, afternoon peak) and determines the number of trips per hour needed to satisfy the passenger demand in each planning period.

2.8.2.3 Transit network timetabling (TNT): Defines arrival and departure times of buses at all stops along the transit network in order to achieve different goals such as: meet a given frequency, satisfy specific demand patterns, maximize the number of well-timed passenger transfers, and minimize waiting times. In some cases, the number of trips is given while other problems may also determine the number of trips based on vehicle capacity and demand patterns.

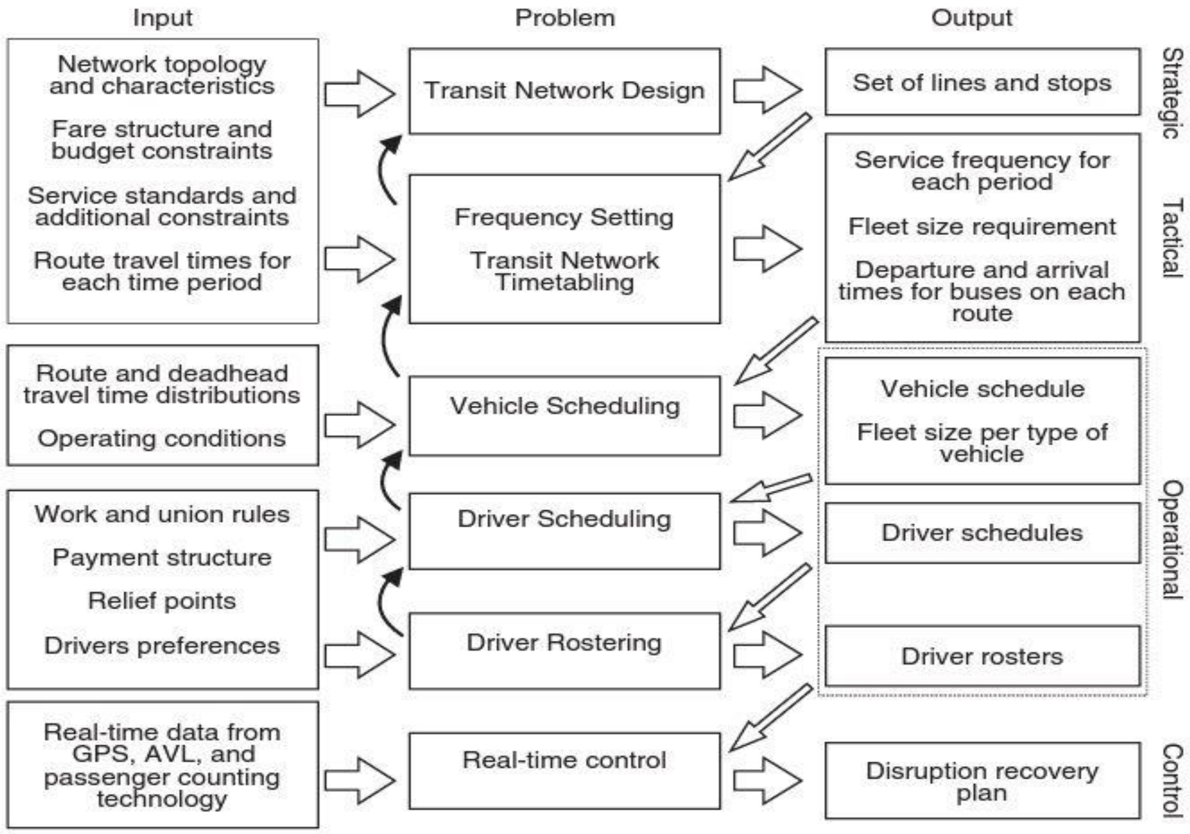
2.8.2.4 Vehicle scheduling problem (VSP): Determines the trips-vehicles assignment to cover all the planned trips such that operational costs based on vehicle usage are minimized. Vehicle scheduling refers to the problem of determining the optimal allocation of vehicles to carry out all the trips in a given transit timetable. A chain of trips is assigned to each vehicle, although some of them may be deadheading (DH) or empty trips in order to reach optimality. The number of feasible solutions to this problem is extremely high, especially in the case in which the vehicles are based in multiple depots. Much of the focus of the literature on scheduling procedures is, therefore, on computational issues. Delle and Filippi (1998) developed several heuristic formulations, based on a shortest-path problem, that seek to minimize the number of required vehicles in a multiple-depot schedule. The algorithm presented is performed in stages, in each of which the duty of a new vehicle is determined. In each such stage, a set of forbidden arcs is defined, and then a feasible circuit through the network is sought that does not use any of the forbidden arcs.

Computational efficiency is obtained by searching for the shortest path across a subset of all arcs in the network, rather than searching the entire network. Several modifications to the basic algorithms are offered that save computer time by substituting parts of the full problem with problems of a reduced size. These modifications include, for instance, solving the re-assignment of trips as a single-depot problem; an attempt to swap parts of duty segments; and an internal re-assignment of trips within each pair of vehicles associated with different depots.

Löbel (1999), discussed the multiple-depot vehicle scheduling problem and its relaxation into a linear programming formulation that can be tackled using the branch-and-cut method. A special multi-commodity flow formulation is presented, which, unlike most other such formulations, is not arc-oriented. A column-generation solution technique is developed, called Lagrangean pricing; it is based on two different Lagrangean relaxations. Heuristics are used within the procedure to determine the upper and lower bounds of the solution, but the final solution is proved to be the real optimum. Kwan *et al.* (1999) described an object-oriented approach for bus scheduling, based on the VAMPIRES algorithm for iterative improvement of the solution presented by Smith and Wren (1988).

2.8.2.5 Driver Scheduling Problem (DSP): Defines daily duties that cover all the scheduled trips and minimize the cost of driver wages. A solution of the DSP must satisfy specific labor regulations for drivers such as minimum/maximum work length, maximum working time without a rest, and daily rest for all drivers.

2.8.2.6 Driver Rostering Problem (DRP): Given a set of generic duties defined over a certain time horizon (a month) for the drivers assigned to a particular depot, the DRP assigns these duties to the available drivers to their work schedules, called rosters, such that labor regulations are satisfied and driver wages are minimized. The interdependence between the sub-problems of the TNP given by Ibarra *et al.*, 2017 is represented in Figure 2.1



(Source: Ibarra *et al.*, 2017)

Figure 2.1: Interaction between stages of the planning process and real-time control strategies

For example, different frequencies may imply different vehicle schedules and driver duties which strongly influence operational costs. Therefore, an integral approach considering all decisions towards solving the TNP would be desirable. However, for the purpose of this research, efforts will be on tactical planning decision; for further readings on the strategic and tactical planning, refer to Ibarra *et al.* (2015).

2.8.3 The operational planning decomposition process

The transit-operation planning process commonly includes four basic activities, usually performed in sequence: (1) network route design, (2) timetable development, (3) vehicle scheduling, and (4) crew scheduling (Ceder, 2001). This research deals with Bus Time Table development and vehicle scheduling.

2.9 Overview of Transit Vehicles

Transit vehicles are divided into two categories: fixed route vehicles and demand responsive vehicles.

2.9.1 Fixed route vehicles

2.9.1.1 Transit bus (or transit coach): A bus with front and center doors, normally with a rear-mounted engine, low-back seating, and without luggage compartments or restroom facilities for use in frequent stop service. This is what is used most typically on fixed route systems. A 40-foot coach is the common type bus used in larger systems. This vehicle can usually hold about 42 ambulatory passengers when two wheelchair tie downs are provided. The cost of such a bus averages between $250,000 and $280,000.

2.9.1.2 Articulated bus: Extra-long (54 to 60 feet) bus with the rear body section connected to the main body by a joint mechanism. The accordion-like joint mechanism allows the vehicle to bend when in operation for sharp turns and curves and yet have a continuous interior. It can hold about 60 passengers and costs about $375,000.

2.9.1.3 Double decked bus: High-capacity bus having two levels of seating, one over the other, connected by one or more stairways. Total bus height is usually 13 to 14.5 feet, and typical passenger seating capacity ranges from 40 to 80 people.

2.9.1.4 Intercity bus: Also referred to as an over-the-road coach. A Bus with front door only, separate luggage compartments, and usually with rest room facilities and high-backed seats for use in high-speed long-distance service.

2.9.1.5 Suburban bus: A bus with front doors only, normally with high-backed seats, and without luggage compartments or restroom facilities for use in longer-distance service with relatively few stops. They are usually 35 to 42 feet in length and cost about $290,000.

2.9.1.6 Trolley replica bus: A bus with an exterior (and usually an interior) designed to look like a streetcar from the early 1900s. They usually hold 20 to 40. The cost varies greatly, from $140,000 to custom models at $260,000 and up, depending on quality of construction materials (pine vs. walnut), type of suspension (spring vs. air.

2.9.1.7 Commuter rail car: Commuter rail passenger vehicle. There are two types: 1) Commuter Rail Passenger Coach: not independently propelled and requiring one or more locomotives for propulsion; and 2) Commuter Rail Self-propelled Passenger Car: not requiring a separate locomotive for propulsion.

2.9.1.8 Commuter rail locomotive: Commuter rail vehicle used to pull or push commuter rail passenger cars. Locomotives do not carry passengers themselves.

a) Heavy rail car: Rail car with motive capability, driven by electric power taken from overhead lines or third rails, configured for passenger traffic and usually operated on exclusive right-of-way.

b) Light rail vehicle: Rail car with motive capability, usually driven by electric power taken from overhead lines, configured for passenger traffic and usually operating on non-exclusive right-of-way.

2.9.2 Demand responsive vehicles

2.9.2.1 Standard van: A factory-built 12- or 15-passenger vehicle (including the driver) that is manufactured by Ford, GM or Chrysler. The minimum cost is usually about $20,000. These vehicles have side passenger doors and are difficult for some elderly persons to board because they must pull themselves up into the vehicle while also ducking down at the same time. Furthermore, because of the cramped quarters and low ceiling height, and because entry into the final row requires one to step over a wheel well, movement within the vehicle is also difficult. In the past, some vans have been retrofitted with wheelchair lifts and extended roofs, but such retrofits do not meet ADA requirements.

2.9.2.2 Minivan: A factory-built vehicle designed to be something between a car and a van. They can be obtained for about $28,000. A wheel chair minivans one which has gone through an extensive after factory conversion. The firms performing this after-factory work raise the roofs and literally drop the floor of the minivans about six inches, enabling them to use short wheelchair ramps, rather than wheelchair lifts. These vehicles usually hold two wheelchairs and one ambulatory passenger, in addition to the driver.

2.9.2.3 Van conversion: A standard factory-built van that has been significantly altered by a specialty retrofitter after leaving the van maker's factory. These retrofitters remove the seats and the top half of the van. Among the features are an extended height roof, a specific wheelchair entry door, a front entry door with a convenient low step for ambulatory passengers, and new seating with a center aisle. The conversion van has three-across seating: two-person seats on the driver's side and one-person seats on the other. The usual configuration is 8 ambulatory seats and one wheelchair tie down.

2.9.2.4 "Body-on-chassis" minibus: A specially-made body placed on a Ford or Chevy "cutaway" truck (not van) chassis. The chassis is made by Ford or Chevy, but the bodies are manufactured by companies such as Champion, Collins, Diamond, El Dorado, and Supreme. These vehicles are wider and taller than standard vans. Like van conversions, they have walk-in, front entry doors and a center aisle, but they are wider and higher than van conversions, with interiors tall enough to allow a person to stand and four across seating. Minibuses are made with various wheelbases, designed to accommodate 16, 20, 24 or 28 ambulatory passengers (excluding the driver). When equipped to handle 24 or more passengers, an extra rear axle, referred to as a “tag axle,” is usually added by the manufacturer.

2.10 Models in Public Transit Planning

2.10.1 Kalman-filter prediction algorithms

This prediction modeling system consists of two Kalman-flter algorithms. In general, the Kalman-flter is a linear recursive predictive update algorithm used to estimate the parameters of a process model. Starting with initial estimates, the Kalman-flter allows the parameters of the model to be predicted and adjusted with each new measurement. Its ability to combine the effects of noise of both the process and measurements, in addition to its easy computational algorithms, has made it very popular in many research fields and applications, particularly in the area of autonomous and assisted navigation Maybeck (1979).

The main assumption used in developing the Kalman-filters is that the patterns of the link running time and passenger arrival rate at stops are cyclic for a specific period of day. In other words, knowledge of the link travel time and number of passengers waiting for a specific bus in a certain period of time will allow one to predict these variables for the next bus during the same period, so long as conditions remain steady. When conditions change (for example, demand surge at a stop and/ or an incident occurred at a link), the model can update the effect of the new conditions on the predictions, so long as the new conditions persist for a sufficient length of time (at least one headway length).

The Kalman filter algorithm works conceptually as follows. The last three-day historical data of actual running times along a particular link at the instant k+1 plus the last running time observation at the instant k on the current day are used to predict the bus running time at the instant k+1. Similarly, passenger arrival rates of the previous three days at the instant k+1 plus the passenger arrival rate at the instant k on the current day are used to predict the passenger arrival rate at the instant k+1.

The historical passenger arrival rate is obtained from the APC data as in this fashion: The number of on-passengers at a bus stop is divided by the most recent headway (that is; the arrival time of the previous bus minus the arrival time of the current bus (Shalaby and Farhan, 2014).

2.10.2 Mixed linear programming model

Mayyani *et al.* (2017) used a mixed integer programming for frequency determination of bus rapid transit (BRT) applied on Service System of Trans Mataram Metro Bus to Minimize the Operational Cost. The public transportation service in Mataram City is currently in a fairly apprehensive condition. Currently there are only two public transport routes operating in Mataram City whose service performance has been very much decreased. Referring to the Detail Engineering Design (DED) report of Trans Mataram Metro public transport interconnection, the average load factor of daily city transport operators is less than 46% and tends to be a collapse condition. However, when viewed from the mobile activities within the city today, Mataram as the capital of West Nusa Tenggara province (NTB) shows a high traffic flow than the surrounding area. People prefer to use private vehicles like as motorcycles or private cars because they can easily be owned and operated. This conditions for a large city typically require a reliable public transport service to accommodate the mobility needs of the population that also support the city's economic growth (Sufiani and Hadian, 2016)

According to Advani and Tiwari (2006), a well-planned bus system can provide high mobility to most populations with the minimum operational costs. One way to minimize operational costs is to optimize the determination of the operating bus frequency. The optimal bus frequency is achieved when all the demand of passengers is covered. Optimization problems in terms of minimizing or maximizing costs can be formed into linear functions with constraint functions in the form of linear equalities and/or linear inequalities (Silalahi and Dewi, 2014).

Several similar studies have been conducted, among others (Wihartiko *et al.*, 2017); (Making *et al.*, 2017); (Aman *et al.*, 2015); (Chien *et al.*, 2001); (Ekowicaksono, 2012) and (Ngamchai, 2003). The research generally has the objective function of minimizing costs and also route and frequency bus as its decision variable. This research aims to make mathematical model of BRT frequency determination, to test model with several test scenarios, and to apply the model to Trans Mataram Metro bus service system.

The general description of this problem is to determine the optimal bus frequency with demand of all passengers that is fulfilled so the minimum vehicle operational cost was obtained. The formulation of the bus corridor frequency determination problem can be modeled into the form of mixed integer linear programming (MILP). The objective function of this problem is to minimize the vehicle operational cost by the multiplication of the vehicle operational cost of each corridor with the decision variable generated by the model that is the bus frequency of each corridor. Mathematically, the objective function of the problem is:

$$min\left(\sum_{\forall i,j,k} BOK(i,j,k) x FK(i,j,k)\right) \quad (2.1)$$

$BOK =$ Vehicle operational cost in one trip from terminal i to terminal j

FK = Bus frequency from i to j on route k. Refer to Mayyani *et al.*, (2017) for further reading.

2.11 Genetic Algorithm

Genetic algorithms are a type of optimization algorithm, meaning they are used to find the optimal solution(s) to a given computational problem that maximizes or minimizes a particular function. Genetic algorithms represent one branch of the field of study called evolutionary computation (Kinnear, 1994), in that they imitate the biological processes of reproduction and natural selection to solve for the `fittest' solutions (Goldberg, 1989). Like in evolution, many of a genetic algorithms processes are random, however this optimization technique allows one to set the level of randomization and the level of control (Goldberg, 1989).

These algorithms are far more powerful and efficient than random search and exhaustive search algorithms (Kinnear, 1994), yet require no extra information about the given problem. This feature allows them to find solutions to problems that other optimization methods cannot handle due to a lack of continuity, derivatives, linearity, or other features.

2.11.1 Components, structures and terminologies

Since genetic algorithms are designed to simulate a biological process, much of the relevant terminology is borrowed from biology. However, the entities that this terminology refers to in genetic algorithms are much simpler than their biological counterparts (Mitchell, 1995). The basic components common to almost all genetic algorithms are:

i Population of Chromosomes

ii Fitness function for optimization

iii Selection of which chromosomes will reproduce

iv Crossover to produce next generation of chromosomes

v Random mutation of chromosomes in new generation

2.11.1 Fitness function

The fitness function is the function that the algorithm is trying to optimize (Mitchell, 1995). The word fitness" is taken from evolutionary theory. It is used here because the fitness function tests and quantities how fit' each potential solution is. The fitness function is one of the most pivotal parts of the algorithm, so it is discussed in more detail at the end of this section. The term chromosome refers to a numerical value or values that represent a candidate solution to the problem that the genetic algorithm is trying to solve (Mitchell, 1995). Each candidate solution is encoded as an array of parameter values, a process that is also found in other optimization algorithms (Haupt and Haupt, 1998). If a problem has $Npar$ dimensions, then typically each chromosome is encoded as an

$$Npar - element\ array\ chromosome\ = [p1;\ p2; \because:;\ pNpar\ ] \qquad (2.2)$$

Where, each pi is a particular value of the ith parameter (Haupt and Haupt, 1998). It is up to the creator of the genetic algorithm to devise how to translate the sample space of candidate solutions into chromosomes. One approach is to convert each parameter value into a bit string (sequence of 1's and 0's), then concatenate the parameters end-to-end like genes in a DNA strand to create the chromosomes (Mitchell, 1995). Historically, chromosomes were typically encoded this way, and it remains a suitable method for discrete solution spaces. Modern computers allow chromosomes to include permutations, real numbers, and many other objects; but for now we will focus on binary chromosomes.

A genetic algorithm begins with a randomly chosen assortment of chromosomes, which serves as the first generation (initial population). Then each chromosome in the population is evaluated by the fitness function to test how well it solves the problem at hand. Now the selection operator chooses some of the chromosomes for reproduction based on a probability distribution defined by the user. The fitter a chromosome is, the more likely it is to be selected. For example, if f is a non-negative fitness function, then the probability that chromosome C53 is chosen to reproduce might be

$$P(C53) = \left|\frac{f(C_{53})}{\sum_{i=1}^{N_{pop}} f(C_i)}\right| \tag{2.3}$$

The selection operator chooses chromosomes with replacement, so the same chromosome can be chosen more than once. The crossover operator resembles the biological crossing over and recombination of chromosomes in cell meiosis. This operator swaps a subsequence of two of the chosen chromosomes to create two offspring. For example, if the parent chromosomes $[11010111001000]\ and\ [01011101010010]$ are crossed over after the fourth bit, then $[01010111001000]\ and\ [11011101010010]$ will be their offspring.

The mutation operator randomly flips individual bits in the new chromosomes (turning a 0 into a 1 and vice versa). Typically mutation happens with a very low probability, such as 0.001. Some algorithms implement the mutation operator before the selection and crossover operators; this is a matter of preference. At first glance, the mutation operator may seem unnecessary. In fact, it plays an important role, even if it is secondary to those of selection and crossover (Goldberg, 1989). Selection and crossover maintain the genetic information of fitter chromosomes, but these chromosomes are only fitter relative to the current generation. This can cause the algorithm to converge too quickly and lose potentially useful genetic material (1's or 0's at particular locations)" (Goldberg, 1989).

In other words, the algorithm can get stuck at a local optimum before finding the global optimum (Haupt and Haupt, 2004). The mutation operator helps protect against this problem by maintaining diversity in the population, but it can also make the algorithm converge more slowly. Typically the selection, crossover, and mutation process continues until the number of offspring is the same as the initial population, so that the second generation is composed entirely of new offspring and the first generation is completely replaced. However, some algorithms let highly fit members of the first generation survive into the second generation. Now the second generation is tested by the fitness function, and the cycle repeats. It is a common practice to record the chromosome with highest fitness (along with its fitness value) from each generation, or the best-so-far chromosome (Koza, 1994).

Genetic algorithms are iterated until the fitness value of the best-so-far" chromosome stabilizes and does not change for many generations. This means the algorithm has converted to a solution(s). The whole process of iterations is called a run. At the end of each run there is usually at least one chromosome that is a highly fit solution to the original problem.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

For the purpose of this research, the following materials were used:

1 GPS: Hand held GPS was used to generate the coordinates of all the bus stops and the two terminals and the distance apart. It also record the travel times for different bus capacity types.

2 CCTV Cameras: Four (4) CCTV cameras were used with two each at Gidan-kwano and Bosso campuses as shown together with other materials in Plate II.

3 Four (4) Buses: Different bus capacities were available at the park. The capacities are 18, 30, 35, 43, 54 and 60 seats capacities. But only 18, 35 and 60 capacities were used for the design.

Plate II: Equipment/materials used

3.1.1 Study Area

Transport vehicle plying the study corridor includes local school Buses, private cars and individual owned commercial vehicles. The Bosso – Gidan-kwano is a stretch of 19.55km with an average travel time of 38 minutes as shown in Figure 3.1. There are five (5) major intersections along the route with rotary or round about at kpakungu.

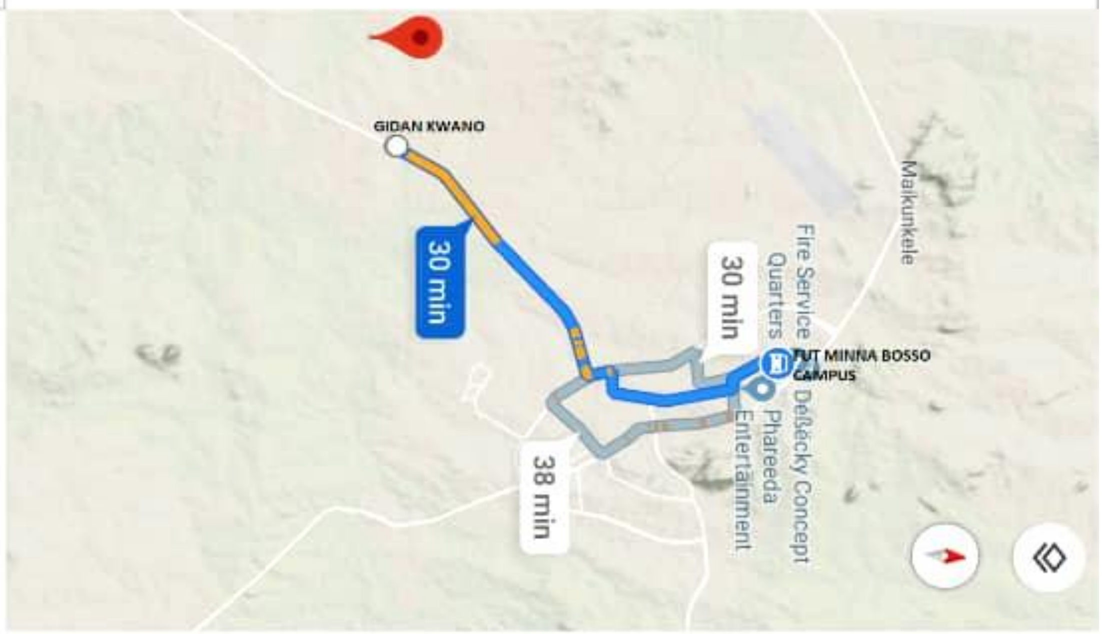


Figure 3.1: Route map connecting Bosso-GidanKwano campus

Using GPS, the various intersections along the corridor were breakdown in terms of distances apart and their corresponding travel time as presented in Figure 3.2 using ArcGIS 10.3.

A-B Gidan Kwano Bus Park to School Gate, 1.4km	2 minutes
B-C School Gate to Kpakungu, 10km	23minutes
C-D Kpakungu to Murtala Nyako Road, 6km	9minutes
D-E MurtalaNyako Road to Okada Road, 1.4km	2minutes
E-F Okada Road to Abu Turab Primary School, 0.35km	1minute

F-G Abu Turab Primary School to Bosso Campus Bus Park 0.4km 1minute

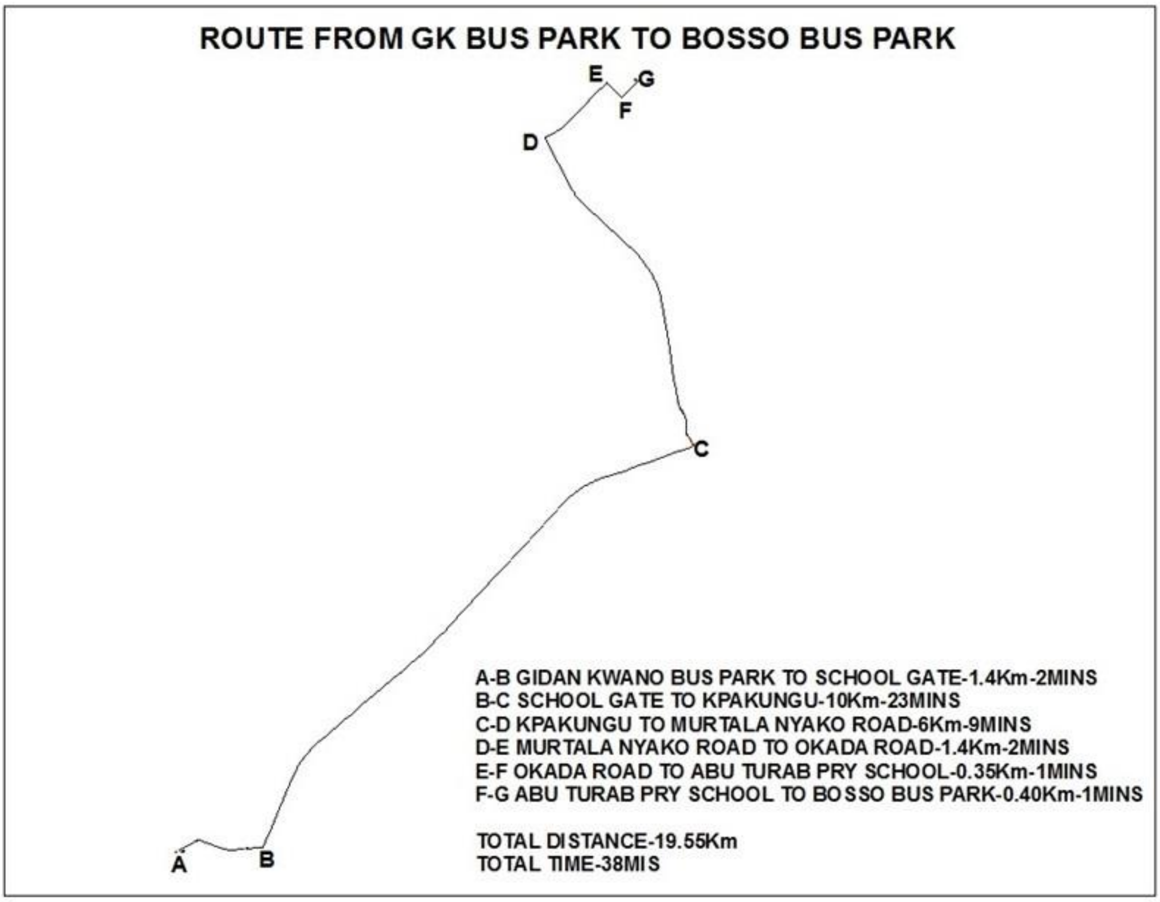


Figure 3.2: Route Map using ArcGis 10.3

3.2 Methods

In order to achieve the set out objectives, the following methods were adopted.

i Fleet characteristics

ii Travel demand data collection

iii Travel time determination

iv Excel draft time table

v Linear programming model

vi Genetic algorithm

3.3 Fleet Characteristics

The Bus system coordinator was interviewed to obtain detailed information about the passenger behaviors in terms of travel demand. It was revealed that the travel demand pattern vary from exam period (peak) and normal lecture period (off-peak). The cost of each driver per month, day and trips, the fuel and maintenance cost per trip per liters were noted and the revenue per passenger per trip was also recorded. This information's were expressed in Naira and represented in the results.

There are different types of buses available by the University Bus System Management. External Buses were allowed during peak period in transporting students between the campuses. The Maintenance costs of the bus types (Plate III) were expressed in terms of liters of oil consumed per trip. The fuel cost was also expressed in terms of petrol/diesel consumption per trip**.**

3.4 Travel Demand Data Collection

The travel demand data was collected using two methods. These methods include:

3.4.1 Manual data collection

The numbers of passengers and Bus arrival and departure time at the Bus Parks were recorded from 6:00a.m to 6:00p.m at 15minutes interval per day for peak (Examination) and off-peak (lecture) period. The buses types and their capacity were also recorded. These data were used to calibrate the CCTV video data collected as described below. Plate III shows a Bus loading passengers and other passengers waiting on queue for the next Bus.

Plate III: Students Boarding Bus at GK and Bosso Campus Bus

3.4.2 CCTV data collection

Two numbers of CCTV cameras each were installed at strategic positions of bus parks in both campuses. The numbers of passengers boarding the buses including those standing were recorded. The number of students and buses arriving and departing from the bus parks were captured by different cameras all at 24 hours (daily) and only 12 hours data were used for the research (6:00am to 6:00pm). The videos from CCTV were exported (Plate IV) to the external hard disk (HD) for both campuses and analyzed at fifteen (15) minutes intervals by observation methods. The daily, weekly and 2-week travel demand data for both campuses in Examination and lecture seasons were presented in the Appendix A and the summary were computed and presented in the results for peak and off peak period and for both campuses.

Plate IV: Exporting CCTV Videos at Bosso and GK Campuses Bus Parks.

3.5 Travel time determination

As in the case of travel demand data collection, travel time data were collected using the following methods:

3.5.1 Manual method: Two observers were stationed at both campuses to record the departure and arrival time of different bus types. The algebraic difference of the buses between individual bus arrival and departure time were recorded as the travel time. This was repeated to obtain the average.

3.5.2 GPS: A global positioning system was used to measure the time taken by a bus to traverse between two campuses while the observer was also inside the bus with the GPS. The time taken was represented as the travel time considering all delays along the road.

3.5.3 CCTV: The travel time of the various bus types were measured from the CCTV record data. This was obtained by the algebraic sum and/or difference of arrival and departure time as recoded from the CCTV. The average of these travel time were presented in the results and are used to evaluate the linear programming model (LP) for the Bus Time Table development.

Plate V: Bus Types available at FUTMINNA Bus Park

3.6 MS Excel Bus Time Table Development

The Bus Time Table was drafted using MS Excel for the peak and off-peak period at both campuses considering the constraints such as the travel time and demand. The total operational cost which includes; Maintenance cost, fuel cost, driver remunerations, waiting time compensation represented as the penalty cost in Naira were also computed. The bus revenue paid per passenger was also computed. The optimum run result was presented in the Appendix II. From these results, the drafted time table was used as the initial population for the optimization using genetic algorithm.

3.7 Linear Programming Model and Constraints

The objective function was to optimize a $Z(x)$ function. The function is a multiple of two parameters which are; the total net profit/loss of a bus with its departure frequency. The function was maximize but subject to the following constraints.

i Ensures the bus capacities of buses A, B and C are not exceeded.

ii Ensures that the difference between two successive departures times of bus A, B and C is not less than 90minutes, 85 minutes and 80 minutes respectively.

iii Ensures that for every 15 minutes, a bus departs.

These constraints and the LP model were mathematically represented in equations 4.1 to 4.2 in chapter four (4)

3.8 Genetic Algorithm

Genetic algorithm codes written were run on a Matlab software to generate the required optimal bus time table with the following inputs and output.

3.8.1 G.A input

The major inputs to the algorithms are basically in the following categories;

3.8.1.1 Bmatrix

The component of Bmatrix includes the different size of vehicles which are 60, 35 and 18 sitter capacities with a varying number depending on the travel demand and the bus time table required. Other variables includes the maximum journey time for different bus sizes considering all possible delays, revenue per passenger and operational cost consisting of fuel cost and driver remuneration.

3.8.1.2 Travel demand

The maximum travel demands for the two campuses at different periods (Examination and Lecture) were also computed into the algorithm as part of the variable. For every maximum travel demand at a given exam or lecture period, the optimal time table was generated.

3.8.1.3 Numbers of chromosomes, Iterations and Extermination Criterion

The number of chromosomes representing the population sizes or the search agents varies from 200 to 1000 at an interval of 200, while the iteration was fixed at 1000 and the chosen extermination criterion was the iteration with maximum best cost and minimum violations. The programme was run 20 times for every chromosome until the best cost was achieved.

3.8.2 G.A output

The outputs from the GA were presented in the following categories;

3.8.2.1 Best solution

i) Position Matrix: This is an nxm matrix where n and m represents respectively the number of buses and the departure time. In this case, there are 38 buses in all with 49 departure times from 6:00am to 6:00pm at every 15 minute interval.

ii) Cost**:** This is an integer representing the maximum cost at maximum iterations of 1000

iii) Violations**:** This is a vector 1xn, where n represents the number of departure time. It is in binary where 1 represents scheduled violations and 0 for no violations.

3.8.2.2 Best cost

This is also a vector represented as number of iterations with the corresponding cost as; 1000x1 (double). The best cost was generated at every number of chromosomes trials until the optimum chromosome was obtained.

3.8.2.3 Number of violations

This is an integer generated at every chromosome which is also a determinant for the choice of optimal chromosomes with least violations. The higher the value of violation generated, the smaller the probability of selecting the corresponding chromosomes.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Fleet Characteristics

Table 4.1 shows the fleet characteristics for buses available at the university bus park. 18 sitting capacity buses currently in use is 15 being the highest number though with little income generation. However, it has the maximum trips of 3 for only to and not fro. This total number is not limited to only the bus owns by the university but also those of the private ownership. Currently, the two (2) numbers of 30 sitting capacity buses are not in good conditions as such, they are not in use. Only two (2) numbers each of 43, 54 and 60 sitting capacities are available currently though with different amount of revenue generation and also with 2 average daily trips.

Most times, due to inadequate and poor planning of the bus system, passengers usually board buses especially 43, 54 and 60 even when full to their capacity, hence they stand inside the bus while moving from one terminal to another. This is unhealthy to the passengers and discomfort to the bus itself.

Table 4.1:Fleet Characteristics

Type of Bus	Maximum Allowable Standee	Number Available	Revenue/run (₦)	Average Daily Trips
18	N.A	15	1800	3
30	N.A	2	3000	N.A
35	N.A	3	3500	2
43	20	2	4300	2
54	25	2	5400	2
60	10	2	6000	2

As part of the parameters needed as input for the GA, Table 4.2 shows the information on Bus associated travel demand cost collected from the Coordinator by interview method.

Table 4.2: Bus Associated Travel Demand Cost

Type of Bus	Maximum Allowable Standee	Revenue/run (₦)	Fuel Cost/run (₦)	Driver Cost (₦)	Maintenance Cost (₦)
18	N.A	1800	330.00	100.00	52.27
30	N.A	3500	660.00	100.00	65.33
35	N.A	3500	660.00	100.00	65.33
43	20	6000	1237.50	100.00	326.67
54	25	6000	1237.50	100.00	326.67
60	10	6000	1237.50	100.00	326.67

The revenue representing the amount paid per passenger is a flat rate of ₦100 for all vehicle types owned by the university and ₦150 for outside buses. The variation on fuel cost for the buses are also presented, 18 sitters are the least (₦330) followed by 30 and 35 sitters which are the same amount (₦660) and the highest fuel cost of (₦1237.50) which represent for 43, 54 and 60 sitters. The drivers cost is a flat rate of (₦100) per trips obtained from the driver monthly (25-day) income considering a maximum of three trips in a day. The maintenance cost for different sitters are shown in the last column.

To obtain the optimum bus time table, 18 (Small), 35 (Medium) and 60 (Large) sitter buses were chosen taking into consideration the information provided on Table 4.1

4.2 Buses Travel Time Determination

The travel time between the two campuses by different bus capacities for peak and off peak period were measured by using GPS and arrival and departure time capture from the CCTV as presented in Table 4.3 (a and b). For each of the method, the maximum travel time for each of the bus capacities were determined as presented in Table 4.3(c) and the highest among the two was chosen for the time table design. Only the travel time for 18, 35 and 60 capacities buses were used.

Table 4.3 (a): GPS Travel Time

Periods	Time	Bus Travel Time Average (minutes)					
		18	**30**	**35**	**43**	**54**	**60**
Lecture Periods	6:00-10:00	44.15	Nil	46.27	48	52	54.32
	10:00-1:00	40.55	Nil	41.55	44.5	47.67	48.08
	1:00-4:00	39.20	Nil	40.3	42.2	44.45	45.36
	4:00-6:00	3.10	Nil	44.45	49	51.69	49.39
Exam Period	6:00-10:00	44.29	Nil	46	47.5	51.65	54.45
	10:00-1:00	41.1	Nil	42.1	43.36	46.25	47.68
	1:00-4:00	40.1	Nil	41.2	42	44	44.98
	4:00-6:00	44.2	Nil	44.35	51.1	51.75	49.79

Table 4.3 (b): CCTV Travel Time

Periods	Time	Bus Travel Time Average (minutes)					
		18	**30**	**35**	**43**	**54**	**60**
Lecture Periods	6:00-10:0 0	35	Nil	48	43	47	44
	10:00-1:00	36	Nil	40	38	35	49
	1:00-4:00	38	Nil	42	40	57	47
	4:00-6:00	40	Nil	50	49	41	57
Exam Period	6:00-10:00	36	Nil	48	44	46	43
	10:00-1:00	34	Nil	39	39	38	47
	1:00-4:00	38	Nil	40	40	50	48
	4:00-6:00	39	Nil	48	48	40	56

Table 4.3(c): Maximum Design Travel Time

Bus Capacity	Range of Travel time	Maximum Travel Time
18	34-40mins	40mins
35	39-50mins	50mins
60	43-60mins	60mins

4.3 Travel Demand

The row data captured from the CCTV which constitute the number of students arriving the park, number of students on queue number of passengers in a loading and departing bus all at every interval of 15-minuteare presented in the appendix. The travel demands are calculated from the row data.

4.3.1 Bosso exam period travel demand

At 6:00am on Monday, the number of student demanding for travel at bosso to GK was about 268 which is almost the same as that of Tuesday at the same time. The demand fall by 6:30am and then rises again to the peak value of 375 at 6:45am. This high demand at the early time of the day was as a result of students trying to meet up with the 8:00am scheduled examinations. The demand increment from 8:30am to 10:00am was also observed but less compare to the first batch departure. These students were trying to meet up with their examination scheduled for 11:00am.

The peak demand for Tuesday was between 8:30am to 9:45am. The peak demand on Saturday was between 10:45am to 12:15pm, this is an indication that, most examination scheduled on Saturday was likely 1:00pm to 2:00pm. The Wednesday peak demand was between around 10:00am to 12:30pm. Generally, significant number of demand for all days ended at 1:45pm who might likely be scheduled for 3:00pm examination. The relationship between the travel demands with time per day for week1 and 2 were presented in Figure 4.1(a) and (b). Table A1 (a) and (b) in Appendix A present the travel demand for exam period at Bosso campus for week 1 and 2.

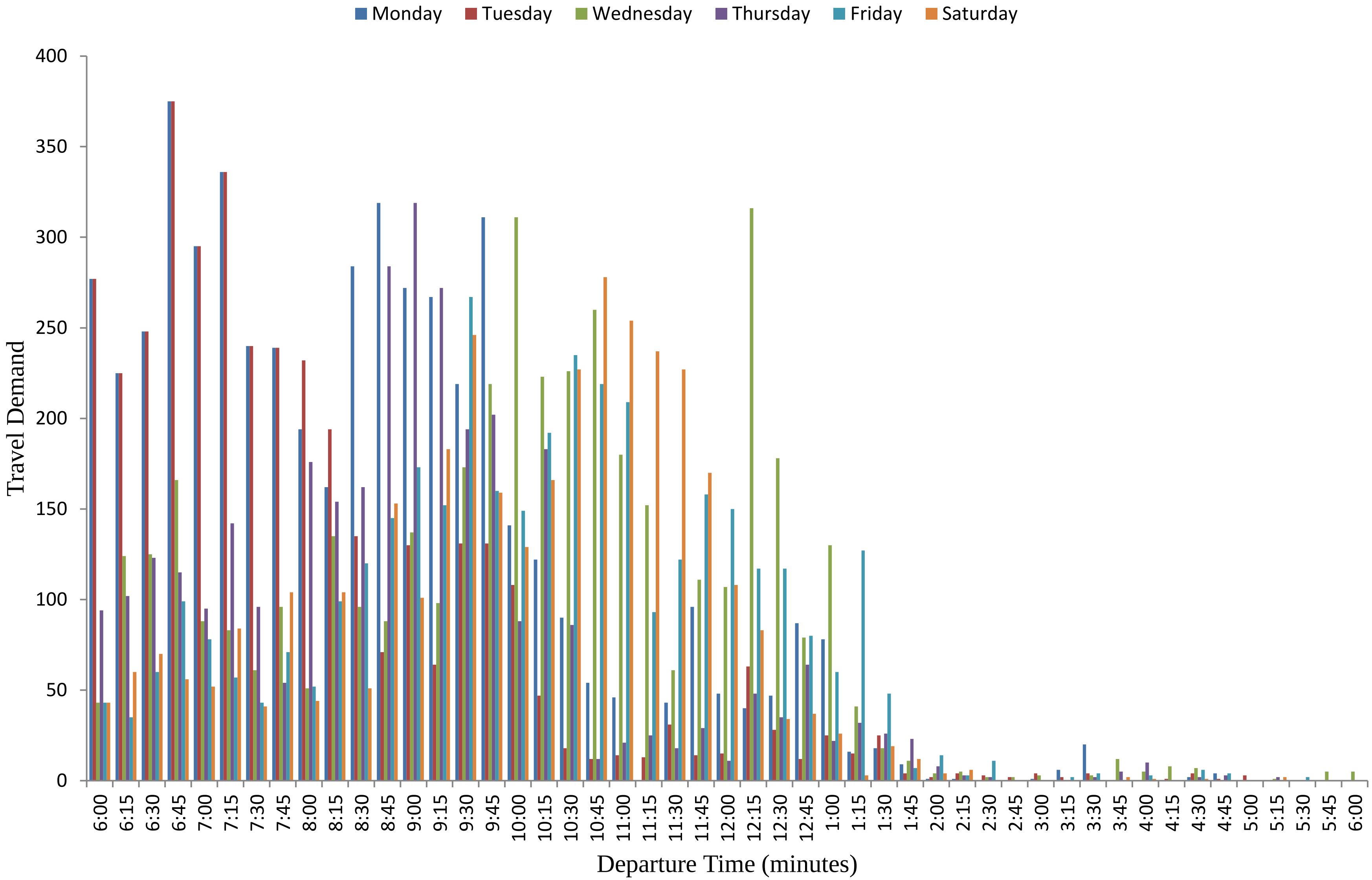


Figure 4.1(a): Week 1 Bosso Exam Period Demand

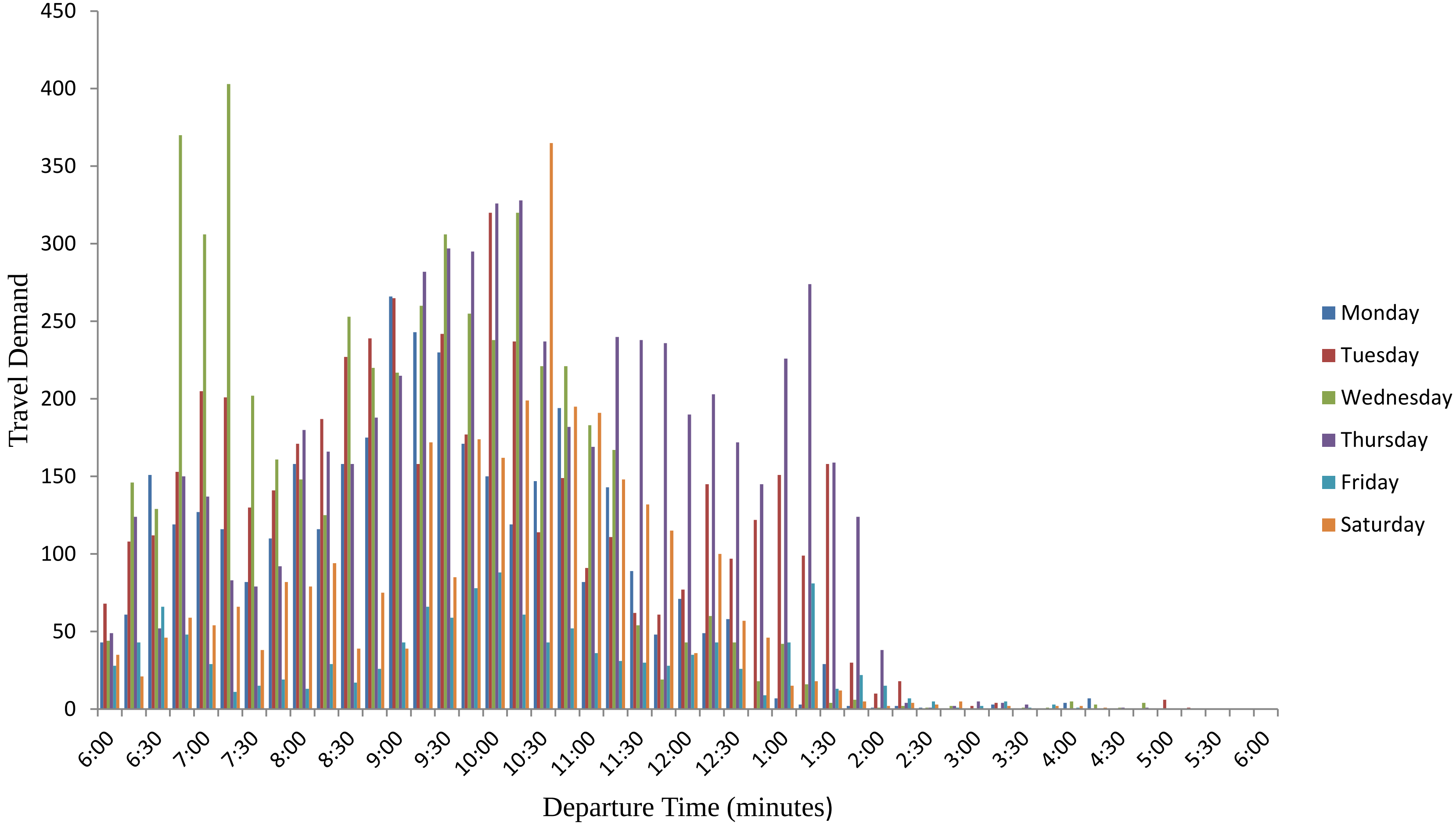


Figure 4.1(b): Week 2 Bosso Exam Period Travel Demand

4.3 GK exam period travel demand

Between 6:00am to about 9:45am, there was very little or no demand for travel from GK back to Bosso campus during examination period. This resulted from the fact that most students to return were yet to finish the 8:00am scheduled examination. Another reason might be due to the fact that, there was high travel time especially in case of large bus sizes that might be dispatch to convey the first batch of students, these buses usually do not returned back as soon as possible until it has reasonable number to convey in order to reduce the loss. Unlike that of Bosso campus, a different trend was observed as the peak demand for all days during examination period were towards the last hour, which is from 5:00pm to 6:00pm.

For all days, the demand was found to increases from 11:00am to 12:30pm which usually is the period of finishing the first batch examination. However, on Tuesday at about 12:15pm, a unique number of demands, about 238 were observed around 12:15pm. At 6:00pm on Thursday, more than 400 passengers were found demanding to travel to Bosso campus, while the least number of demand at the same time was found on Tuesday. Table A2 (a) and (b) in Appendix A respectively presents the GK campus travel demand for week 1 and 2 at peak/exam period. Which were plotted against time as shown in Figure 4.2(a) and (b).

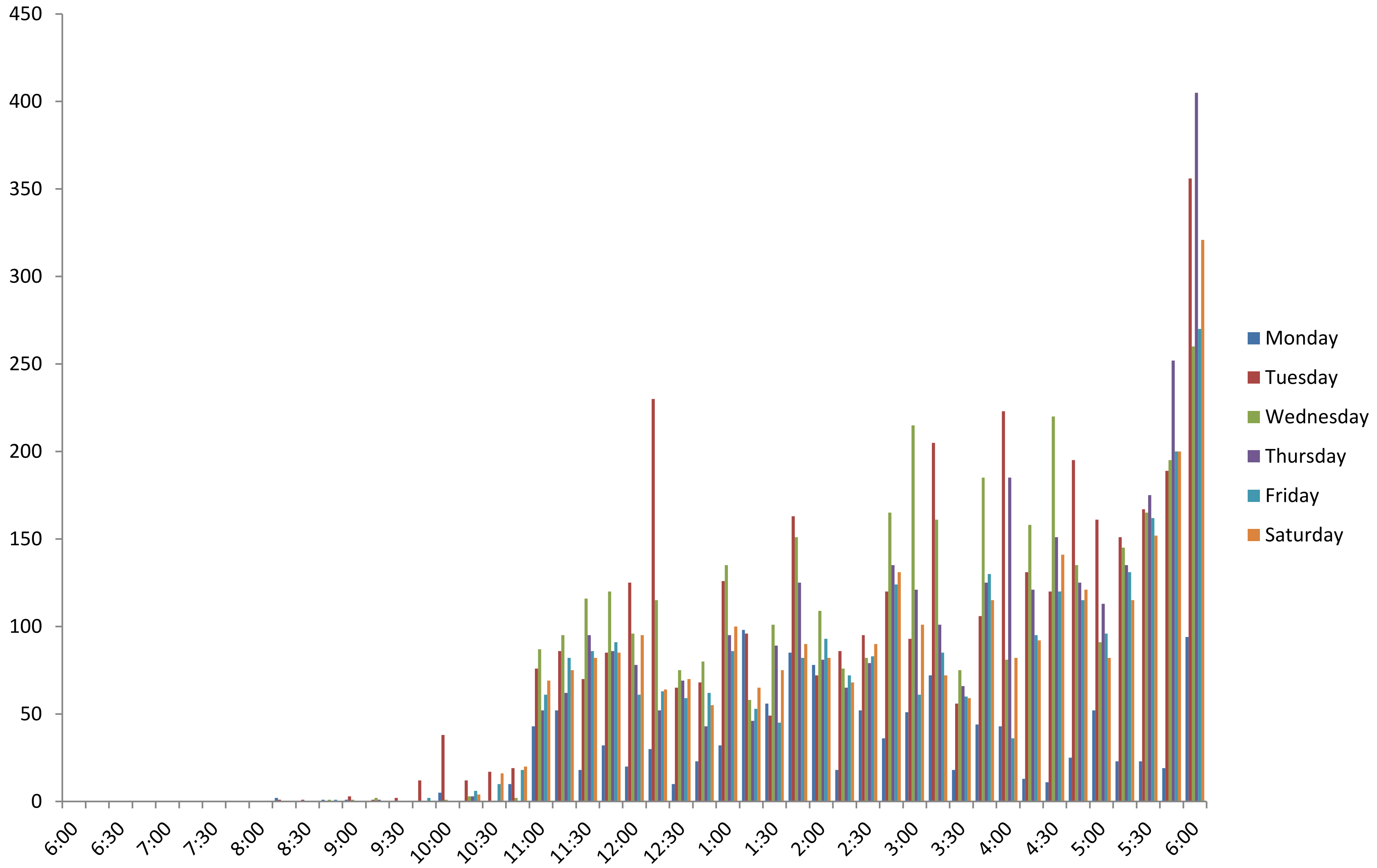


Figure 4.2(a): Week 1 GK Exam period travel demand

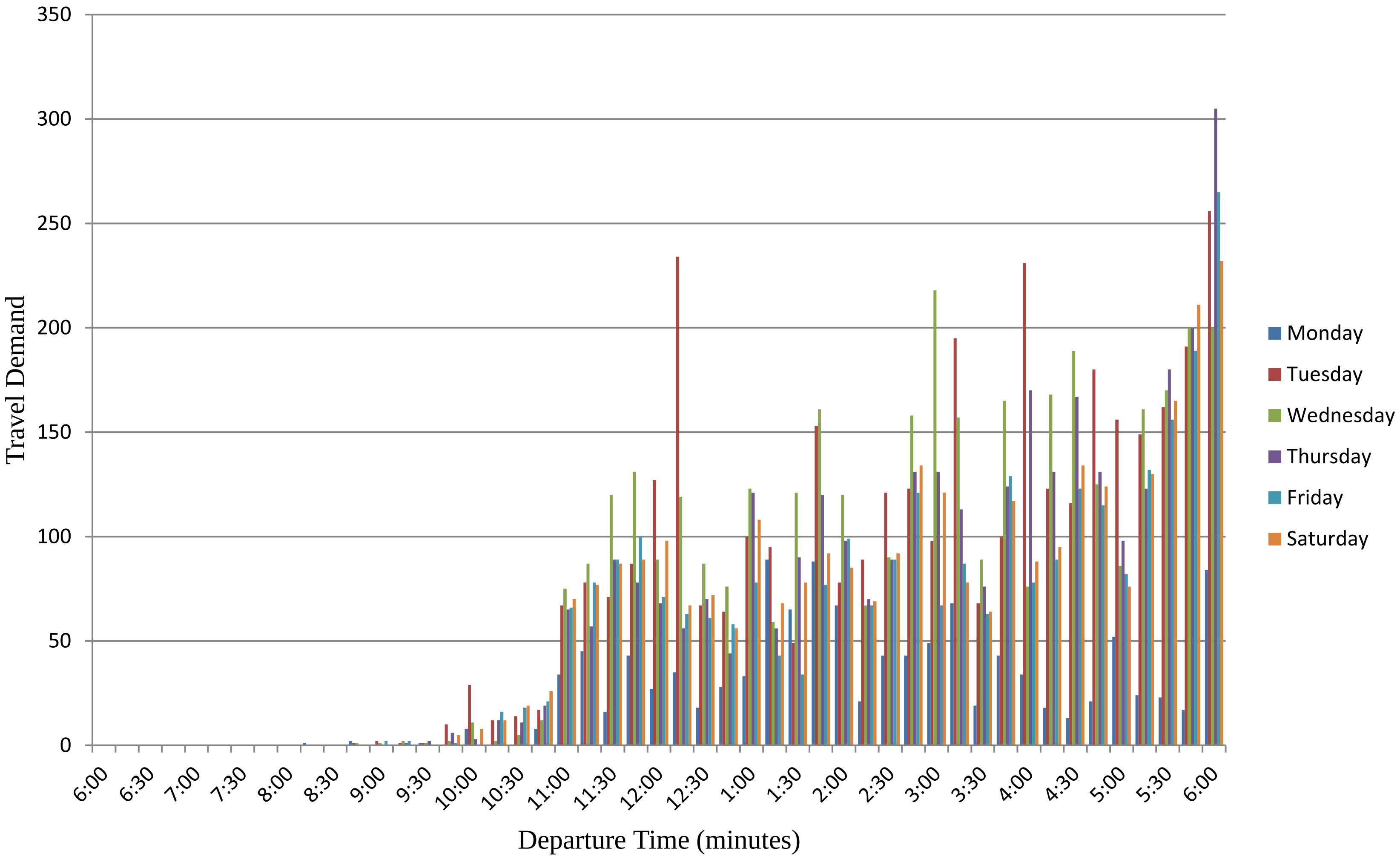


Figure 4.2(b): Week 2 GK Exam period travel demand

4.3.3 Bosso lecture period travel demand

In the first week at Bosso campus, the demand during lecture period was generally found to be lower compare to that of exam season. The maximum average demand at all 15 minutes interval from 6:00am to 6:00pm was about 85 passengers. The demand raise from 7:15am to 8:00-8:30am before falling and subsequently increases again until at 11:00am on Monday with great demand up to about 145 passengers. At 11:45am, there was clearly low demand as most students were already at GK for lectures.

A stochastic demand was achieved on Tuesday, Wednesday and Saturday showing reasonable demand but at late hours of around 5:30pm. Similar trend was observed in the second week at Bosso Campus. The travel demand pattern for the lecture period at Bosso for both week 1 and 2 were respectively presented in Table A3 (a) and (b) of the Appendix A. These relationships between the two weeks demands with time are presented in Figure 4.3(a) and (b).

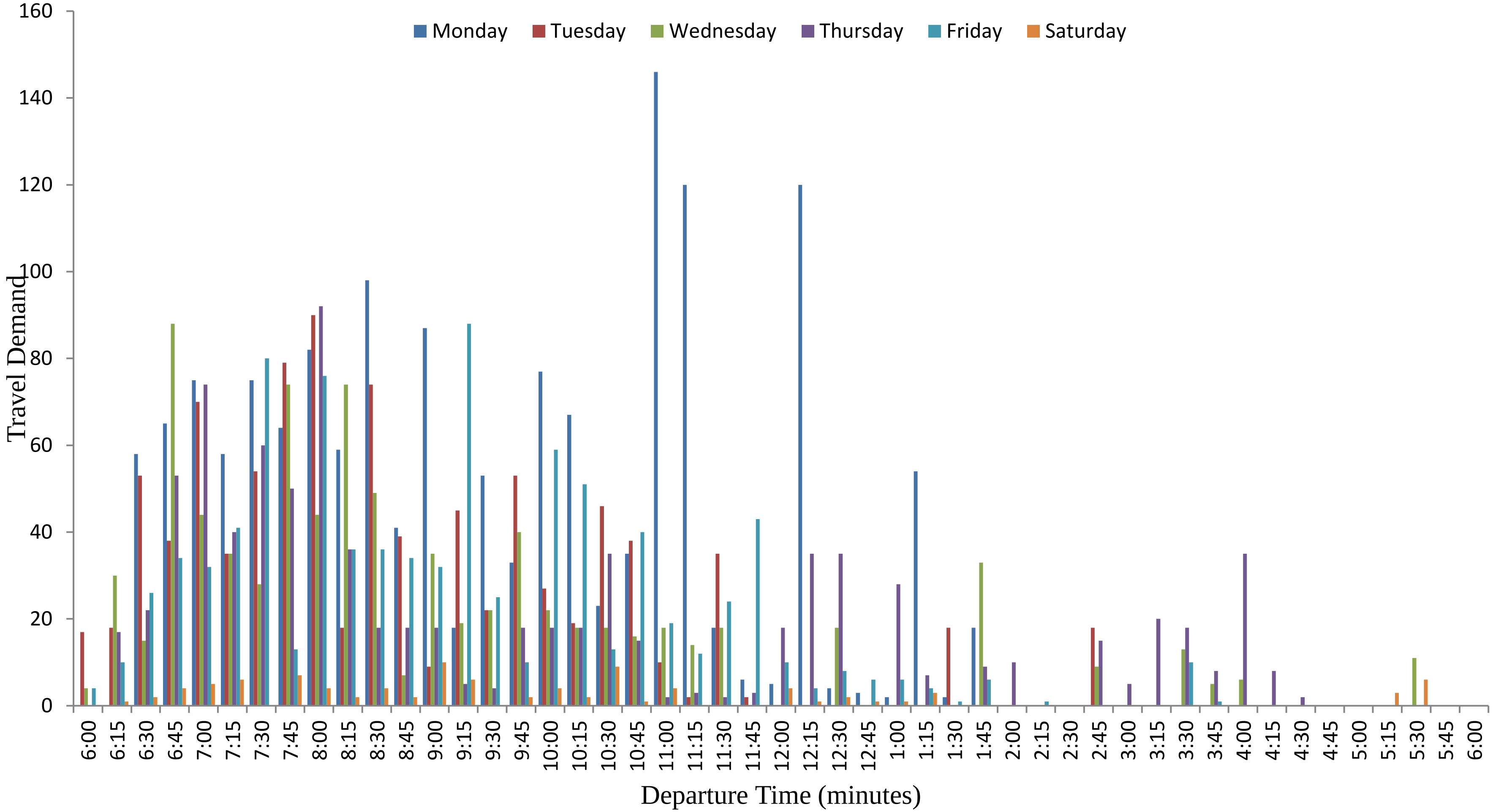


Figure 4.3(a): Week 1 Bosso Lecture Period Travel Demand

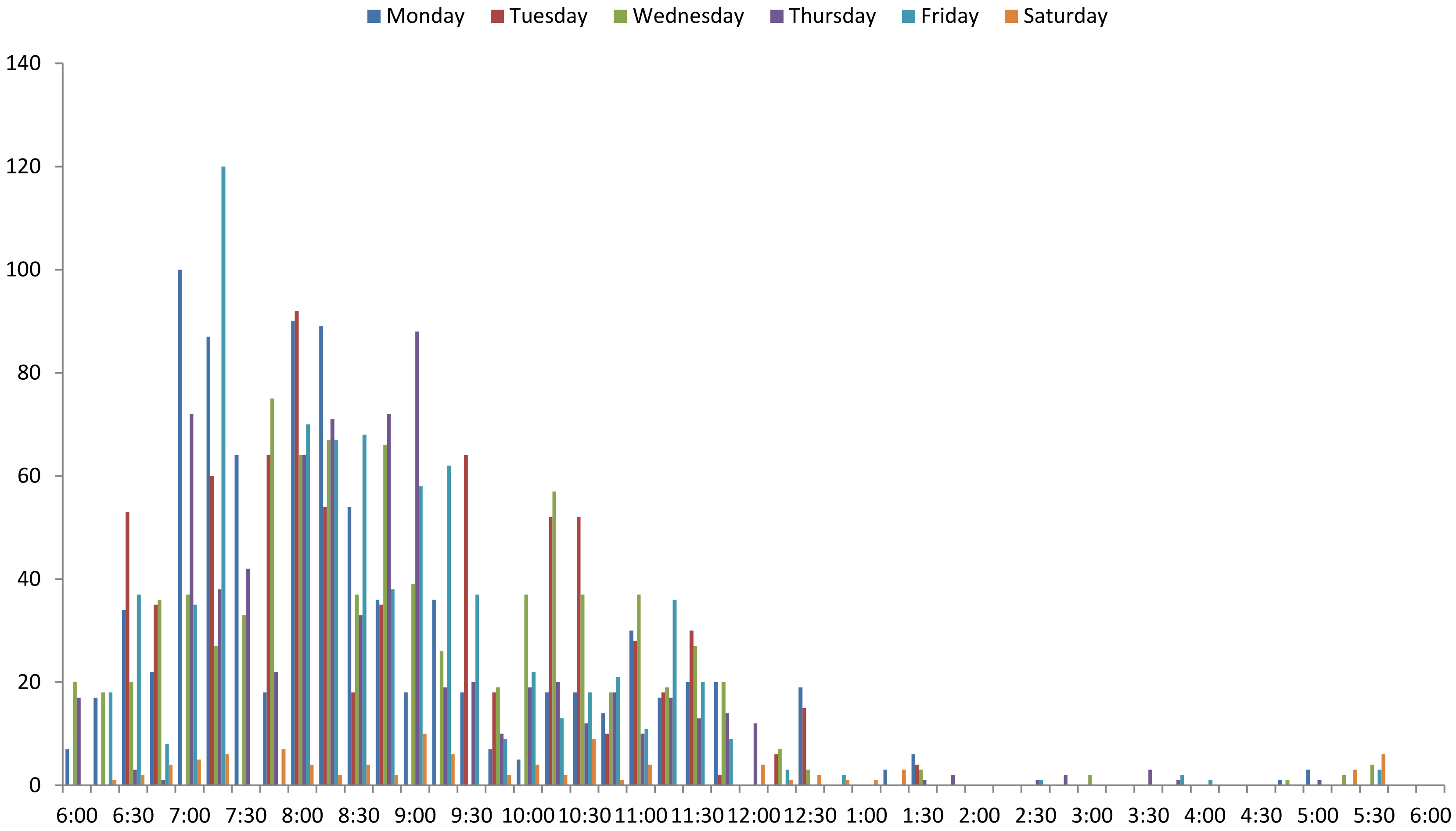


Figure 4.3(b): Week 2 Bosso Lecture Period Travel Demand

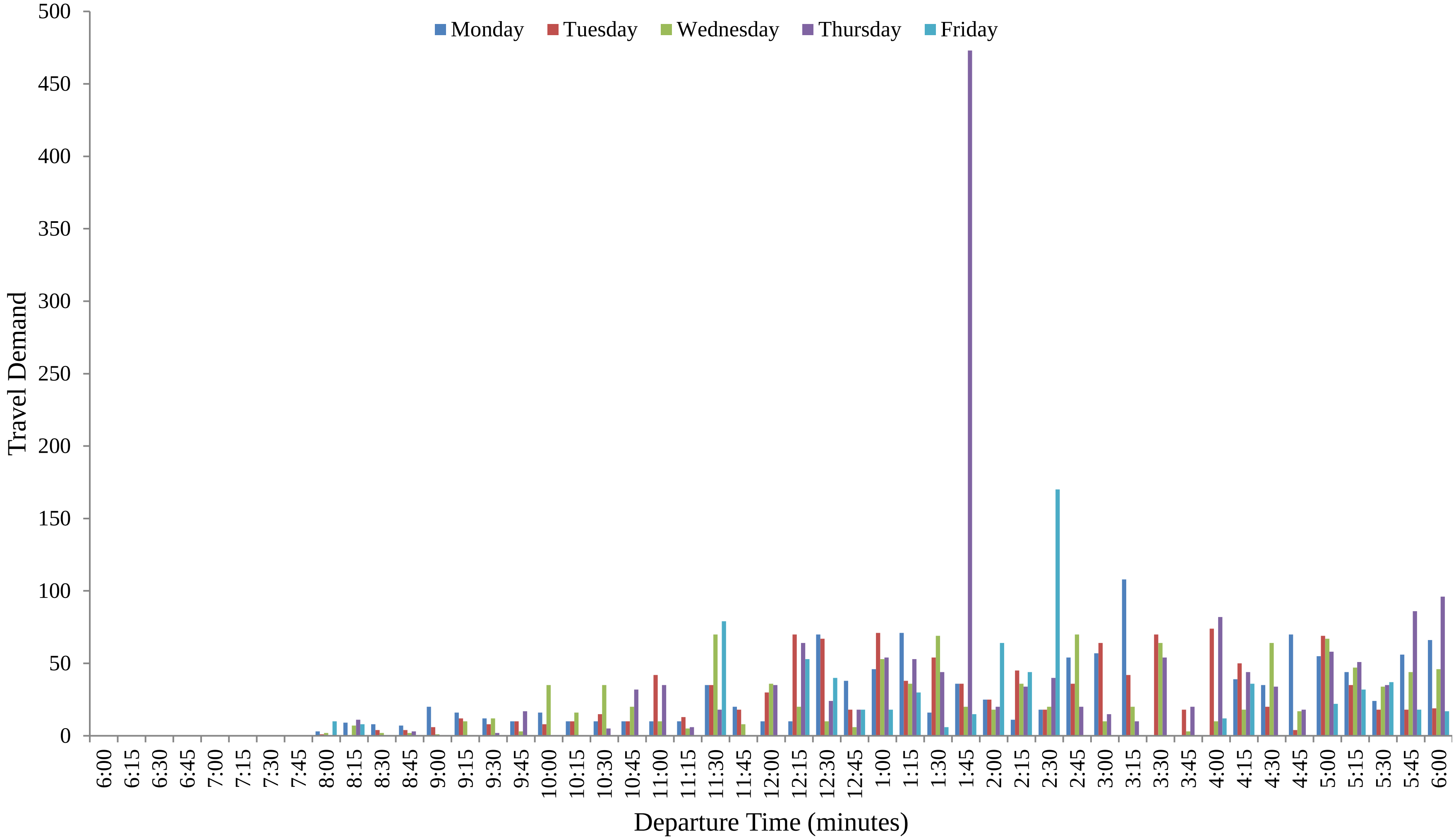


Figure 4.4(a): Week 1 GK Lecture Period Travel Demand

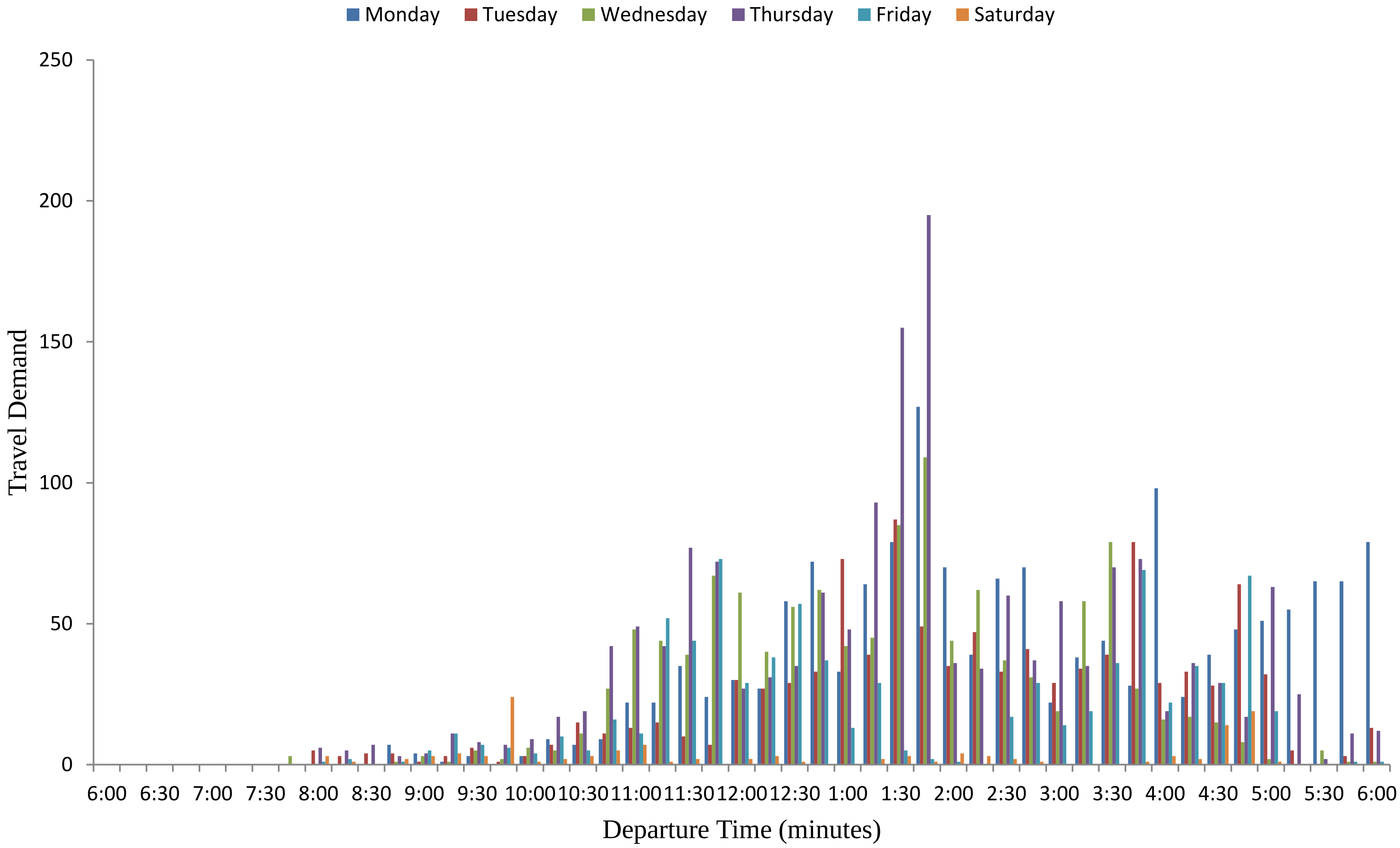


Figure 4.4(b): Week 2 GK Lecture Period Travel Demand

4.3.4 GK lecture period travel demand

At the first week, initially there was no demand from GK to Bosso until around 8:30am for all days and began to increases to about 180 passengers at 1:45pm. This may be due to the laboratory practical arranged for the students. Another pattern starts from 2:00pm to 4:00pm. The same scenario was observed in week two (2). The travel demand for the lecture periods at GK for week 1 and 2 were respectively presented in Table A4(a) and (b) and illustrated in Figure 4.6(a) and (b).

From the Figure, it can be revealed that. There was no demand until around 8:15 am for the two weeks period and peak up at about 1:00 pm with as high as 470 numbers of passengers waiting for the bus. It was discovered that this highest value of demand was as a result of the laboratory practical taking place for student at Bosso campus. For this reason, all the passengers must be cleared by the scheduled buses with time. Thursday was the day with the maximum demands for the two weeks at GK campus.

4.3.5 Maximum travel demand

The maximum travel demand for both campuses during lecture and examination periods were computed as the maximum of daily demands for all 15 minutes period from 6:00am to 6:00pm.
This was applied for week 1 and week 2 at each campus as presented in Table 4.5. The variations of demand in relation to time were graphically presented.

Figure 4.5(a) shows the maximum demand variations with time during examination season at Bosso Campus. The demand was found to be high at the early minute that is at the early 15 minutes interval. After 7:00am, when demand was more than 400 passengers, this value decreases down and raised after 8:00am before finally coming down to very low or no demand at 4:00pm to 6:00pm

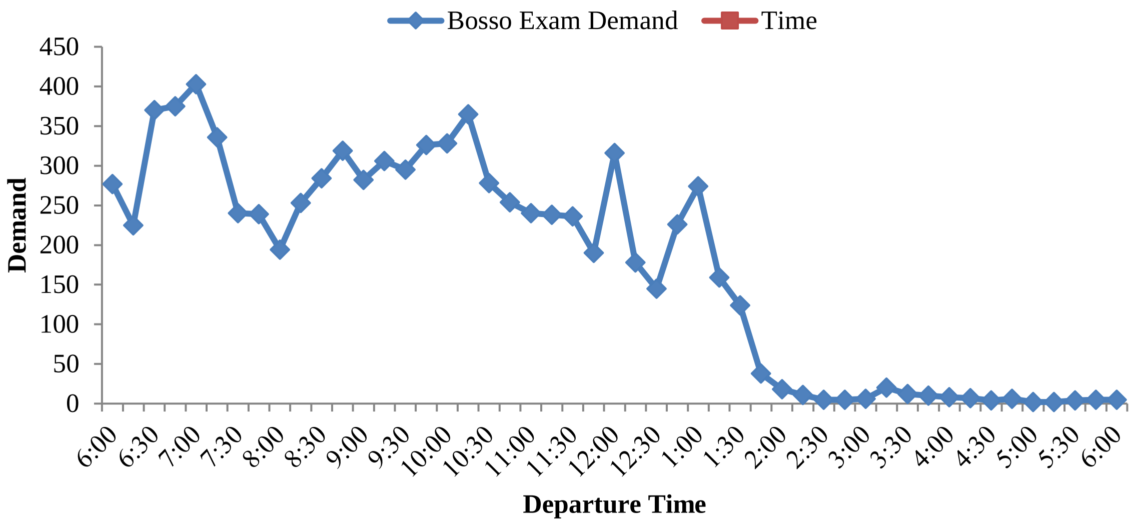


Figure 4.5(a): Maximum Bosso Exam Period Demand

Also, Figure 4.5(b) shows the maximum demand variations with time during examination season at Bosso Campus. In this case, the reverse is the case of Bosso Campus demand at early minute of the day. There were no demands from 6:00am till 9:15am until at about 10:30am where the demand value raises sinusoidal until it was about 400 passengers at GK Campus by 6:00pm.

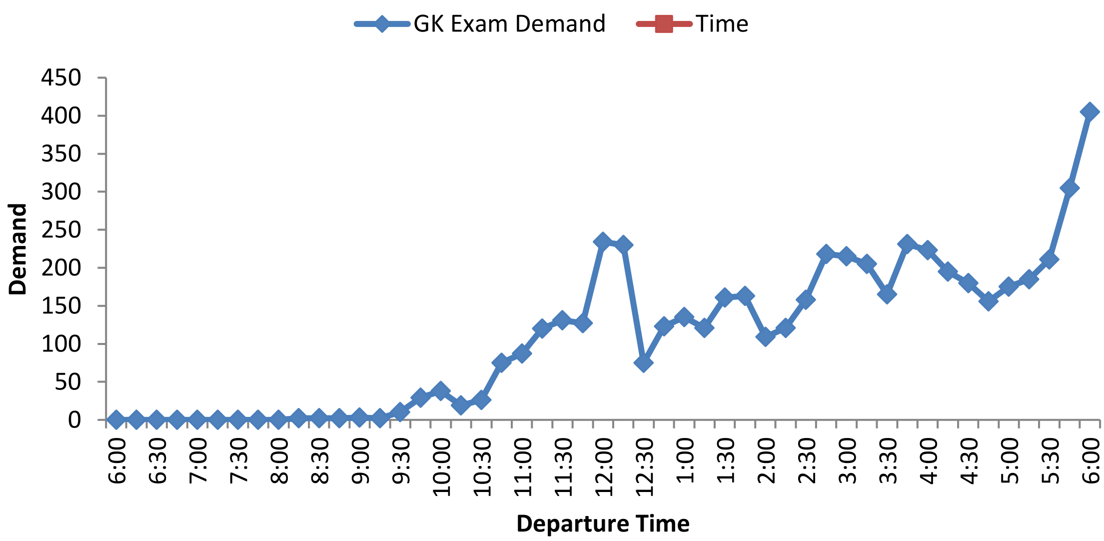


Figure 4.5(b): Maximum GK Exam Period Demand

During lecture season, the demand raises from 6:00am to about 121 passengers at 7:15am shown in Figure 4.5(c) which shows the maximum demand variations with time during maximum lecture season at Bosso Campus. The peak demand was achieved at about 11:00am and reduces down to lower or no demand at 5:45pm.

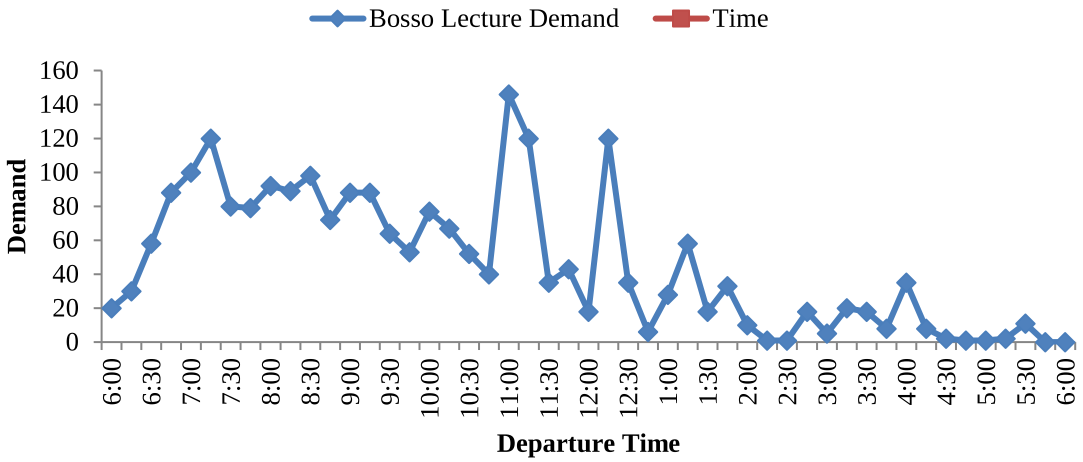


Figure 4.5(c): Maximum Bosso Lecture Period Demand

Figure 4.5(d) presents the graph of variation in maximum travel demand for GK lecture period. At the early minutes from 6:00am to amount 9:30am there were no travel demand. This may also be due to the fact that, the origin was at Bosso. This demand continued increasing gradually until a peak maximum demand of about 425 passengers was achieved at 1:45pm before further brought down to very few demands.

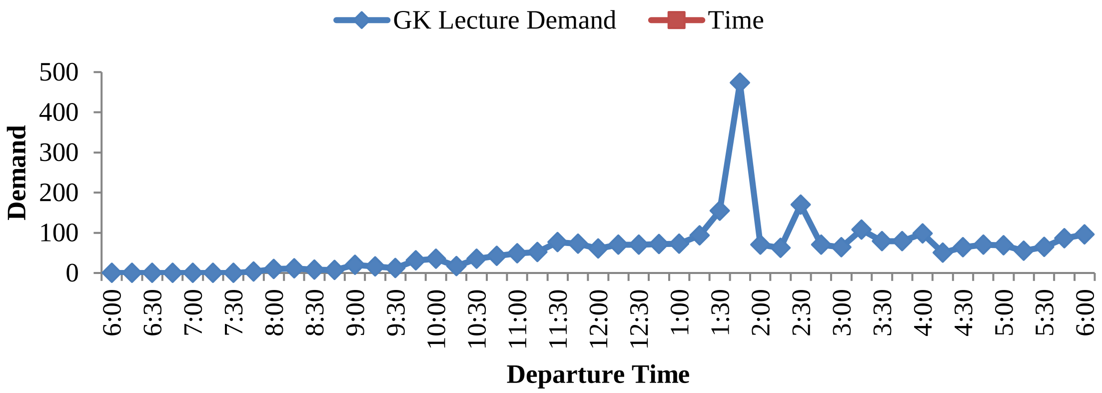


Figure 4.5(d): Maximum GK Lecture Period Demand

With these maximum demands, four different MS Excel bus Time table and scheduling were drafted. The maximum demands were used for the bus Time Table design to avoid delay of passenger and to ensure passengers are served timely and appropriately.

4.4 MS Excel Draft Bus Time Table

The buses Time Table for both campuses during exam and lecture period were presented in the Appendix C. The MS word Excel Time Table and schedule results were used to predict the minimum and maximum number of the various bus types which is required for producing GA based bus time table and scheduled.

Four different bus time table as presented in Appendix C were produced with two (2) each for Bosso and GK campus for both exam and lecture period. From the Time Table, different number of bus capacities released at every 15 minutes depends largely on the available demand at the terminal at that particular time. The next column represents the line capacity obtained as the sum of the products of the vehicle capacity with its total number released at that every 15-minute. Total penalty is the next column obtained as the product of the net value of line capacity and travel demand (number of passengers delayed) by three naira (₦3.00). That is, three naira will be given to each passenger for missing the targeted departed bus after 15 minutes. Total revenue is the product of line capacity with per passenger flat rate fare of (₦100.00).

Operational cost comprises of the maintenance cost, fuel and drivers remunerations. The driver cost per 15 minutes is obtained as the product of number of buses departing by a unit of ₦100.00 with the assumption that, the maximum number of trips per driver is three. Each of the bus capacities (18, 35 and 60) have their respective monthly maintenance which is expressed in per trip. The per trip bus maintenance cost is multiply by the number of buses released for departing. The fuel cost is also expressed in per trip for different bus sizes. The total operational cost is deducted from the total revenue to obtain the net income value. The products of the net income with the frequency are calculated and sum up as conformed to the linear programming model:

$$Maximize; Z(x) = \sum_{i=1}^{n}(C_r.X_r) \quad (4.1)$$

The summary of the excel bus Time Table are presented in Table 4.4(a-d) representing the Bosso Exam period, GK Exam period, Bosso lecture period and GK lecture period.

Table 4.4(a): Summary of Bosso Lecture Period Bus Time Table (Ms Excel)

Bus Capacity	**Total Number of Trips**	**Total Revenue**	**Total Expenditures**	**Net Revenue**
18	46			
35	10			
60	18	₦222,200.00	₦98,625.00	₦123,575.00

Table 4.4(b): Summary of GK Lecture Period Bus Time Table (Ms Excel)

Bus Capacity	**Total Number of Trips**	**Total Revenue**	**Total Expenditures**	**Net Revenue**
18	28			
35	10			
60	30	₦261,800.00	₦115,248.00	₦146,552.00

Table 4.4(c): Summary of Bosso Exam Period Bus Time Table (Ms Excel)

Bus Capacity	**Total Number of Trips**	**Total Revenue**	**Total Expenditures**	**Net Revenue**
18	36			
35	54			
60	50	₦303,300.00	₦233,116.00	₦70,184.00

Table 4.4(d): Summary of GK Exam Period Bus Time Table (Ms Excel)

Bus Capacity	**Total Number of Trips**	**Total Revenue**	**Total Expenditures**	**Net Revenue**
18	38			
35	52			
60	64	₦447,900.00	₦267,808.00	₦180,092.00

4.5 Linear Programming Model and Constraints

The linear programming model represented by the equation 4.1 shows that the optimization is to maximize the product of the net profit/loss with the number of frequency. For this research, only one route was considered with varying scheduled variations, V and partitions, P. The net profit/loss is obtained as the algebraic difference of total revenue and total expenditure for any departure frequency considered.

$$Maximize, Z = \sum_{r \in R} \sum_{v \in V} \sum_{p \in P} C_{r,v,p} \, . \, x_{r,v,p} \tag{4.1}$$

$$where \; C_{r,v,p} = inC_{r,v,p} - outC_{r,v,p} \tag{4.2}$$

$$Subject \; to:$$

$$\begin{Bmatrix} 0 \le q_{c+y} \le 60, if \; q_{typ} = A \\ 0 \le q_{c+y} \le 35, if \; q_{typ} = B \\ 0 \le q_{c+y} \le 18, if \; q_{typ} = C \end{Bmatrix} \tag{4.3}$$

$$\begin{Bmatrix} t_{r,p,A} - t_{r,p,(A-1)} \ge 90mins, if \; q_{typ} = A \\ t_{r,p,B} - t_{r,p,(B-1)} \ge 85mins, if \; q_{typ} = B \\ t_{r,p,C} - t_{r,p,(C-1)} \ge 80 \; mins, if \; q_{typ} = C \end{Bmatrix} \tag{4.4}$$

$$\frac{2T_{r,p}}{q_{bus,r}} \le 15minutes \tag{4.5}$$

Equation 4.3 represents the constraint showing that the three different fleet sizes used for the time table design are represented with the letters Ai, Bi, Ci with the respective capacities of 60, 35 and 18. The second constraint 4.4 shows that the maximum travel time between the two campuses bus park for $A, B \; and \; C$ are respectively 45, 42.5 and 40 minutes, while the constraints 4.5 shows that buses depart for every 15 minutes.

4.6 Genetic Algorithm

4.6.1 Bosso campus GA examination period result

Table 4.5 presents the summary table for the best cost and corresponding violation for different population sizes.

Table 4.5: GA summary result for Bosso Campus Exam Period

Populations	Best Cost (₦)	Violations
200	256,738.82	15
400	259,075.60	15
600	258,689.85	14
800	266,500.20	17
1000	258,885.00	15

It was observed that the best cost does not increase with violations. Population size of 200 and 400 have the same violations but with the later having higher cost. From the different chromosomes consider, 1000 was selected as it has 15 violations with high tendencies of line capacities. It Bus Time Table and scheduled were presented in Appendix E1 while the relationship between the best cost and various population size was also presented in appendix D1. The variation in 1000 iteration for the 1000 population sizes was illustrated in Figure 4.6.

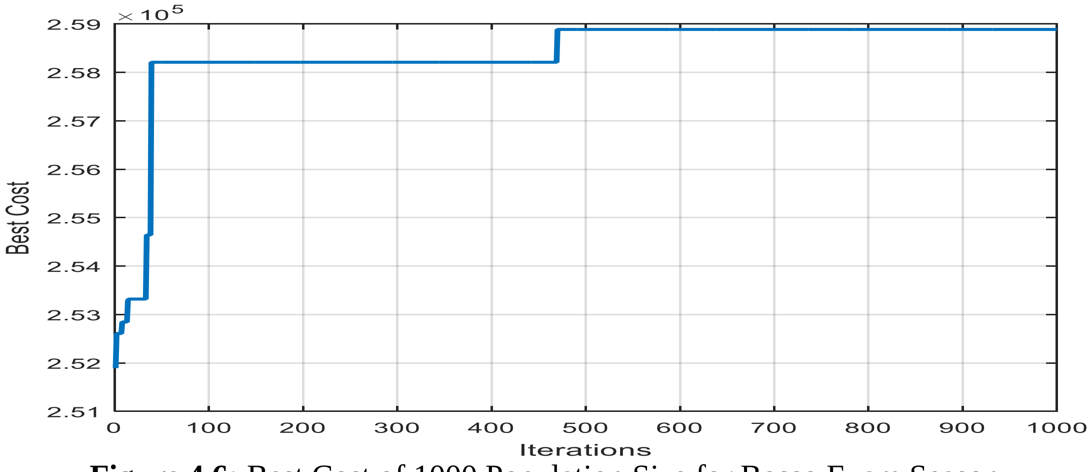


Figure 4.6: Best Cost of 1000 Population Size for Bosso Exam Season

4.6.2 Gidan Kwano campus GA Exam Period result

Table 4.6: GA summary result for GK Campus Exam Period

Population	**Best Cost (₦)**	**Violations**
200	275,740.14	14
400	275,028.42	13
600	275,802.62	13
800	275,656.18	11
1000	275,963.00	12

Table 4.6 shows the best cost and corresponding violations for different population sizes for GK campus exam period bus time table. It was observed that 400 and 600 population sizes gave the same violations with different cost. While 1000 population size results in maximum best cost but with 1 violations more than that of 800 chromosomes, hence 1000 chromosome was chosen and it time table generated was presented in appendix E2 while the relationship between the best cost and various population size was also presented in appendix D2. The variation in 1000 iteration for 70 population sizes was illustrated in Figure 4.7. The total 17 violation attract a penalty cost of ₦124,000.00 which reduces the best cost to ₦271,060.70.

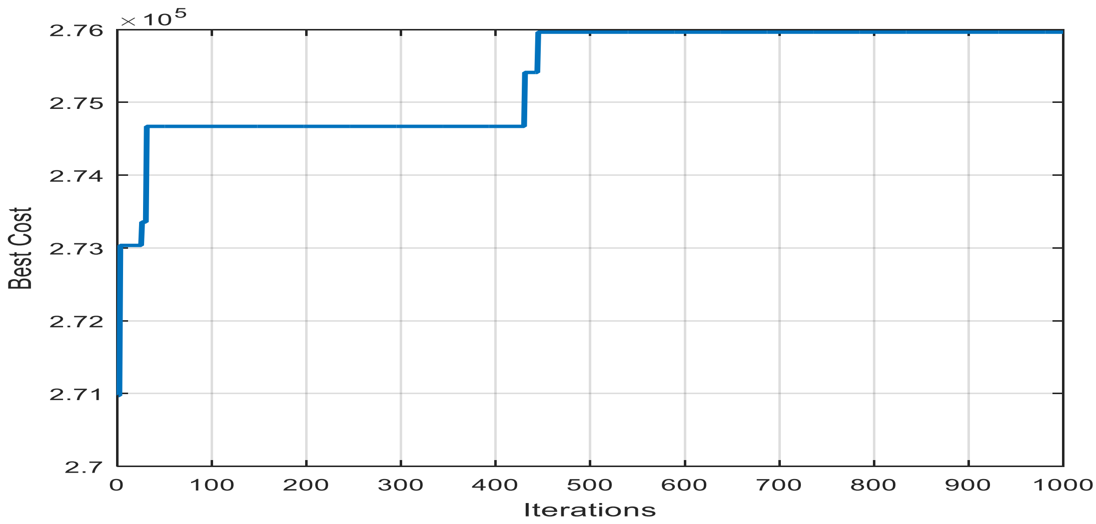


Figure 4.7: Best Cost of 1000 Population Size for GK Exam Season

4.6.3 Bosso campus GA lecture period result

Table 4.7 present the results for the best cost with their corresponding violations for different sizes of the selected populations.

Table 4.7: GA summary result for Bosso Campus Lecture Period

Population	Best Cost (₦)	Violations
200	57,981.41	7
400	57,424.57	7
600	60,359.93	4
800	60,927.58	6
1000	61,324.47	4

From the Table 4.10, the maximum best cost was ₦61,324.47 with violations corresponding to 1000 number of population sizes and 4 violations. Figure 4.8 therefore present the variation in 1000 iteration for the 1000 population sizes. The time table generated was presented in appendix E3 while the relationship between the best cost and various population sizes was also presented in Appendix D3.

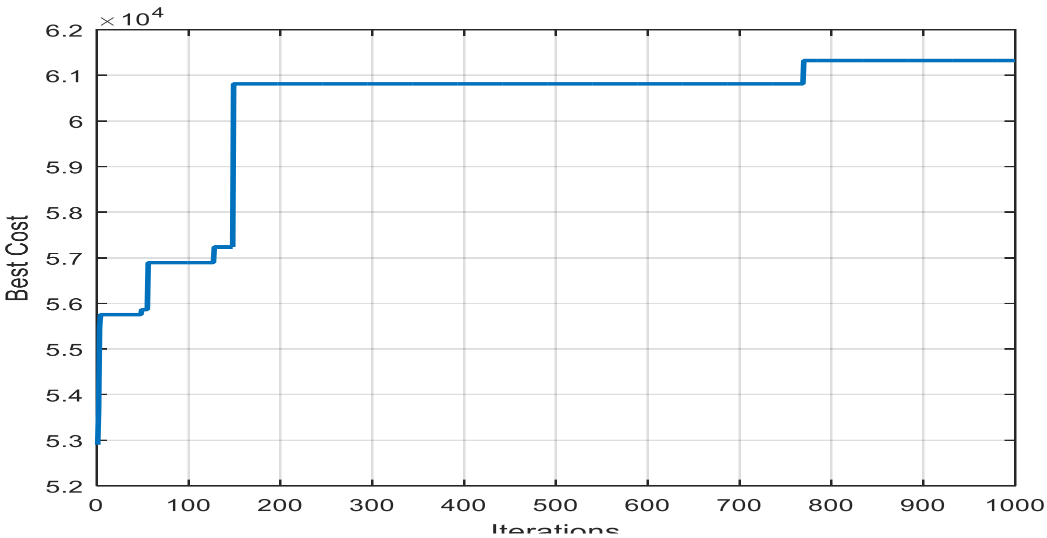


Figure 4.8: Best Cost of 1000 Population Size for Bosso Lecture Season

4.6.4 Gidan kwano campus GA lecture period result

The GA bus time table result for the GK campus lecture period is summarily presented in Table 4.8. It was observed that, the maximum and minimum best cost were respectively obtained at

Table 4.8: GA Summary Result for GK Campus Lecture Period

Population	Best Cost (₦)	Violations
200	123,302.15	6
400	122,689.11	5
600	123,444.94	6
800	125,613.33	5
1000	125,045.68	5

1000 and 200 population sizes with corresponding violations of 5 and 6. However, since the maximum serviced demand is required, 1000 population size with best cost value of ₦125,045.68 was chosen. Figure 4.9 shows the variation in 1000 iteration for the 1000 chromosome as generally shown in Plate VI. The time table generated was presented in appendix E4 while the relationship between the best cost and various population sizes was also presented in appendix D4.

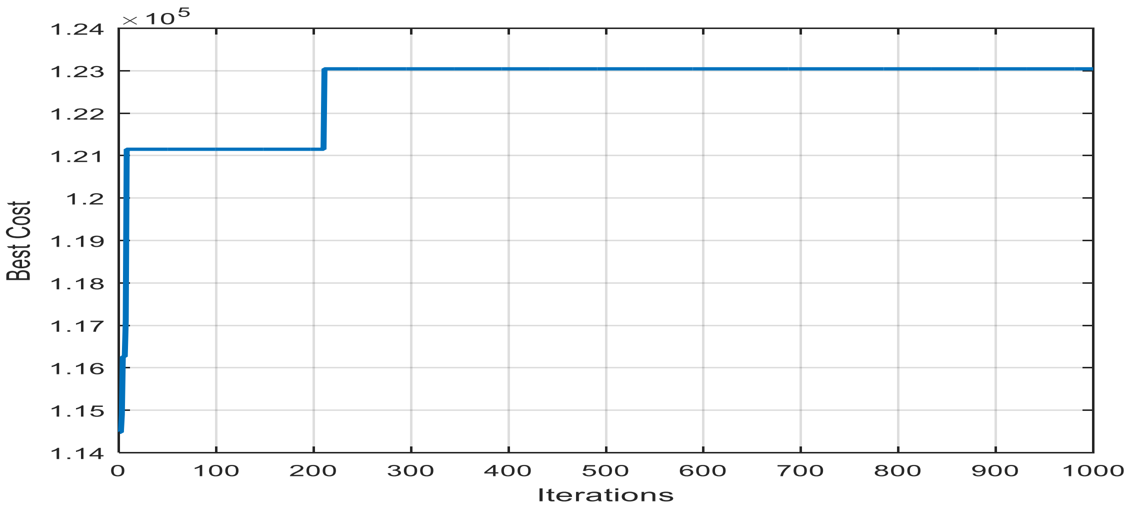


Figure 4.9: Best Cost of 1000 Population Size for GK Lecture Season

4.7 Trip Generation for the Scheduled Buses

Table 4.9: Trip Generation from Scheduled Buses

Periods	Campus	Bus Types	Total Trips
		18	161
		35	41
	Bosso	60	29
		18	147
		35	47
Exam	GK	60	38
		18	149
		35	42
	Bosso	60	32
		18	155
		35	40
Lecture	GK	60	27

Table 4.9 shows the total trips generated for every 15 minutes bus departure time at different campus and different periods (peak and off-peak). Generally at the two periods and both campuses, 18 sitter buses were found to generate more trips, In fact, 18 sitter trips was about 3-4 times that of 35 sitters and 4-6 times that of 60 sitters. This is due to its more number and low journey time compared to other capacities buses. It was also observed that the total trips during peak period were respectively 231 and 232 for Bosso and GK campuses, while during lecture period, 223 trips were generated at bosso campus and 222 trips at GK campus. The various 15 minute departure time and scheduled buses was presented in Appendix F, the schedule was also presented in Figure 4.10.

Departure Time

Periods	Campus	Bus Types	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:46	10:00
		18	5	3	1	2	1	3	7	2	2	1	3	7	2	1	4	1	7
		35	0	2	0	2	0	0	0	1	3	0	1	0	1	0	1	3	0
	Bosso	60	0	1	0	1	0	0	0	0	1	0	0	0	0	3	1	0	0
		18	2	5	2	3	1	2	4	2	2	3	2	3	0	5	4	1	2
		35	1	0	1	0	1	1	1	1	0	1	0	2	0	2	0	0	3
Exam	GK	60	1	0	0	0	0	1	0	1	0	0	2	0	0	0	0	0	0
		18	2	4	0	3	2	5	3	1	5	2	3	4	1	2	3	3	3
		35	2	0	0	1	0	0	0	2	1	0	0	1	1	0	1	1	1
	Bosso	60	0	0	1	0	1	1	0	1	0	1	1	0	0	1	0	1	0
		18	1	3	2	0	4	3	3	4	0	5	3	4	7	0	1	3	6
		35	0	0	0	2	1	0	1	0	1	0	0	2	1	2	0	1	0
Lecture	GK	60	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0

Periods	Campus	Bus Types	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15
		18	5	0	2	1	6	7	1	2	1	8	4	1	2	4	8	3	2
		35	1	0	1	0	1	3	1	0	0	2	0	1	1	1	1	0	1
	Bosso	60	2	0	0	0	1	0	0	1	2	1	0	0	1	0	0	2	2
		18	0	6	4	1	3	3	6	4	1	3	1	8	4	2	3	0	7
		35	0	1	0	3	0	1	2	0	2	0	3	0	1	3	0	1	0
Exam	GK	60	2	1	1	1	0	0	2	1	1	1	2	0	0	1	2	1	1
		18	2	2	1	5	6	3	3	1	4	4	3	3	3	5	4	2	3
		35	1	2	1	0	1	1	0	0	3	1	0	1	1	1	0	3	1
	Bosso	60	1	2	0	0	0	0	1	1	1	2	0	0	0	0	0	3	2
		18	8	1	1	2	6	6	1	2	2	5	4	1	2	3	4	5	2
		35	0	1	1	3	0	1	0	0	1	1	4	0	1	0	0	1	1
Lecture	GK	60	1	0	1	1	2	1	0	1	0	0	1	1	1	1	0	1	1

Periods	Campus	Bus Types	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00	Total rips
		18	2	3	7	3	2	3	5	7	3	2	2	5	5	3	0	161
		35	2	0	1	1	0	1	1	3	0	1	1	0	1	1	0	41
	Bosso	60	2	0	0	0	0	0	3	3	2	0	0	0	0	0	0	29
		18	5	3	2	1	6	3	6	2	2	5	3	6	2	2	0	147
		35	3	0	2	2	0	1	0	3	0	2	2	0	1	0	0	47
Exam	GK	60	2	1	0	0	2	2	1	2	1	1	0	0	2	2	0	38
		18	5	3	4	3	3	4	2	5	3	3	5	1	5	3	0	149
		35	0	1	1	1	0	3	1	0	1	1	1	0	3	1	0	42
	Bosso	60	2	0	1	0	0	0	2	2	2	0	1	1	0	0	0	32
		18	3	3	3	4	3	5	3	4	3	3	5	4	4	4	0	155
		35	4	0	1	0	0	1	1	4	0	1	0	0	1	1	0	40
Lecture	GK	60	1	1	1	0	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	27

Figure 4.10: Number of Scheduled Buses for every 15 minutes Departure Time

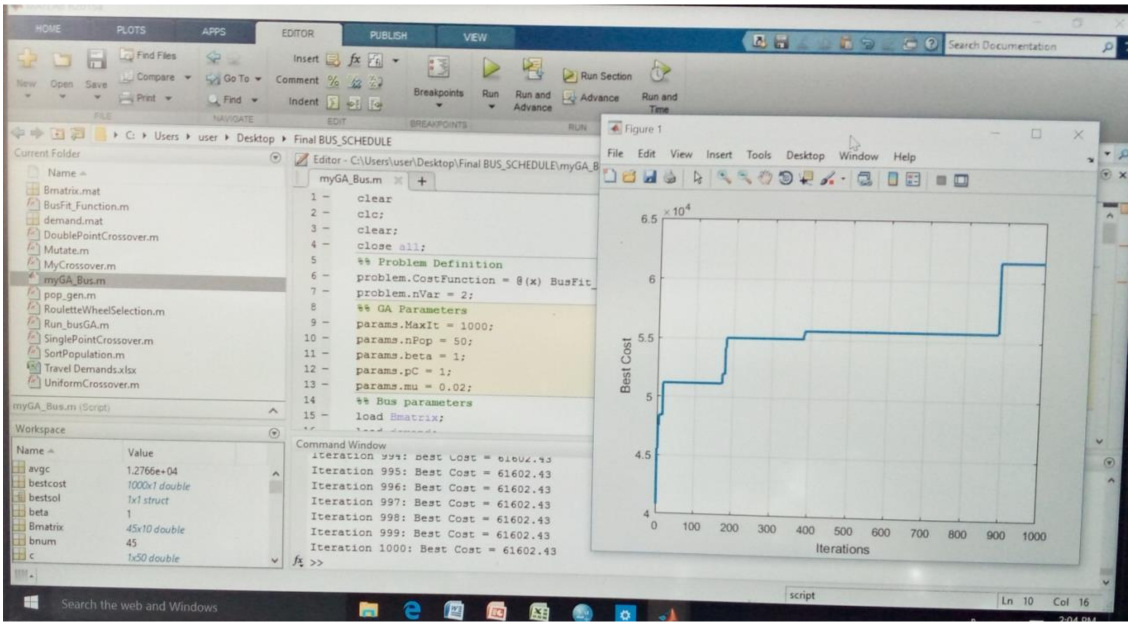


Plate VI: A G.A Operation on Matlab Interface

4.8 Matching Line Capacity with Travel Demands

Line capacity is simply the number of passengers transported at a given time on a given route. It was observed that, the 18, 35 and 60 sitter capacities buses provided meets up with the travel demand.

At Bosso campus exam seasons, the peak travel demand was at 7:00am with over 400 passengers which were all moved by different bus combination. This scheduled as shown in Figure 4.11, ensured satisfy the constraint by ensuring bus departure at every 15 minutes. Hence all passengers were satisfied. Also, Figure 4.12 presents a comparative chart between the travel and line capacity achieved from the schedules. It was observed that, all passengers especially at peak period around 5 to 6pm were satisfied with the bus combination scheduled.

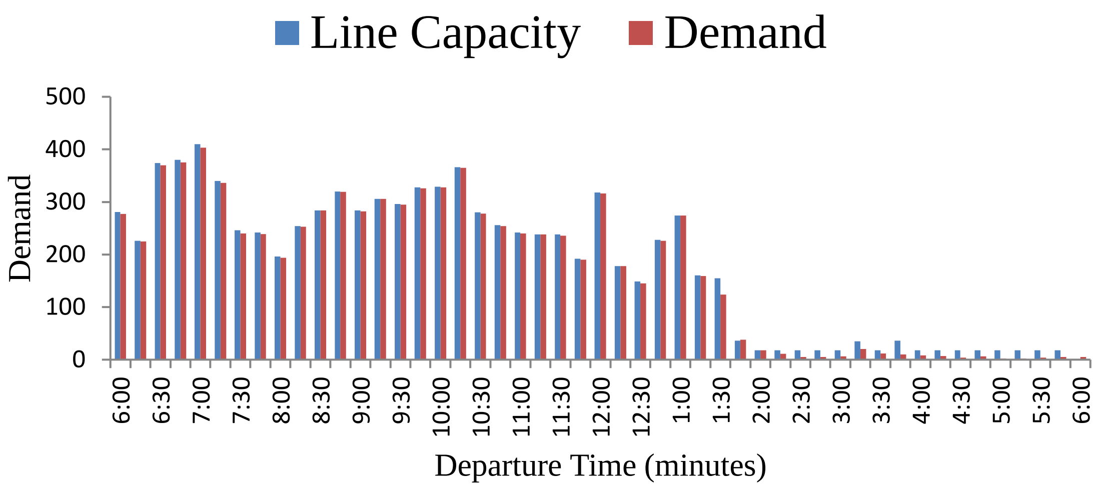


Figure 4.11: Matching Bosso Exam Seasons Line Capacity with Demand

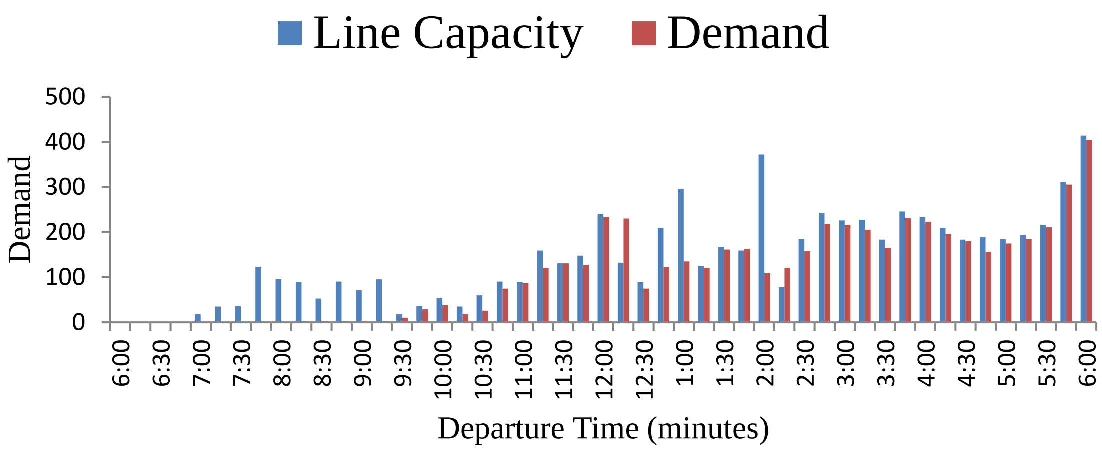


Figure 4.12: Matching GK Exam Seasons Line Capacity with Demand

At lecture season, the demands and line capacities at the Bosso campus was also compared as shown in Figure 4.13. Clearly, the pattern of these demand vary from that of exam seasons. In this case, the demands are generally low but are more distributed compared to that of exam seasons. The peak demand was at 11 am and then reduces from 12:30pm down to 6pm. Also, at GK campus, the demands are generally low with a peak period at 1:45pm with a demand closed to 500 passengers as shown in Figure 4.14. These demands were also cleared by the bus combination schedule.

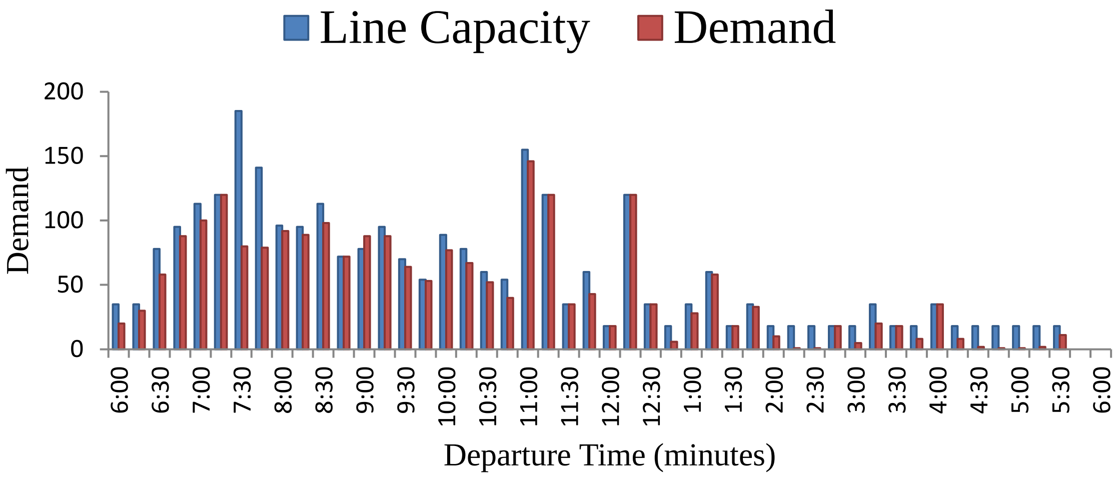


Figure 4.13: Matching Bosso Lecture Seasons Line Capacity with Demand

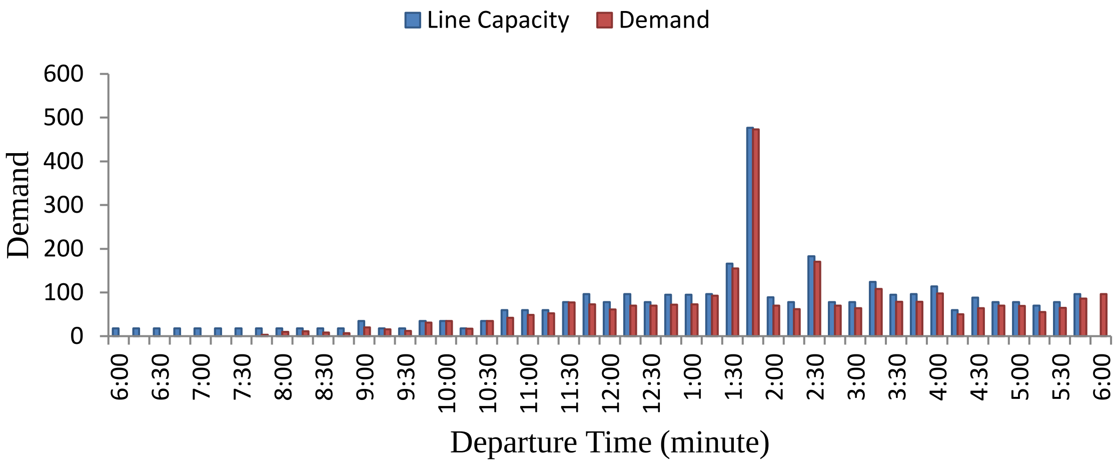


Figure 4.14: Matching GK Lecture Seasons Line Capacity with Demand

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

At the end of this research, the following conclusions were drawn:

Three different bus sizes 18, 35 and 60 sitters capacities were selected on the basis of their net cost and journey time per run to generate four different optimal Bus schedules representing Bosso and GK campuses at both lecture and examination season, for the university transit management using Genetic Algorithms.

It was found that 19 number of 18 (154 trips), 11 of 35 (44 trips) and 15 of 60 (34 trips) sitting capacity buses with respective travel time of 40, 50 and 60 minutes was most effective at the current traffic and road condition. A net total of N185,000 would be obtained during lecture season per day to effectively transport 2562 students and the amount would increase by 289% at examination season if this scheduled is adopted.

5.2 Recommendations

From the results obtained, the following recommendations were drawn:

1. More number of busses should be deployed at the bus parks for conveying student between the campuses.
2. At most 15 minutes should be set as departure time for the buses to clearly passengers on queue.
3. Due to variations in travel time, resulting from improvement in traffic and road conditions (Road reconstruction), similar bus scheduled should be developed.

5.3 Contributions to Knowledge

18, 35 and 60 sitter capacity buses were used to schedule bus time Table using LP model with GA and these schedules sufficiently conveyed the travel demands with minimum or no delay along the Bosso-Gidan Kwano corridor. Unlike the conventional methods of data collection, CCTVs were strategically positioned to capture the travel demand at both campuses during lecture and examination seasons.

Further Research

1. Similar time table should be prepared for special period/event such as; weekends, University post UTME period, second semester session of the university as the demand are low compared to first semester because of 400L students on industrial training (I.T).
2. With the ongoing reconstruction of Minna-Bida road where lies Bosso-GK route, the travel time at the end of project completion will as much as possible be reduced, this will therefore cause decrease in travel time and subsequently increase the buses trip frequency.

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APPENDICES

APPENDIX A

Table 4.3(a): Bosso Peak Travel Demand (week 1)

Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Monday	277	225	248	375	295	336	240	239	194	162	284	319	272	267	219	311	141
Tuesday	277	225	248	375	295	336	240	239	232	194	135	71	130	64	131	131	108
Wednesday	43	124	125	166	88	83	61	94	51	135	96	88	137	98	173	219	311
Thursday	94	102	132	115	95	142	96	54	176	154	162	284	319	272	194	202	88
Friday	43	35	60	99	78	57	43	71	52	99	120	145	173	152	267	160	149
Saturday	43	60	70	56	52	84	41	104	44	104	51	153	101	183	246	159	129

Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45
Monday	122	90	54	46	0	43	96	48	40	47	87	78	16	18	9
Tuesday	47	18	12	14	13	31	14	15	63	28	12	25	15	25	4
Wednesday	223	226	260	180	152	61	111	107	316	178	79	130	41	18	11
Thursday	183	86	12	21	25	18	29	11	48	35	64	22	32	26	23
Friday	192	235	219	209	93	122	158	150	117	117	80	60	127	48	7
Saturday	166	227	278	254	237	227	170	108	83	34	37	26	3	19	12

Time	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Monday	1	1	0	0	1	6	20	0	0	0	2	4	0	0	0	0	0
Tuesday	2	4	3	2	4	2	4	0	0	1	4	1	3	0	0	0	0

Wednesday	4	5	2	2	3	0	3	12	5	8	7	0	0	1	0	5	5
Thursday	8	3	2	0	0	0	2	5	10	0	2	3	0	2	0	0	0
Friday	14	3	11	0	0	2	4	0	3	0	6	4	0	0	2	0	0
Saturday	4	6	0	0	0	0	0	2	1	0	1	0	0	2	0	0	0

Table 4.3(b): Bosso Peak Travel Demand (week2)

Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Monday	43	61	151	119	127	116	82	110	158	116	158	175	266	243	230	171	150
Tuesday	68	108	112	153	205	201	130	141	171	178	227	239	265	158	242	177	320
Wednesday	44	146	129	370	306	403	202	161	148	125	253	220	217	260	306	255	238
Thursday	49	124	52	150	137	83	79	92	180	166	158	188	215	282	297	295	326
Friday	28	43	66	48	29	11	15	19	13	29	17	26	43	66	59	78	88
Saturday	35	21	46	59	54	66	38	82	79	94	39	75	93	172	85	174	162

Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45
Monday	119	147	194	82	143	89	48	71	49	58	0	7	3	29	2
Tuesday	237	114	149	91	111	62	61	77	145	97	122	151	99	158	30
Wednesday	320	221	221	183	167	54	19	43	60	43	18	42	16	4	6
Thursday	328	237	182	169	240	238	236	190	203	171	145	226	274	159	124
Friday	61	43	52	36	31	30	28	35	43	26	9	43	81	31	22
Saturday	199	365	195	191	148	132	115	36	100	57	46	15	18	12	5

Time	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00

Monday	1	2	1	0	0	3	0	0	4	7	0	0	0	0	0	0	0
Tuesday	10	18	0	0	2	4	0	0	0	0	0	0	6	1	0	0	0
Wednesday	1	2	1	2	0	0	1	1	5	3	1	4	0	0	0	0	0
Thursday	38	4	1	2	5	4	3	0	0	0	1	1	0	0	0	0	0
Friday	15	7	5	1	2	5	1	3	1	0	0	0	0	0	0	0	0
Saturday	2	4	3	5	0	2	0	2	2	1	0	0	0	0	0	0	0

Table 4.4(a): G.K Peak Travel Demand (week1)

Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Monday	0	0	0	0	0	0	0	0	0	2	0	1	1	0	0	0	5
Tuesday	0	0	0	0	0	0	0	0	0	1	1	0	3	1	2	12	38
Wednesday	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	1
Thursday	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Friday	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0
Saturday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45
Monday	0	0	10	43	52	18	32	20	30	10	23	32	98	56	85
Tuesday	12	17	19	76	86	70	85	125	230	65	68	126	96	49	163
Wednesday	3	0	2	8	95	116	120	96	115	75	80	135	58	101	151
Thursday	3	0	0	52	62	95	86	78	52	69	43	95	46	89	125
Friday	6	10	18	61	82	86	91	61	63	59	62	86	53	45	82
Saturday	4	16	20	69	75	82	85	95	64	70	55	100	65	75	90

Time	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Monday	78	18	52	36	51	72	18	44	43	13	11	25	52	23	23	19	94
Tuesday	72	86	95	120	93	205	56	106	223	131	120	195	161	151	167	189	356
Wednesday	109	76	82	165	215	161	75	185	81	158	220	135	91	145	165	195	260
Thursday	81	65	79	135	121	101	66	125	185	121	151	125	113	135	175	252	405
Friday	93	72	83	124	61	85	60	130	36	95	120	115	96	131	162	200	270
Saturday	82	68	90	131	101	72	59	115	82	92	141	121	82	115	152	200	321

Table 4.4(b): G.K Peak Travel Demand (week2)

Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Monday	0	0	0	0	0	0	0	0	0	1	0	2	0	0	1	0	8
Tuesday	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	10	29
Wednesday	0	0	0	0	0	0	0	0	0	0	0	1	1	2	1	2	11
Thursday	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	6	3
Friday	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	1	0
Saturday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	8

Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45
Monday	0	0	8	34	45	16	43	27	35	18	28	33	89	65	88
Tuesday	12	14	17	67	78	71	87	127	234	67	64	100	95	49	153
Wednesday	2	5	12	75	87	120	131	89	119	87	76	123	59	121	161
Thursday	12	11	19	65	57	89	78	68	56	70	44	121	56	90	120
Friday	16	18	21	66	78	89	100	71	63	61	58	78	43	34	77
Saturday	12	19	26	70	77	87	89	98	67	72	66	108	68	78	92

Time	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Monday	67	21	43	43	49	68	19	43	34	18	13	21	52	24	23	17	84
Tuesday	78	89	121	123	98	195	68	100	231	123	116	180	156	149	162	191	256
Wednesday	120	67	90	158	218	157	89	165	76	168	189	125	86	161	170	200	200
Thursday	98	70	89	131	131	113	76	124	170	131	167	131	98	123	180	200	305
Friday	99	67	89	121	67	87	63	129	78	123	115	82	132	156	189	265	85
Saturday	85	69	92	134	121	78	64	117	88	95	134	124	76	130	165	211	232

Table 4.5(a): Bosso lecture period Travel Demand (week1)

Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Monday	0	0	58	65	75	58	75	64	82	59	98	41	87	18	53	33	77
Tuesday	17	18	53	38	70	35	54	79	90	18	74	39	9	45	22	53	27
Wednesday	4	30	15	88	44	35	28	74	44	74	49	7	35	19	22	40	22
Thursday	0	17	22	53	74	40	60	50	92	36	18	18	18	5	4	18	18
Friday	0	10	26	34	32	41	80	13	76	36	36	34	32	88	25	10	59
Saturday	0	1	2	4	5	6	0	7	4	2	4	3	10	6	0	2	4

Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45
Monday	67	25	35	146	120	18	6	5	120	4	3	2	54	2	18
Tuesday	19	46	38	10	2	35	2	0	0	0	0	0	0	18	0
Wednesday	18	18	16	18	14	18	0	0	0	18	0	0	0	0	33
Thursday	18	35	15	2	3	2	3	18	35	35	0	28	7	0	9

Friday	51	13	40	19	12	24	43	10	4	8	6	6	4	1	6
Saturday	2	9	1	4	0	0	0	4	1	2	1	1	3	0	0

Time	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Monday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tuesday	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0
Wednesday	0	0	0	9	0	0	13	5	6	0	0	0	0	0	11	0	0
Thursday	10	0	0	15	5	20	18	8	35	8	2	0	0	0	0	0	0
Friday	0	1	0	0	0	0	10	1	0	0	0	0	0	0	0	0	0
Saturday	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	0	0

Table 4.5(b): Bosso lecture period Travel Demand (week2)

Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Monday	7	17	34	22	100	87	64	18	90	89	54	36	18	36	18	7	5
Tuesday	0	0	53	35	0	60	0	64	92	54	18	34	0	0	64	18	0
Wednesday	20	18	20	36	37	27	33	75	64	67	37	66	39	26	0	19	37
Thursday	70	0	3	1	72	38	42	22	64	71	33	72	88	19	20	10	19
Friday	0	18	37	8	35	120	0	0	70	67	68	38	58	62	37	9	22
Saturday	0	1	2	4	5	6	0	7	4	2	4	2	10	6	0	2	4

Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45
Monday	18	18	14	30	17	20	20	0	0	19	0	0	3	6	0
Tuesday	52	52	10	28	18	30	2	0	6	15	0	0	0	4	0

Wednesday	57	37	18	37	19	27	20	0	7	3	0	0	0	3	0
Thursday	20	12	18	10	17	13	14	12	0	0	0	0	0	1	2
Friday	13	18	21	11	36	20	9	0	3	0	2	0	0	0	0
Saturday	2	9	1	4	0	0	0	4	1	2	1	1	3	0	0

Time	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Monday	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0
Tuesday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wednesday	0	0	0	0	2	0	0	0	0	0	0	1	0	2	4	0	0
Thursday	0	0	1	2	0	0	3	1	0	0	0	0	1	0	0	0	0
Friday	0	0	1	0	0	0	0	2	1	0	0	0	0	0	3	0	0
Saturday	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	0	0

Table 4.6(a): G.K lecture period Travel Demand (week1)

Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Monday	0	0	0	0	0	0	0	0	3	9	8	7	20	16	12	10	16
Tuesday	0	0	0	0	0	0	0	0	1	0	4	4	6	12	8	10	8
Wednesday	0	0	0	0	0	0	0	0	2	7	2	2	1	10	12	3	35
Thursday	0	0	0	0	0	0	0	0	0	11	0	3	0	0	2	17	0
Friday	0	0	0	0	0	0	0	0	10	8	0	0	0	0	0	0	0
Saturday																	

Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45
Monday	10	10	10	10	10	35	20	10	10	70	38	46	71	16	36
Tuesday	10	15	10	42	13	35	18	30	70	67	18	71	38	54	36
Wednesday	16	35	20	10	5	70	8	36	20	10	6	53	36	69	20
Thursday	0	5	32	35	6	18	0	35	64	24	18	54	53	44	473
Friday	0	0	0	0	0	79	0	0	53	40	18	18	30	6	15
Saturday															

Time	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Monday	25	11	18	54	57	108	0	0	0	39	35	70	55	44	24	56	66
Tuesday	25	45	18	36	64	42	17	18	74	15	20	4	69	35	18	18	19
Wednesday	18	36	20	70	10	20	64	3	10	18	64	17	67	47	34	44	46
Thursday	20	34	40	20	15	10	54	20	82	44	34	18	58	51	35	86	96
Friday	64	44	170	0	0	0	0	0	12	36	0	0	22	32	37	18	17
Saturday																	

Table 4.6(b): G.K lecture period Travel Demand (week2)

Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Monday	0	0	0	0	0	0	0	0	0	0	0	7	4	1	3	0	3
Tuesday	0	0	0	0	0	0	0	0	5	3	4	4	1	3	6	1	3
Wednesday	0	0	0	0	0	0	0	3	0	0	0	1	3	1	5	2	6
Thursday	0	0	0	0	0	0	0	0	6	5	7	3	4	11	8	7	9
Friday	0	0	0	0	0	0	0	0	1	2	0	1	5	11	7	6	4
Saturday	0	0	0	0	0	0	0	0	3	1	0	2	3	4	3	24	1

Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45
Monday	9	7	9	22	22	35	24	30	27	58	72	33	64	79	127
Tuesday	7	15	11	13	15	10	7	30	27	29	33	73	39	87	49
Wednesday	5	11	27	48	44	39	67	61	40	56	62	42	45	85	109
Thursday	17	19	42	49	42	77	72	27	31	35	61	48	93	155	196
Friday	10	5	16	11	52	44	73	29	38	57	37	13	29	5	2
Saturday	2	3	5	7	1	2	0	2	3	1	0	0	2	3	1

Time	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Monday	70	39	66	70	22	38	44	28	98	24	39	48	51	55	65	65	79
Tuesday	35	47	33	41	29	34	39	79	29	33	28	64	32	5	0	3	13
Wednesday	44	62	37	31	19	58	79	27	16	17	15	8	2	0	5	1	1
Thursday	36	34	60	37	58	35	70	73	90	36	29	17	68	25	2	11	12
Friday	1	0	17	29	14	19	36	69	22	35	29	67	19	0	0	1	1
Saturday	4	3	2	1	0	0	0	1	3	2	14	19	1	0	0	0	0

APPENDIX B

Table B1 (a): Bosso Exam Period Travel Demand (Week1)

Departure Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Maximum Travel Demand	277	225	248	375	295	336	240	239	194	162	284	319	272	267	219	311	223

Departure Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15
Maximum Travel Demand	235	278	254	237	227	170	150	316	178	87	130	127	48	23	14	6	11

Departure Time	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Maximum Travel Demand	2	4	6	20	12	10	8	7	4	3	2	2	4	5	5

Table B1 (b): Bosso Exam Period Travel Demand (Week 1)

Departure Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Maximum Travel Demand	68	151	370	306	403	202	161	180	187	253	239	266	282	306	295	326	328

Departure Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15
Maximum Travel Demand	365	221	191	240	238	236	190	203	172	145	226	274	159	124	38	18	5

Departure Time	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Maximum Travel Demand	5	5	5	3	3	5	7	1	4	6	1	0	0	0	0

Table B2 (a): G.k Exam Period Travel Demand (Week1)

Departure Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Maximum Travel Demand	0	0	0	0	0	0	0	0	0	2	1	1	3	2	2	12	38

Departure Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15
Maximum Travel Demand	12	17	20	87	95	116	120	125	230	75	80	135	98	101	163	109	86

Departure Time	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Maximum Travel Demand	95	165	215	205	75	185	223	195	161	151	175	185	190	252	405

Table B2 (b): G.K Exam Period Travel Demand (Week2)

Departure Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Maximum Travel Demand	0	0	0	0	0	0	0	0	0	0	2	2	2	2	10	29	16

Departure Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15
Maximum Travel Demand	19	26	75	87	120	131	127	234	87	76	123	95	121	161	120	89	121

Departure Time	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Maximum Travel Demand	158	218	195	89	165	231	168	189	180	156	161	180	211	305	305

Table B3 (a): Bosso Lecture Period Travel Demand (Week1)

Departure Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Maximum Travel Demand	17	30	58	88	75	58	80	79	92	59	98	41	87	88	53	53	77

Departure Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15
Maximum Travel Demand	67	46	40	146	120	35	43	18	120	35	6	28	58	18	33	10	1

Departure Time	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Maximum Travel Demand	0	18	5	20	18	8	35	8	2	0	0	0	11	0	0

Table B3 (b): Bosso Lecture Period Travel Demand (Week2)

Departure Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Maximum Travel Demand	20	18	53	36	100	120	64	75	92	89	68	72	88	62	64	19	37

Departure Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15
Maximum Travel Demand	57	52	21	37	36	30	20	12	7	19	2	0	3	6	2	0	0

Departure Time	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Maximum Travel Demand	1	2	2	0	3	2	1	0	0	1	1	2	4	0	0

Table B4 (a): G.K Lecture Period Travel Demand (Week1)

Departure Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Maximum Travel Demand	0	0	0	0	0	0	0	0	10	11	8	7	20	16	12	31	35

Departure Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15
Maximum Travel Demand	16	35	32	42	13	70	20	36	70	70	38	71	71	69	473	64	45

Departure Time	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Maximum Travel Demand	170	70	64	108	70	20	82	50	64	70	69	51	37	86	96

Table B4 (b): G.K Lecture Period Travel Demand (Week2)

Departure Time	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00
Maximum Travel Demand	0	0	0	0	0	0	0	3	6	5	7	7	5	11	8	24	9

Departure Time	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15
Maximum Travel Demand	17	19	42	49	52	77	73	61	40	58	72	73	93	155	195	70	62

Departure Time	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
Maximum Travel Demand	66	70	58	58	79	79	98	36	39	67	51	55	65	65	79

APPENDIX C

Table C1: Bosso Exam Period MS Excel Bus Time Table

Time	Demand	Bus Capacity			Total Capacity	Penalty(₦3 for 5mins)	Total Revenue (₦)	Operation Cost				Total	Net Revenue
		60	35	18				Penalty (₦)	Driver (₦)	Maintenance (₦)	Fuel (₦)		
6:00	277	3	2	1	268	9	26,800.00	27.00	600.00	5,350.00	5,364.00	11,341.00	15,459.00
6:15	225	3	1	0	215	10	21,500.00	30.00	400.00	4,350.00	4,374.00	9,154.00	12,346.00
6:30	248	2	3	1	243	5	24,300.00	15.00	600.00	4,700.00	4,786.00	10,101.00	14,199.00
6:45	156	0	3	2	141	15	14,100.00	45.00	500.00	2,600.00	2,640.00	5,785.00	8,315.00
7:00	219	2	2	1	208	11	20,800.00	33.00	500.00	4,100.00	4,126.00	8,759.00	12,041.00
7:15	295	3	2	2	286	9	28,600.00	27.00	700.00	5,750.00	5,694.00	12,171.00	16,429.00
7:30	336	3	3	2	321	15	32,100.00	45.00	800.00	6,350.00	6,354.00	13,549.00	18,551.00
7:45	114	1	1	1	113	1	11,300.00	3.00	300.00	2,250.00	2,228.00	4,781.00	6,519.00
8:00	125	0	2	3	124	1	12,400.00	3.00	500.00	2,400.00	2,310.00	5,213.00	7,187.00
8:15	232	2	3	0	225	7	22,500.00	21.00	500.00	4,300.00	4,456.00	9,277.00	13,223.00
8:30	194	2	2	0	190	4	19,000.00	12.00	400.00	3,700.00	3,796.00	7,908.00	11,092.00
9:00	206	1	3	2	201	5	20,100.00	15.00	600.00	3,850.00	3,878.00	8,343.00	11,757.00
9:30	195	2	2	0	190	5	19,000.00	15.00	400.00	3,700.00	3,796.00	7,911.00	11,089.00
10:00	131	1	2	0	130	1	13,000.00	3.00	300.00	2,450.00	2,558.00	5,311.00	7,689.00
10:15	108	0	2	2	106	2	10,600.00	6.00	400.00	2,000.00	1,980.00	4,386.00	6,214.00
10:30	47	0	0	2	36	11	3,600.00	33.00	200.00	800.00	660.00	1,693.00	1,907.00
11:30	30	0	0	1	18	12	1,800.00	36.00	100.00	400.00	330.00	866.00	934.00
12:00	27	0	0	1	18	9	1,800.00	27.00	100.00	400.00	330.00	857.00	943.00
1:30	0	1	0	1	0	0	0.00	0.00	200.00	1,650.00	1,568.00	3,418.00	-3,418.00
1:45	0	1	1	1	0	0	0.00	0.00	300.00	2,250.00	2,228.00	4,778.00	-4,778.00
2:00	0	1	2	1	0	0	0.00	0.00	400.00	2,850.00	2,888.00	6,138.00	-6,138.00
2:15	0	1	1	1	0	0	0.00	0.00	300.00	2,250.00	2,228.00	4,778.00	-4,778.00
2:30	0	1	1	0	0	0	0.00	0.00	200.00	1,850.00	1,898.00	3,948.00	-3,948.00
2:45	0	1	1	1	0	0	0.00	0.00	300.00	2,250.00	2,228.00	4,778.00	-4,778.00
3:00	0	2	2	2	0	0	0.00	0.00	600.00	4,500.00	4,456.00	9,556.00	-9,556.00
3:15	0	0	1	1	0	0	0.00	0.00	200.00	1,000.00	990.00	2,190.00	-2,190.00
3:30	0	2	2	0	0	0	0.00	0.00	400.00	3,700.00	3,796.00	7,896.00	-7,896.00
3:45	0	1	1	1	0	0	0.00	0.00	300.00	2,250.00	2,228.00	4,778.00	-4,778.00
4:00	0	2	2	1	0	0	0.00	0.00	500.00	4,100.00	4,126.00	8,726.00	-8,726.00
4:15	0	1	1	1	0	0	0.00	0.00	300.00	2,250.00	2,228.00	4,778.00	-4,778.00
4:30	0	2	2	0	0	0	0.00	0.00	400.00	3,700.00	3,796.00	7,896.00	-7,896.00
4:45	0	2	1	0	0	0	0.00	0.00	300.00	3,100.00	3,136.00	6,536.00	-6,536.00
5:00	0	1	1	1	0	0	0.00	0.00	300.00	2,250.00	2,228.00	4,778.00	-4,778.00
5:15	0	2	1	1	0	0	0.00	0.00	400.00	3,500.00	3,466.00	7,366.00	-7,366.00
5:30	0	2	0	1	0	0	0.00	0.00	300.00	2,900.00	2,806.00	6,006.00	-6,006.00
5:45	0	2	1	1	0	0	0.00	0.00	400.00	3,500.00	3,466.00	7,366.00	-7,366.00
6:00	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		50	54	36		**TOTAL**	**303,300.00**	**396.00**	**14,000.00**	**109,300.00**	**109,420.00**	**233,116.00**	**70,184.00**

Table C2: GK Exam Period MS Excel Bus Time Table

Time	Demand	Bus Capacity			Total Capacity	Penalty(₦1 for 5mins)	Total Revenue (₦)	Operation Cost				Total	Net Revenue
		60	35	18				Penalty (₦)	Driver (₦)	Maintenance (₦)	Fuel (₦)		
7:00	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7:15	0	3	2	1	0	0	0.00	0.00	600.00	5,350.00	5,364.00	11,314.00	-11,314.00
7:30	0	2	1	1	0	0	0.00	0.00	400.00	3,500.00	3,466.00	7,366.00	-7,366.00
8:00	0	2	3	1	0	0	0.00	0.00	600.00	4,700.00	4,786.00	10,086.00	-10,086.00

Table C4: GK Lecture Period MS Excel Bus Time Table

Time	Demand	Bus Capacity			Total Capacity	Penalty(₦3 for 5mins)	Total Revenue (₦)	Operation Cost				Total	Net Revenue
		60	35	18				Penalty (₦)	Driver (₦)	Maintenance (₦)	Fuel (₦)		
6:00	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6:15	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6:30	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6:45	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7:00	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7:15	0	0	0	1	0	0	0.00	0.00	100.00	400.00	330.00	830.00	-830.00
7:30	0	0	0	1	0	0	0.00	0.00	100.00	400.00	330.00	830.00	-830.00
7:45	3	0	0	1	18	-15	1,800.00	-45.00	100.00	400.00	330.00	785.00	1,015.00
8:00	10	0	0	1	18	-8	1,800.00	-24.00	100.00	400.00	330.00	806.00	994.00
8:15	11	0	0	1	18	-7	1,800.00	-21.00	100.00	400.00	330.00	809.00	991.00
8:30	8	0	0	1	18	-10	1,800.00	-30.00	100.00	400.00	330.00	800.00	1,000.00
8:45	7	0	0	1	18	-11	1,800.00	-33.00	100.00	400.00	330.00	797.00	1,003.00
9:00	20	0	0	1	18	2	1,800.00	6.00	100.00	400.00	330.00	836.00	964.00
9:15	16	0	0	1	18	-2	1,800.00	-6.00	100.00	400.00	330.00	824.00	976.00
9:30	12	0	0	1	18	-6	1,800.00	-18.00	100.00	400.00	330.00	812.00	988.00
9:45	31	0	0	1	18	13	1,800.00	39.00	100.00	400.00	330.00	869.00	931.00
10:00	35	0	0	1	18	17	1,800.00	51.00	100.00	400.00	330.00	881.00	919.00
10:15	17	0	0	1	18	-1	1,800.00	-3.00	100.00	400.00	330.00	827.00	973.00
10:30	35	0	1	0	35	0	3,500.00	0.00	100.00	600.00	660.00	1,360.00	2,140.00
10:45	42	0	1	0	35	7	3,500.00	21.00	100.00	600.00	660.00	1,381.00	2,119.00
11:00	49	0	0	2	36	13	3,600.00	39.00	200.00	800.00	660.00	1,699.00	1,901.00
11:15	52	0	0	2	36	16	3,600.00	48.00	200.00	800.00	660.00	1,708.00	1,892.00
11:30	77	1	0	0	60	17	6,000.00	51.00	100.00	1,250.00	1,238.00	2,639.00	3,361.00
11:45	73	1	0	0	60	13	6,000.00	39.00	100.00	1,250.00	1,238.00	2,627.00	3,373.00
12:00	61	1	0	0	60	1	6,000.00	3.00	100.00	1,250.00	1,238.00	2,591.00	3,409.00
12:15	70	1	0	0	60	10	6,000.00	30.00	100.00	1,250.00	1,238.00	2,618.00	3,382.00
12:30	70	1	0	0	60	10	6,000.00	30.00	100.00	1,250.00	1,238.00	2,618.00	3,382.00
12:45	72	1	0	0	60	12	6,000.00	36.00	100.00	1,250.00	1,238.00	2,624.00	3,376.00
1:00	73	1	0	0	60	13	6,000.00	39.00	100.00	1,250.00	1,238.00	2,627.00	3,373.00
1:15	93	1	0	1	78	15	7,800.00	45.00	200.00	1,650.00	1,568.00	3,463.00	4,337.00
1:30	155	2	1	0	155	0	15,500.00	0.00	300.00	3,100.00	3,136.00	6,536.00	8,964.00
1:45	473	5	4	1	458	15	45,800.00	45.00	1,000.00	9,050.00	9,160.00	19,255.00	26,545.00
2:00	70	1	0	0	60	10	6,000.00	30.00	100.00	1,250.00	1,238.00	2,618.00	3,382.00
2:15	62	1	0	0	60	2	6,000.00	6.00	100.00	1,250.00	1,238.00	2,594.00	3,406.00
2:30	170	2	1	0	155	15	15,500.00	45.00	300.00	3,100.00	3,136.00	6,581.00	8,919.00
2:45	70	1	0	0	60	10	6,000.00	30.00	100.00	1,250.00	1,238.00	2,618.00	3,382.00
3:00	64	1	0	0	60	4	6,000.00	12.00	100.00	1,250.00	1,238.00	2,600.00	3,400.00
3:15	108	1	0	1	78	30	7,800.00	90.00	200.00	1,650.00	1,568.00	3,508.00	4,292.00
3:30	79	1	0	1	78	1	7,800.00	3.00	200.00	1,650.00	1,568.00	3,421.00	4,379.00
3:45	79	1	0	1	78	1	7,800.00	3.00	200.00	1,650.00	1,568.00	3,421.00	4,379.00
4:00	98	1	0	1	78	20	7,800.00	60.00	200.00	1,650.00	1,568.00	3,478.00	4,322.00
4:15	50	0	0	2	36	14	3,600.00	42.00	200.00	800.00	660.00	1,702.00	1,898.00
4:30	64	1	0	0	60	4	6,000.00	12.00	100.00	1,250.00	1,238.00	2,600.00	3,400.00
4:45	70	1	0	0	60	10	6,000.00	30.00	100.00	1,250.00	1,238.00	2,618.00	3,382.00
5:00	69	1	0	0	60	9	6,000.00	27.00	100.00	1,250.00	1,238.00	2,615.00	3,385.00
5:15	45	0	1	0	35	10	3,500.00	30.00	100.00	600.00	660.00	1,390.00	2,110.00
5:30	55	0	1	1	53	2	5,300.00	6.00	200.00	1,000.00	990.00	2,196.00	3,104.00
5:45	60	1	0	0	60	0	6,000.00	0.00	100.00	1,250.00	1,238.00	2,588.00	3,412.00
6:00	96	1	0	2	96	0	9,600.00	0.00	300.00	2,050.00	1,898.00	4,248.00	5,352.00
		30.00	**10.00**	**28.00**		**TOTAL**	**261,800.00**	**768.00**	**6,800.00**	**54,700.00**	**52,980.00**	**115,248.00**	**146,552.00**

APPENDIX D

Appendix D1

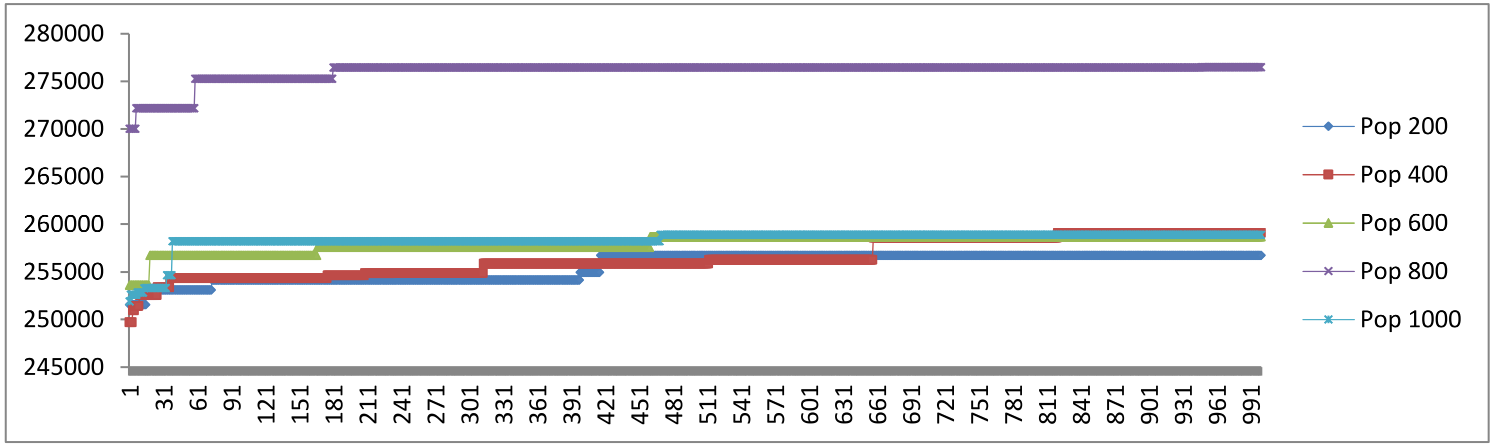

Figure D1: Bosso Exam Period Best Cost Variations with Population Sizes

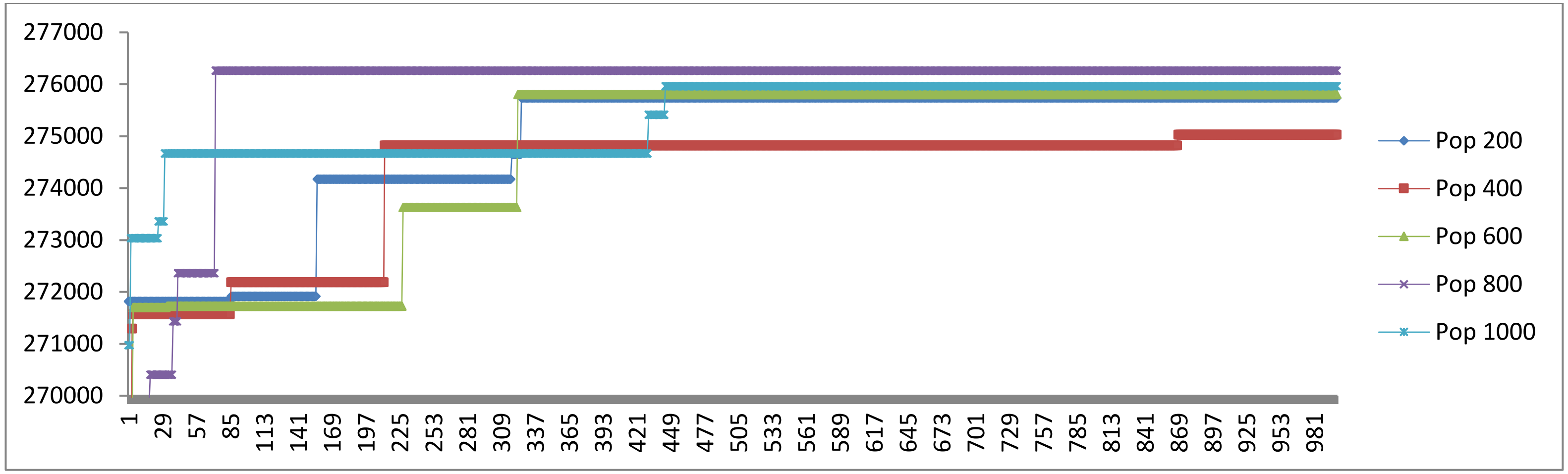

Figure D2: GK Exam Period Best Cost Variations with Population Sizes

Appendix D3

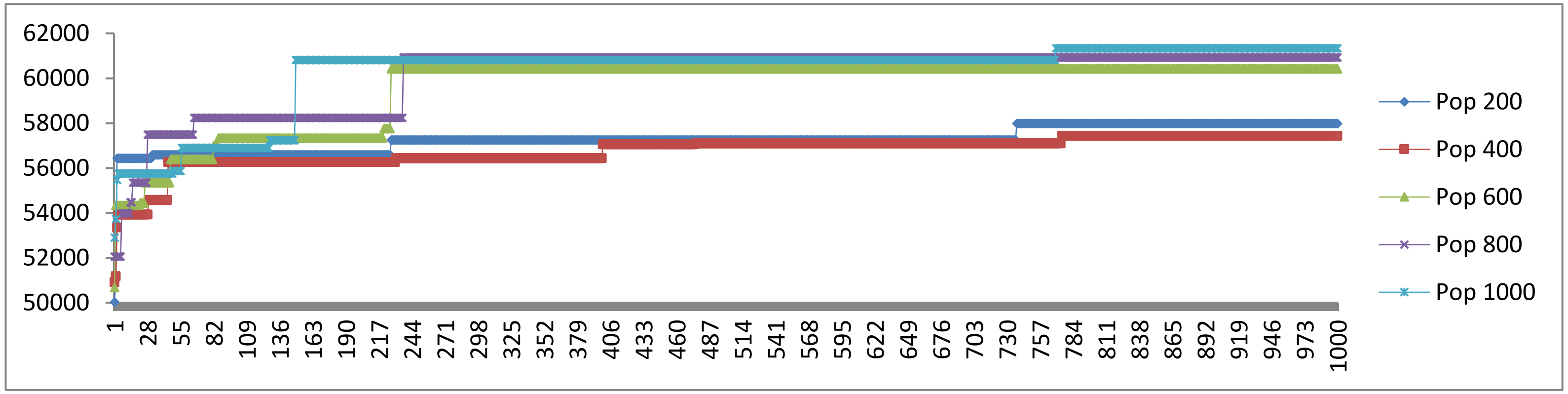

Figure D3: Bosso Lecture Period Best Cost Variations with Population Sizes

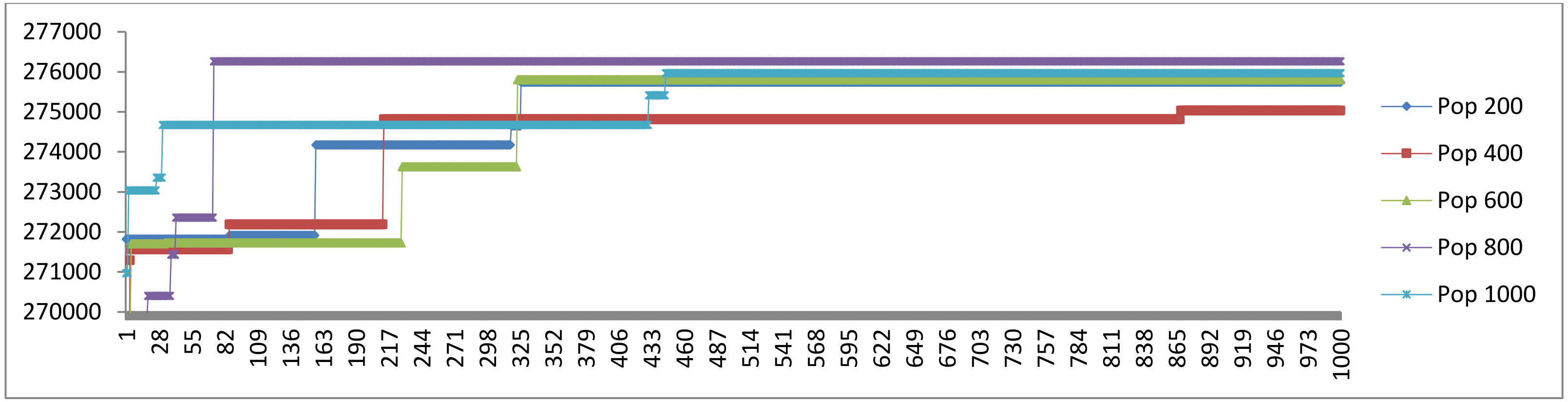

Figure D4: GK Lecture Period Best Cost Variations with Population Sizes

APPENDIX E

Table E1: Bosso Exam Period Bus Time Table

	Departure Time																																																
Buses	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:46	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
60	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
60	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
35	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
35	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
35	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
35	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
35	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
18	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
18	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0
18	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
18	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
18	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
18	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
18	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0
18	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0
18	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
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18	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0

Table E2: GK Exam Period Bus Time Table

	Departure Time																																																
Buses	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:46	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
60	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
60	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
60	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
35	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
35	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
35	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
35	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
35	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
18	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0
18	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
18	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0
18	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0
18	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
18	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0
18	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0
18	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
18	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
18	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
18	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
18	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0

Table E3: Bosso Lecture Period Bus Time Table

Departure Time

Buses	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:46	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
60	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
60	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
60	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
60	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
35	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
35	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
35	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
35	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
35	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
18	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
18	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
18	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
18	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
18	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
18	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
18	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0
18	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
18	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
18	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0

Table E4: GK Lecture Period Bus Time Table

Departure Time

Buses	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:46	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
60	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
35	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
35	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
35	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
35	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
18	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
18	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0
18	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0
18	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
18	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0
18	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
18	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
18	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0
18	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
18	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
18	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
18	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
18	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
18	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0

APPENDIX F

Table F: Summary of Trip Generations

	Departure Time																																																	
Bus Types	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:46	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00	Total rips
18	5	3	1	2	1	3	7	2	2	1	3	7	2	1	4	1	7	5	0	2	1	6	7	1	2	1	8	4	1	2	4	8	3	2	2	3	7	3	2	3	5	7	3	2	2	5	5	3	0	161
35	0	2	0	2	0	0	0	1	3	0	1	0	1	0	1	3	0	1	0	1	0	1	3	1	0	0	2	0	1	1	1	1	0	1	2	0	1	1	0	1	1	3	0	1	1	0	1	1	0	41
60	0	1	0	1	0	0	0	0	1	0	0	0	0	3	1	0	0	2	0	0	0	1	0	0	1	2	1	0	0	1	0	0	2	2	2	0	0	0	0	0	3	3	2	0	0	0	0	0	0	29
18	2	5	2	3	1	2	4	2	2	3	2	3	0	5	4	1	2	0	6	4	1	3	3	6	4	1	3	1	8	4	2	3	0	7	5	3	2	1	6	3	6	2	2	5	3	6	2	2	0	147
35	1	0	1	0	1	1	1	1	0	1	0	2	0	2	0	0	3	0	1	0	3	0	1	2	0	2	0	3	0	1	3	0	1	0	3	0	2	2	0	1	0	3	0	2	2	0	1	0	0	47
60	1	0	0	0	0	1	0	1	0	0	2	0	0	0	0	0	0	2	1	1	1	0	0	2	1	1	1	2	0	0	1	2	1	1	2	1	0	0	2	2	1	2	1	1	0	0	2	2	0	38
18	2	4	0	3	2	5	3	1	5	2	3	4	1	2	3	3	3	2	2	1	5	6	3	3	1	4	4	3	3	3	5	4	2	3	5	3	4	3	3	4	2	5	3	3	5	1	5	3	0	149
35	2	0	0	1	0	0	0	2	1	0	0	1	1	0	1	1	1	1	2	1	0	1	1	0	0	3	1	0	1	1	1	0	3	1	0	1	1	1	0	3	1	0	1	1	1	0	3	1	0	42
60	0	0	1	0	1	1	0	1	0	1	1	0	0	1	0	1	0	1	2	0	0	0	0	1	1	1	2	0	0	0	0	0	3	2	2	0	1	0	0	0	2	2	2	0	1	1	0	0	0	32
18	1	3	2	0	4	3	3	4	0	5	3	4	7	0	1	3	6	8	1	1	2	6	6	1	2	2	5	4	1	2	3	4	5	2	3	3	3	4	3	5	3	4	3	3	5	4	4	4	0	155
35	0	0	0	2	1	0	1	0	1	0	0	2	1	2	0	1	0	0	1	1	3	0	1	0	0	1	1	4	0	1	0	0	1	1	4	0	1	0	0	1	1	4	0	1	0	0	1	1	0	40
60	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	1	2	1	0	1	0	0	1	1	1	1	0	1	1	1	1	1	0	1	0	1	2	1	0	1	0	1	0	0	27