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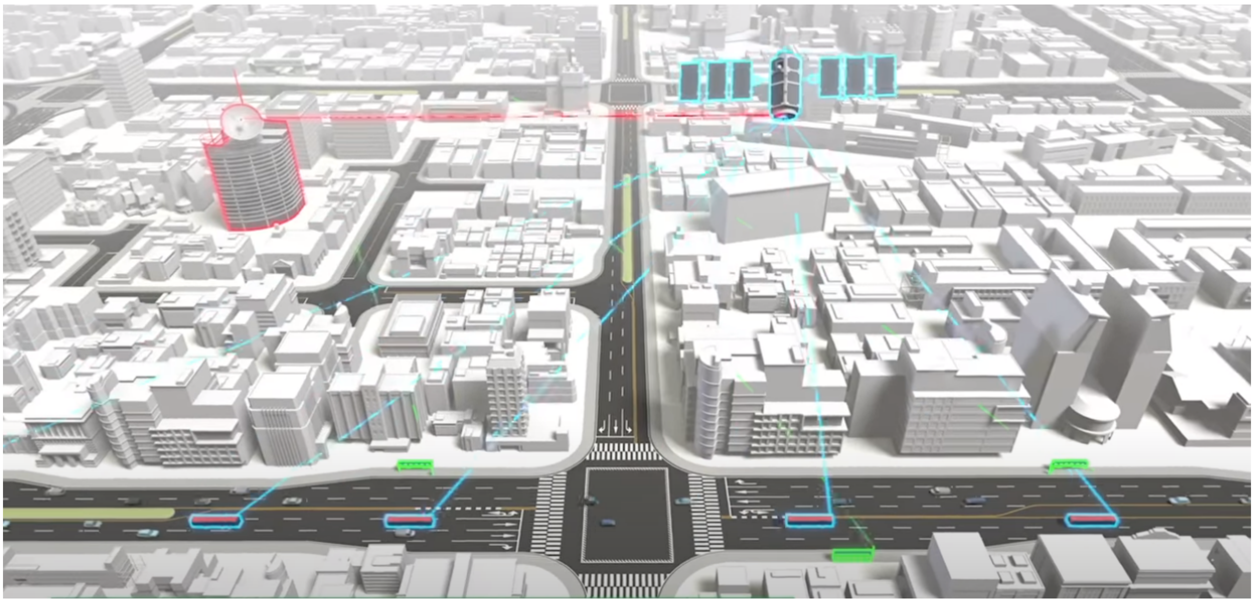

Enhancing the mobility services by the implementation of real-time passenger information system in the capital city of Kigali, Rwanda

Master's thesis in Master Programme Infrastructure and Environmental Engineering

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Abstract

One of the most essential measures of urban modernity and civilisation is the availability of developed efficient, safe, accessible, and environmentally sustainable public transport. This thesis studies the impacts of implementing a Real-Time information system (RTPIS) in the public transport of Kigali, the capital city of Rwanda. Four modes of transport are investigated, three are currently in operation i.e., bus, car, motorbike and one additional hypothetical mode i.e., a bus equipped with RTPIS referred to as iBus. The assessment showed that the key attributes influencing commuters transport mode choice in Kigali are waiting time, in-vehicle travel time, Cost, and crowding, from that a stated preference survey was developed to collect data of travel behaviour. Logit model theory was used to analyse the responses and Python Biogeme to estimate the attributes' coefficients. The results show that the commuters in Kigali value in-vehicle travel over waiting time and crowding. This suggests that the RTPIS should be implemented altogether with in-vehicle travel time improving systems such as bus dedicated lane. The value of waiting time and in-vehicle travel time are 0.089 USD/h and 0.043 USD/h respectively. The implementation of a real-time information system will potentially attract more commuters from 10.1 per cent to 36.2 percent of the total commuters in Kigali, this can make public transport the first traveller's attractive mode in Kigali currently being the last. Sustainable public transport in Kigali has to include the RTPI system because of its benefits such as congestion reduction, car ownership decrease, traffic emissions reduction and citizen satisfaction in public transport services.

Keywords: Kigali, RTPIS, stated preference, attributes, sustainability.

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Asghar Ali, Bertin Irakoze, Gothenburg, June 2021

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Abbreviations

RTDA: Rwanda Transport Development Agency
RTPIS: Real-time passenger information system
ITS: Intelligent transport system
PT: Public transport/ Public transit
RTPI: Real-time information system
iBus: Bus with information system
TT: Travel time
WT: Waiting time
CT: Cost
CD: Crowding
U: Utility
BC2: Bus crowding level 2
BC3: Bus crowding level 3
IBC2: Crowding level 2 for bus with information system
IB3: Crowding level 3 for bus with information system

1
Introduction

Public transportation that is developed, reliable, safe, accessible, and environmentally sustainable is regarded as one of the most important indicators of urban modernization and civilization [1]. The satisfaction level of certain bus routes has been low due to low bus service levels such as long waiting times at the bus terminal and a high average capacity rate [2]. Some commuters who are waiting at bus terminals will switch to alternative bus routes or other modes of transportation, such as taxis, shared bikes, motto, car-sharing, and so on. Some travellers will choose to use private motor vehicles for their next trips, reducing the mode share of public transportation and increasing the load on the road network during peak traffic periods. As a result, road traffic congestion, environmental pollution, and other external costs are beginning to emerge. To address these issues in the city, it is critical to implement measures to increase the appeal of public transportation and reduce commuters loss, particularly for passengers waiting at bus stations [3].
Public transportation appears to be the best option for saving money on new roads, reducing traffic congestion in urban areas, and lowering pollution. [4].

The city's overall structure and size, as well as its transportation network, established the necessary mobility standards for an entire region. One of the major problems in cities is the steady increase in car ownership and traffic levels as a result of the devolution of different activities within the cities. While people want to move quickly to different places, the situation has an impact on their daily lives. The challenge for sustainable transportation demands a shift away from the need for car mobility and towards combined modes of transportation such as buses, trams and metros. Concerning the entire public transportation network, buses are one of the most important and well-known components of efficient urban transportation, recommending a flexible as well as a sustainable mode of transportation to the public [5].

Considering all of these circumstances, it is critical to increase the use and desirability of bus systems designed for all groups of stakeholders. The intelligent transport system (ITS) suggests a significant opportunity for improving bus operations in urban areas. The ITS is a tool for improving service quality and providing new services to passengers. ITS systems are extremely prevalent in public transportation, but in most cases, they are merely oriented to passenger information and are therefore extremely expensive. The vast majority of small-city public transportation companies do not implement these systems because the costs are prohibitively expensive and the return is not justified [4].

The usage of ITS in public transportation has grown in popularity in recent years. Systems placed in public transportation vehicles, as well as terminals, stops and interchanges, are included in the ITS. A critical component of those systems for public transportation is the provision of real-time multimodal information on routes, departure times, potential interruptions, and connecting services to passengers. From a passenger point of view, these measures are very useful in reducing uncertainty about waiting, the duration of travel which is both very adverse to users of public transport, and in providing them with access to information of any kind, including fare, schedule, connections etc. These technologies are critical for controlling bus timetables, routes, and incidents, and so improving the bus service's reliability [5].

Bus schedules tell passengers when buses are scheduled to leave the terminal and when they might arrive at key stops, although actual departure and arrival times may differ from those listed. Regular commuter the timing of buses traveling on routes is affected by traffic congestion, road traffic lights, and a large number of persons boarding and disembarking from buses. Users prefer to be informed of the current situation in addition to having access to schedules, so they can plan around the deviation from the timetables [6]. Bus riders have shown a strong need to know how far away the next bus is from their stop.

Both transport operators and consumers benefit greatly from an accurate estimate of the estimated arrival time of the very next bus at specific bus stops. With this information, transportation operators might immediately respond to unplanned service interruptions and delays by implementing a variety of bus control tactics, such as holding and stop skipping. As a result, the entire value of transit service may be improved, making public transportation more user-friendly and engaging in comparison to other means of transportation such as driving [7].

Information on bus arrival times might also be distributed to passengers via electronic-boards mounted at bus stops, the internet, and cellular phones. Such information may be able to lessen passengers' anxiety while waiting for buses, as well as saving them time on their journey by allowing them to arrive at bus stops closer to schedules. Improved information thus aids in the retention of current passengers as well as the attraction of new trip producers who would not otherwise utilize public transportation.

Having access to a real-time passenger information system (RTPIS) for public transportation makes users feel safer, and it allows passengers to make better-informed decisions. Consumers are more keen to utilize buses than they were previously because of the improvements in punctuality and reliability that have resulted from the employment of buses (RTPIS). Passengers might demonstrate a higher perceived level of service when stations and buses are equipped with information devices, according to researchers.As a result, public transportation organizations and government authorities should provide more passenger-oriented services to the general public in order to promote population mobility [8].

The aim of the research to improve the public transportation system and implement the real-time passenger information system (RTPIS) in the capital city of Kigali, Rwanda, as well as to evaluate whether new technologies are offering more attractive bus provides the best in services and a better operation system, which can persuade car users to travel by bus. In the study, we assess various steps to be carried out for RTPIS throughout the city of Kigali and the impacts of RTPIS on the travel behaviour of the passengers.

1.1 Background and study area

Kigali city is the country's national capital and the greatest business centre in Rwanda. It has a high altitude, surrounded by tropical climate along with a mountainous landscape sprawling around the ridge and wet the valley. Kigali is the main city of Rwanda, with roughly 45 per cent of Rwanda's urbanized population [9]. It is situated almost in the centre of the country and its geographical position is on the latitude towards the south and longitude on the east side as illustrated in figure 1.

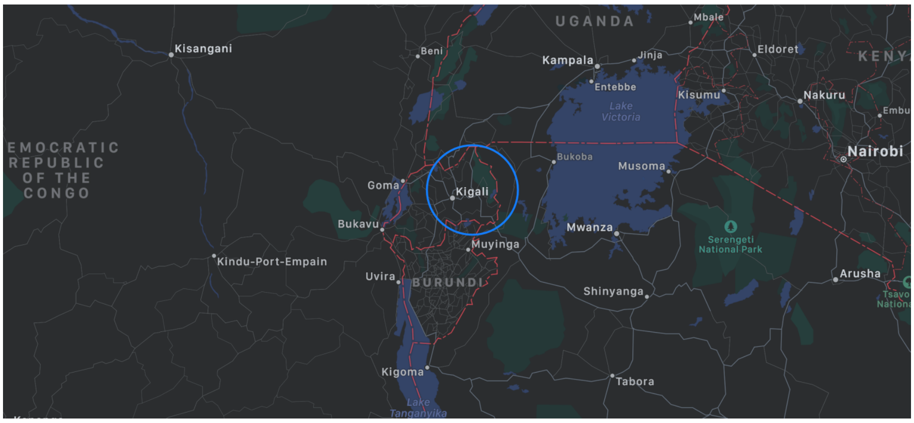

Figure 1.1: Kigali City

Rapid urbanization throughout the city had caused unplanned settlements, urban sprawl, and an increase in urban poverty. The fast growth of urban regions and population puts a particular issue to Kigali city. The rapid development influences the public transportation sector as well. The capacity of available buses for public transport is getting more and more ineffective in supplying the necessary services to the face of the increasing demand, while public transport is the mainstay of most travellers. Due to a limited range of the public transport routes network, the newly-developed sections of the city are lacking public transport service, as well as the people have to walk the long distance for access to bus stops [9].
Considering all the modifications to the Kigali is suffering, much more attention should be given to the problem of enhancing the public transport system, mostly in the term of the routes need to be managed as well as their service facility. Moreover, the implementation of a new system along with RTPIS will be also focused to

ease the mobility services through buses in the entire city. The vision of the State Government of Rwanda on Kigali public transport is to develop modern infrastructure as well as cost-efficient and quality essential services with due consideration given to the safety and the environment concerns in accordance with the vision 2050. Efforts would be made to improving urban public transportation services. An improved urban public transport system must by then to decrease the traffic congestion throughout the city, reduce pollution, and enable buses to sustain services throughout the day [10].

1.2 Research questions

This thesis aims to reveal how studying appropriately the travel behaviour of commuters in Kigali city and to assess the impacts of implementing real-time passenger information system (RTPIS) in Kigali city. To reach the objectives the following research questions to be answered:

- Steps to implement Real Time Passenger Information System (RTPIS) in public transport in Kigali
- Impacts of RTPIS on travel behaviour of the passengers
- A case study analysis based on travel choice modeling.

2

Literature

To acquire improved knowledge about the real-time passenger information system (RTPIS) as a whole and in the specific area of the thesis, which is Kigali city, a literature study has been carried out. Facts associated with the background and the features of the study area in terms of public transport system have been examined. To obtain a thorough understanding of the existing public transport and the bus without RTPIS of the Kigali city and future developments, reports from the Rwanda Transport Development Agency (RTDA) have been studied. Additional, numerous sources as books, scientific articles, and research publications from the foundation of this project are also analyzed.

Enabling travellers to identify their degree of pleasure is one typical method of evaluating real-time data. The majority of research have found that having real-time information is generally favourable and satisfying for travellers [11]. Arnström (1986), for example, concluded that 97 percent of passengers were satisfied with the system in a relatively early review of real-time information systems in the Stockholm Metro. Early studies of the London Transport Countdown system [12]. also shown a promising outlook [14].

Another strategy is to try to comprehend the perceived or actual benefits of real-time data. Despite the fact that not all research tell the same tale, the majority of them reach similar findings. The benefits of the countdown system were reported by respondents in an early study of the system in London, who said that their real waiting time at the bus stop had decreased, their perceived waiting time had decreased, and they felt safer while traveling [11]. Observational studies in London also demonstrated those stops equipped with real-time information had lower stress levels than other stops.

According to recent studies, real-time transportation solutions may potentially attract new passengers. According to a 2012 assessment of Chicago Transit Authority bus lines that have RTPI installed, the average daily ridership on those routes increased by 2 percent [13]. Similarly, a 2015 study of New York City's bus system found that after three years, the RTPI system had increased ridership by 2 percent, resulting in an additional 5 million USD in fare revenue.

In addition, a research conducted in Helsinki [15] verified same favorable results. Because passengers knew when the bus would arrive at the stop, there was less uncertainty, and they could make better use of their waiting time.

Finally, from a technical standpoint, there is far more hardware, software, and communication technologies available now than there were even ten years ago to make giving real-time information easier [15].

2.1 Passenger Information system and their applications

People who are using inner-city public transport vehicles need to obtain information about the current status of the public transport vehicles as well as they would want to know the travel time of vehicles that are both at the same time as travelling and are waiting for at the bus stops [16].

There are numerous ITS practical application to public transportation, depending upon the required purpose for example the Automatic Vehicle Location (AVL), Real-time Passenger Information System (RTPIS) both at bus stops and on-board buses, Automatic Fare Collection, Urban Traffic Control (UTC) and so on [5]. From within the passenger's perspective delivery of information is certainly the most significant service ITS be able to [17].

It is widely acknowledged that the RTPI systems offers considerable benefits to the public transport consumers, the current and potential, by offering a broad range of information. In this regard, RTPI a system that enhances public transport facilities and services provided by the help trip makers alter their travel behaviour to a more sustainable transport mode specifically the reduction of car use contributing to road decongestion and, in general, to a more well-organized transportation system. Hence, according to which RTPI systems have proven to be mainly developed to facilitate the usage of public transport across both recognized and actual reductions within the passenger waiting time and improve the passenger's satisfaction. The ability to access this information before travel may help in reducing the real waiting time when the information is made available to the traveller on the route; it could help to decrease the perceived waiting time [19].

Further, liable benefits of the RTPI systems are just as follows; increased willingness to pay, more effective and efficient travelling by making better use of waiting time, encouraging psychological impacts as decreased uncertainty, increased feeling of personal safety, creation of a general sense of trust in the public transportation system, increased easiness of use, the better overall image of the system, and greater passenger satisfaction. Various studies have been dealing with these problems coming to the same conclusions that RTPI systems provide numerous advantages to public transport consumers and that the vast majority of users are fairly satisfied with them [5]. Researchers in this area have investigated the possible impact of an introduction of RTPI systems on the perceived value of services and a broad range of bus services performance [17].

2.1.1 Benefits of RTPIS to passengers

Real-Time information could have a positive influence on transportation decision taken by the traveller. The assistance with traveller decision making outcomes in the passenger-oriented framework. Real-time information improves the traveller's experience through having an impact on various aspects involving:

- An individual's decisions to make a trip (Travel choice)
- The decision to take a specific transport mode versus another (mode choice)
- The specific route that the person takes on transit (route choice)
- The stop on which the individual boards a transit on transit (boarding stop choice) as well as
- The time at which a person leaves his/her origin to arrive at that stop or departure time choice.

In brief RTPIS impact passenger experience within five key themes. Three of these subjects are associated with the behavioural outcomes on travellers linked with RTPIS: those are the waiting time, travel time, and public transport they are using. The last two themes influence the passenger's decision-making process. These are passengers' emotions such as satisfaction with the public transport service and awareness such as the perception of the safety and protection of the public transport service [20].

2.1.2 Benefits of RTPIS to operators

Real-time information systems lead to an improvement in traveller satisfaction and raise the desirability of public transport. Therefore, more people would be persuaded to switch over from driving private vehicles to the public transport network for example increase in ridership resulting in the boost of the public transport operations business case.
RTPIS also helps the operators be able to analyse up to date the minute data when it becomes available and uses this data to attain greater planning capability by creating immediate adjustments and publishing more precise information about the service for travellers. Further RTPIS advantages to operates include decreased employees time necessary to monitor for schedule compliance with and intelligent solutions as well as platforms that eliminate the need for spreadsheets and other types of instruction manual data entry and management.

2.1.3 Benefits of RTPIS to authorities

Traffic congestion is one of the most widespread transport problems confronting several authorities, particularly in large urban areas. Improved passenger satisfaction resulting from the launch of RTPIS is leading to the modal switch from private car use to public transport modes. The growth in ridership decreases the levels of traffic and congestion on the city roads, thus reducing the extent of air pollution, greenhouse emissions, traffic accident costs, land-use consumption's such as is the case for a new road infrastructure development as well as the cost of building and transportation systems. An increase in ridership also has the possibility to relieve the subsidy levels for public transport funding. Moreover, improved passenger satisfaction can be viewed as an indication of decent supremacy [20].

2.1.4 Overall economic benefits of RTPIS

Investments in real-time passenger information systems for public transport brings many advantages to individuals, populations, as well as to the regional economy. It has been mentioned in the above paragraphs how RTPIS is leading to the modal switch from cars to public transport. This is the largest single phenomena that lead to most advantages in the overall economy of the country as described below:

- **Reduced traffic congestion:** Public transportation can convey a lot of people in much less space than individuals vehicles, which will help to maintain traffic congestion reduce, which in turns lowers air pollution caused by idling vehicles.
- **Public transportation reduces air pollution:** By relocating people more effectively and efficiently, public transportation generates substantially less air pollution per passenger mile than private transit.
- **Increased fuel efficiency:** Public transportation is also the greater fuel-efficient per passenger mile, thus contributing to an overall reduction in the amount of energy required for transportation.
- **Saves money for citizen:** Using public transportation rather than owning a vehicle could save individuals a substantial amount of money in avoided gas, maintenance, parking, and other expenditures. This increase disposable money for other expenditure which drives overall economic activity.
- **Public transportation is safer:** According to statistics, bus-related accidents occurs at a fewer rate, and which significantly lower passenger's fatality rates than car travel does. Therefore, public resources are saved for other medical reasons for example the emergency health care and rehabilitation.

2.2 Downsides of RTPIS

[18] identified some of the following limitations of the RTI system.

- **Technology adoption:** RTI was only accessible to individuals who had the necessary devices, such as PCs or internet-connected portable devices, therefore riders who lacked these technologies were unable to use it.
- **Awareness of real-time information:** During the time of the study, it is conceivable that many travellers were unaware of RTI.
- **Preliminary difficulties in understanding:** One of the major challenges regarding the implementation of new development projects is the acceptability and understanding among the decision-makers. Moreover, to effectively

establish this new RTPIS system, widespread training will be needed.

- **Initial cost/ RTPIS equipment are costly:** All new Public Transportation infrastructure must be developed from scratch which includes buses, terminals, control rooms digital applications and signboards.
- **Required new road infrastructure of development:** Provision of separate dedicated lanes for public transport has to be built across the whole city. Well-integrated sensors for data collection other support systems including GPS and digital applications have to be built and maintained for the whole project.

2.3 Different components and functionality of RTPIS

RTPIS makes that are available for the traveller all the feasible information about the condition of the transport system as precisely as possible in real-time. Such information could be digitally accessed through the authority, operators, as well as commuter simultaneously in both time and space, although with distinct levels of access. This is accomplished by utilising a combination of various technologies involving for example a Global Positioning System (GPS), communication systems, and cellular phone applications technologies [20].
[28]. The system of the RTPIS is to be implemented as follows and the concept of the entire system is shown in figure 2:

2.3.1 Bus unit

The unit within the bus carries out the following functions such as:

- It downloads coordinates of stops, names of stops and point of interest from a server.
- It calculates the current location and direction.
- It directs the computed information back to the central providing using GPRS.
- It is displaying on board information of passengers with audio announcements.

2.3.2 Server unit

The server unit will continue to maintain a database of all the relevant information of the buses as well as the routes on which these buses travel. It obtains the information of the speed of the bus as well as the current location of a bus. The administrator can easily get to see which bus is over speeding on a specific route.

2.3.3 Bus-Stop unit

The bus-stops module shows the information of all the incoming buses to that stop. It also displays the time required by the bus to reach that stop. Utilizing this information, the commuters will not be wasting their time waiting for the buses and can use alternative means of transport.

2.3.4 Bus arrival Prediction algorithm

The predicting bus arrival times make use of mathematical equations for example model bases on historical data, statistical models, Kalman filtering models as well as machine learning models.

Commercial passenger information systems

- Supplying information through wired wireless media such as SMS, web pages, location based advertisements etc.
- Establishing update notifications via social media for example Facebook and Twitter etc.
- Providing platforms to enhance passenger satisfaction for example complaints feed.
- Offering platforms to facilitates payments through various mobile apps-based ticket purchases and on-board technologies for the ticket buying.

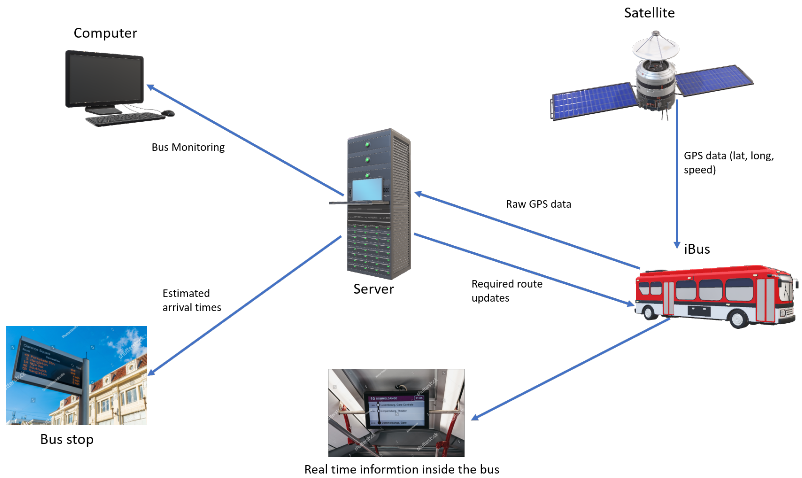

Figure 2.1: RTPIS system description [29]

2.3.5 Discussion

Since the RTPIS system, we will be able to get real-time information about the buses. We can foresee the time that it takes by the bus to get to the next stop and the passenger at the bus stop may be able to get to know how much time exactly it is going to take for the next bus to arrive. The bus panel will look as follows:

Figure 2.2: Bus Module

This module illustrates the distance to be covered to reach the next stop and exactly how long is it going to take to reach that stop. It also provides the latitude and longitude of the bus as well as how much distance that the bus already travelled. The admin module will seem as follow:

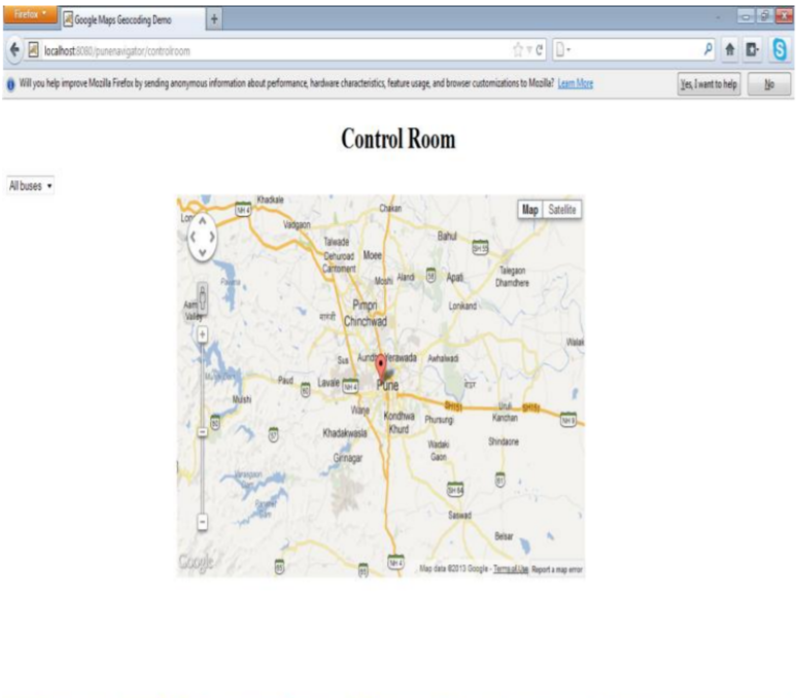

Figure 2.3: Server Module

This module offers all the information to the admin about the present location of a bus. It provides at about which speed a bus is travelling and helps prevent the bus from over speeding. This will help to monitor all the buses in a better way in comparison to the existing system. Finally, a bus module will look as follows:

Figure 2.4: Bus Stop Module

This module displays the time required for the incoming buses at the specific stop. Providing this information enables the passenger waiting time at the stops to decide for how much more time they can wait and then take alternative means of transport to reach their desired destination.

2.4 What digital infrastructure would be required

The key communication links between a transit agency and its drivers are a passenger information system. Passenger data technology enables a transit agency to inform its passengers of bus position and status updates in real-time, schedule and prompt announcements. The transit experience for riders would greatly enhance and improve work for agency staff [21].

Keeping passengers updated: The methods

Passenger information system technologies work in tandem with these features to provide riders with bus status and location information [22]. Transit agencies can choose which approach or mix of ways will best serve their customers while remaining within budget.

2.4.1 Wayside and transfer stations signs

Wayside signs are a frequent method of providing information to passengers. At bus stops or terminals, wayside signs notify passengers of the expected departure time of forthcoming vehicles. They're a good approach for transit authorities to manage and share information in a dynamic fashion. They can provide passengers with information such as time, temperature, and news updates in addition to scheduled bus departure timings. It is critical for transportation authorities to consider the benefits and drawbacks of putting roadside signs in order to determine whether they are a good fit for their operation.

Advantages

- Signs along the road are a great advantage for passengers. They may not be waiting and are unsure when the next bus will arrive.
- They are also added a communication device that helps drivers to identify where their desired buses are located.

Limitations

- Wayside signage are costly and may not be feasible for every municipality. Not only are the signs themselves costly, but the upfront expenditures of putting wayside signs, such as construction and power, are also substantial.
- Some say that wayside signs are no longer necessary because most people nowadays use cell phones. Passengers can access schedules and bus information just as readily by text message or a web-enabled mobile or smartphone.

2.4.2 Website

The majority of public transportation agencies have static schedules available on their websites. This is a good approach for travelers to acquire transit information, but it does not alert them in real time if or when the service is disrupted. An agency website with a passenger information system can provide passengers with much more than just a place to look up schedules. It can provide passengers with a full picture of their service as well as options to improve how they use public transportation. Here are a few things to think about.

Advantages

- Not only can public transportation agencies update static timetable information, but they can also update dynamic transit information. Next bus departure times, real-time bus locations, service delays, emergency information; whether updates or any other changing information the agency needs its clients to know are all examples of dynamic transit information.
- A website can interface with Google and Apple Maps, boosting versatility and providing passengers with a spot to organize their trip from start to finish without having to phone the agency.

Limitations

- Integrating the data feed into the website in real-time requires qualified developers and can be costly.
- The fact that a website provides information on real-time transits may take longer to invest so that data is up to date.

2.4.3 Mobile website

A mobile website offers simple and easy-to-use information. Here are some reasons why authorities may or may not wish to use a mobile website.

Advantages

- Allows passengers to get real-time transit bus information or check the status of their bus at any time, regardless of where they are.
- The majority of the important information that passengers will want to see is available on a mobile website.

Limitations

- The transportation agency will have to incur development costs.
- Smart phones are not used by all travelers, and this technology may not be appropriate for the elderly.

2.4.4 Real-Time SMS

According to recent statistics, 82 percent of individuals in the United States own a cell phone or other mobile device, and 72 percent of these adults send and receive text messages on their phones [23]. As a result, travellers will find that receiving real-time bus information by SMS is a highly helpful choice. Passengers waiting at a bus stop can text a designated phone number and the bus stop code found on the bus stop sign they are at to the authorities. In real time, the system will return the departure times of the next few buses departing that stop.

Advantages

- Having SMS options available at bus stops is a terrific way to stay in touch with passengers.
- Passengers can stay up to date while on the move.

Limitations

- SMS can be costly and difficult to establish.

2.4.5 Mobile applications

Another way to provide riders with real-time bus information is through mobile applications. There are various compelling reasons to consider selling mobile applications, as well as a few points to keep in mind before embarking on this journey.

Advantages

- The release of transit data allows developers to create valuable mobile applications for riders without requiring the authority to invest time or money in development.
- Software developers can take the lead and create apps with a variety of innovative features, many of which exploit data in ways transportation authorities hadn't thought.

- Mobile apps make public transportation more accessible to new riders and can encourage more people to utilize it.

Limitations

- Mobile applications aren't always compatible with all smartphone models. This means that an app designed for Apple customers will not work on Android devices and vice versa.
- Transit authorities have little control over what third-party developers generate if they create apps.
- There is always the risk that a part of the smart phone-using rider base may be left out unless public transportation authorities take complete control and develop mobile applications for every smart phone platform, which can be expensive.

2.4.6 Summary

In today's public transportation world, passenger information systems are becoming increasingly important. They're changing in response to the demand from riders for clear, timely, and real-time transit information.
Passengers and transportation agencies both benefit from the implementation of a passenger information system. Passengers benefit from the system since it provides reliable, real-time information about a bus's position, status, and expected departure time.
A passenger information system allows transportation agencies to provide real-time information in a variety of ways. Any combination of the strategies mentioned above can be used successfully. A passenger information system is certainly within reach if an organization currently has CAD/AVL technology in place that outputs web services.
A passenger information system allows transportation agencies to strengthen their communication networks while also increasing revenue and improving customer service and happiness.

2.5 Travel mode choice behavior

Scholars have raised numerous interconnected concerns about travel behaviour with real-time transit information from the standpoint of the traveller [24]: What kind of transport data are valuable and appealing to users? What factors influence how people use real-time transport information? What is the value of this kind of information, as assessed by travellers' willingness to pay for it? And how would passengers react psychologically and behaviourally to real-time transit information?

Many academics identify sustainable travel behaviour as a crucial factor in the development of socially, ecologically, and economically sustainable communities. The mode of travel is an important consideration while planning a trip. The optimal travel option should provide the most efficiency, the best program, and the most traveller happiness.

The influencing factors of travel mode choice behaviour: It is widely acknowledged that the current rate of human expansion is unsustainable, and that a concerted effort must be made to persuade individuals to abandon driving in favour of more environmentally friendly forms of transportation [25].

Travel demand is influenced by mode choice, which includes personal vehicles, public transportation, and non-motorized modes. As a result, it has a substantial impact on sustainability, air quality, traffic congestion, and system operating costs, among other things. Various aspects, such as traveller's characteristics and alternative specifics, influence mode choice of travel behaviour [26].

Travel mode selection is a complicated decision-making process that is influenced by a variety of elements, including passenger characteristics, travel characteristics, and the service level of different bus routes, and passengers may pick different modes of transportation in different scenarios. Individual preferences toward less tangible features like as comfort and convenience have attracted substantial attention in the recent two decades, despite the well-known impact of instrumental factors such as trip duration's and trip prices in deciding mode choice [27]. It is a form of commodity consumption, and the method of transportation chosen is essentially a consumer's decision. Individual features of each passenger, such as gender, education, and occupation, have an impact on choosing behaviour, which is influenced by cultural variations. Passengers often face an unknown or uncertain waiting state factor, which is particularly stressful if they have certain travel time limitations for passengers with different travel objectives. It will be relatively obvious and increase your expectation and cause negative emotions which can influence the degree of satisfaction of the bus and the waiting of passengers [3]. Such information has to be accounted for when developing logit models as it will significantly improve travel times and passenger satisfaction.

3

Survey design and data collection

3.1 Survey design process: Orthogonal design and utility balance

3.1.1 Alternatives and attributes

Designing the survey to study the travel behavior of commuters in Kigali, The first step was to assess the available transport modes and selecting transport modes for the scope of this paper. The available transport modes alternatives are private car, public buses, Yego cabs taxi, move ride, motor bicycle (Moto), bicycle and walking [30]. In this paper, the non-motorized transport modes are not included due to the research scope and usually the non-motorized modes are used for short distances while the modes considered are used for commuting a long travel distance. Yego cabs and move rides are a kind of Uber version for Kigali which are considered in this paper as private car mode. An addition of one hypothetical transport mode; a bus equipped with a real time passenger information system (iBus) is added to existing commuting alternatives because this research aims to study the impact of implementing this type of travel mode in Kigali. This resulted in the scenario of four alternatives: Bus, Car, Moto and iBus.

The second step was to identify the key variables or attributes considered by commuters in choosing any transport mode. Attributes influencing the mode choice decision in Kigali were obtained from interviewing the public transport regulator and literature [31]. The findings showed that the decisive generic attributes on four mode choices to consider are travel time, waiting time, cost, and crowding. The survey design requires creating scenarios of mode choices with defined attribute levels. Travel time, waiting time and cost are attributes with measured quantity, which is not the case for crowding. Crowding is defined based on available levels.

- **Level 1:** Not crowded with seats available
- **Level 2:** Not crowded with no seats available
- **Level 3:** Crowded with no seats available

The following table 3.1 shows the alternatives and their defined attributes levels.

Alternatives	Attributes	Levels
Bus	Waiting time	(15, 25, 45) min
	In vehicle travel time	(30, 45, 60, 75) min
	Cost	(300, 400, 500, 650) Rwf
	Crowding	(2, 3) Levels
Car	Waiting time	No waiting time
	In vehicle travel time	(15, 25, 35, 45) min
	Cost	(1500, 2500, 3000, 3500) Rwf
	Crowding	No crowdedness
Moto	Waiting time	No waiting time
	In vehicle travel time	(15, 25, 35, 45) min
	Cost	(500, 800, 1200, 1800) Rwf
	Crowding	No crowdedness
iBus	Waiting time	(2, 5, 10) min
	In vehicle travel time	(20, 30, 45, 60) min
	Cost	(350, 450, 550, 700) min
	Crowding	(1, 2, 3) Levels

Table 3.1: Alternatives and their defined attributes levels

3.1.2 Orthogonal design

To generate all the possible choice situations, in case of four alternatives each having two or four attributes with different attribute levels two, three and four, the total number of combinations is more than ten thousands choices. Another way is to select some choice scenarios randomly; the problem with this option is that a respondent might face only low or only high values of attributes leading to wrong results. To overcome all those shortcomings of the previous option discussed above, it requires choosing subsets of a certain number of choice situations from the overall choice situations, and this should be done in a manner that attribute levels are balanced [32]. Orthogonal designs sort-out subsets in a more professionally structured manner. This is a design method for studying multiple factors and multiple levels. It selects choice scenarios representing the total number of choice situations based on orthogonality. A design is orthogonal if it fulfills attribute level balance, and all parameters are independently estimable; these representative choice scenarios should be uncorrelated [34]. In designing the orthogonal choice situation, SPSS Statistics is adopted to generate scenarios. Sixty-four scenarios are generate. See appendix A.

3.1.3 Utility balance

Six-four scenarios is still a large number of choice scenarios for a single respondent to face in a survey, in addition dominating alternatives should be avoided. [35]. If there are dominating alternatives in a choice set, it creates a subjective state in which one alternative is an obvious choice. To deal with that, utilities balance is used. Utility balance is a method that balance the utility of various alternatives to prevent leading options in the set of scenarios [33]. Comparing the design output of various efficiency criteria and a number of discrete models. B-error, C-error and D-error are efficiency criteria, for design objectives each put emphasis measures that differ. B-error attempts heighten the percentage of scenario with balanced utilities. C-error attempts to reduce the variance of the fraction of two variables. In designing D-error attempts to compute the variance-co-variance determinant matrix. B-error built on utility balance of scenarios is used. The first 18 scenarios with least utility average difference were selected for the survey questionnaire. See appendix B.

	Block 1											
Scenarios	**TT bus/min**	**WT bus/ min**	**Cost bus/ Rwf**	**Crow/level**	**TT car/ min**	**Cost Car/Rwf**	**TT moto/min**	**Cost moto/Rwf**	**TT iBus/min**	**WT ibus/min**	**Cost iBus/Rwf**	**Crow ibus/level**
1	45	15	300	2	35	2500	35	500	45	2	450	2
2	30	25	400	2	25	2500	25	800	30	5	450	1
3	30	45	500	2	35	3000	35	1200	45	10	550	1
4	60	25	300	2	45	1500	45	1200	45	2	450	3
5	60	15	400	3	35	2500	35	1800	60	5	350	2
6	75	15	500	2	45	3000	45	800	30	10	350	3
	Block 2											
	TT bus/min	**WT bus/ min**	**Cost bus/ Rwf**	**Crow/level**	**TT car/ min**	**Cost Car/Rwf**	**TT moto/min**	**Cost moto/Rwf**	**TT iBus/min**	**WT ibus/min**	**Cost iBus/Rwf**	**Crow ibus/level**
7	30	15	300	3	15	3000	35	1200	30	5	700	2
8	45	15	650	2	25	3500	25	1200	45	2	350	3
9	45	25	500	3	15	3500	25	1200	20	5	700	2
10	60	25	300	2	45	3000	25	500	60	5	550	3
11	75	15	500	2	45	2500	15	1200	60	2	450	2
12	30	45	500	2	35	1500	15	500	60	2	450	2
	Block 3											
	TT bus/min	**WT bus/ min**	**Cost bus/ Rwf**	**Crow/level**	**TT car/ min**	**Cost Car/Rwf**	**TT moto/min**	**Cost moto/Rwf**	**TT iBus/min**	**WT ibus/min**	**Cost iBus/Rwf**	**Crow ibus/level**
13	45	15	300	2	35	1500	35	800	30	2	700	2
14	30	45	500	2	35	2500	25	800	20	2	700	2
15	60	15	400	3	35	1500	45	1200	20	10	550	3
16	75	15	500	2	45	3500	35	500	45	5	550	1
17	60	25	300	2	45	3500	15	800	20	10	350	3
18	75	25	650	3	35	3000	45	800	60	2	700	1

Table 3.2: Selected Scenarios

3.2 Scenario design

The quality of the questionnaire will dictate the quality of the responses and the usefulness of the data collected in this study; therefore, the questionnaire should be well structured as well as the question and avoid any pitfalls [36]. The attention is taken on the length of the questionnaire, the longer it takes, the more it discourages people from responding. To avoid the longevity of the questionnaire we split 18 scenarios into three blocks, each block with 6 scenarios then every respondent facing 6 scenarios to assure a better quality of the survey.

On the structure, firstly the introduction of the questionnaire should be accompanied by a concise and effective explanatory word in the introduction specifying: The references, in what context the survey is being carried-out, the purpose of the survey, the reason of interviewing the respondents, the anonymity of the survey and appreciate the time spent in responding [37]. Secondly, the questions appearing in the questionnaire can take different forms which will then have specific objectives and treatments. Generally, for the purpose of this study the questionnaires are of single answer multiple-choice questions except one question at the start of the questionnaire for people to choose yes or no. Overall the questions are classified by topic from general to specific questions like ownership of a car to specific questions depending on the previous response, the questionnaire end with socioeconomic questions (Age, Sex, Employment, level of study,). The questionnaire was formulated by avoiding words that are too technical, ambiguous, or too vague, the questions were simple and understandable. The primary language of the survey is English then translated in Kinyarwanda, the local language for a better and comfortable understanding as the survey was intended to be carried in Kigali, the capital city of Rwanda.

The survey was conducted online due to COVID-19 restrictions via google forms, Google forms is a survey platform offered by google. A graphical survey design principle was used to show the attributes of each mode alternative, it helps respondents to get the information quickly. Figure 3.2 shows an example of graphical representation of one scenario. For a full questionnaire See Appendix E.

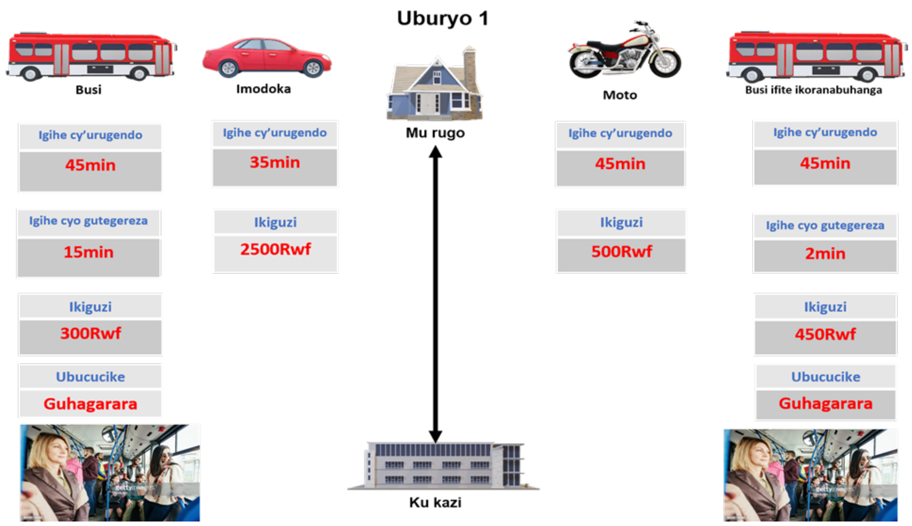

Figure 3.1: Graphical representation of one scenario

3.3 Collected respondent summary

Since the introduction of a bus system with real time passenger information system is a new transport mode in Kigali, it is imperative to base the assessment of its future impacts on stated preference data with a hypothetical alternative added to the existing alternatives [38]. The collection of survey data was carried-out on commuters in Kigali. Two types of questionnaires were distributed, one for car owners and another for the non-car owners. For car-owners four alternatives: bus, car, moto and iBus; for non-car owners three alternatives: bus, moto and iBus. 309 respondents filled the questionnaire, six stated choice scenarios were presented, intending to get 1854 choice situations however 1671 were obtained, see appendix C. The statistics of the valid respondents are illustrated in table 3.1. The sample data shows generally a good distribution of the questionnaire in terms of gender, work time flexibility, commute time.

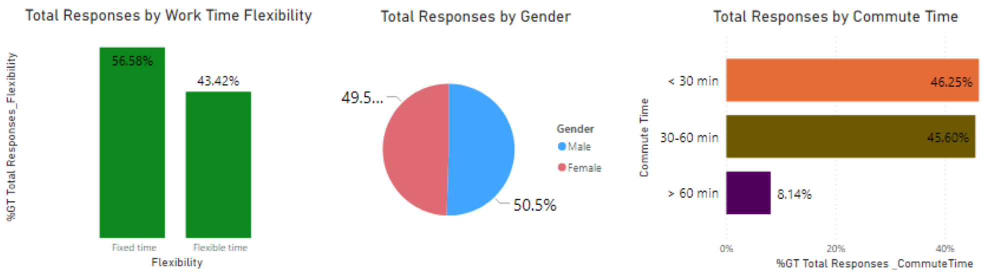

Figure 3.2: Total respondents by time flexibility, gender, and commute time.

however they are some bias in the collected data. The sample data shows uneven distribution of the survey mainly due to carrying the survey online. Firstly, a large number of young population has access to online service this implicated 74 per cent of respondents to be in 20-30 years of age. this accentuated by demography of Rwanda where a large number of population are young, 0-30 years shares 70 percent of the whole population [39].

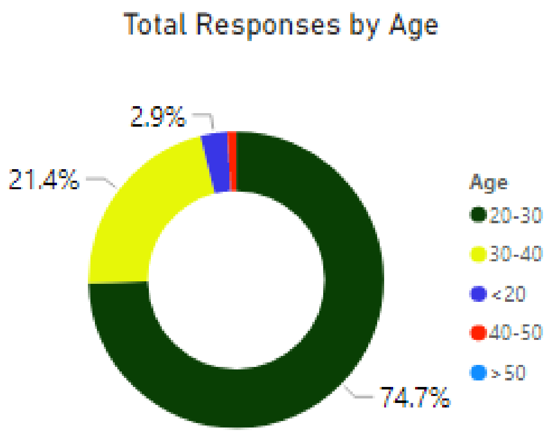

Figure 3.3: Respondents age range

Secondly, educated people are likely to easily use online platform, this caused the sample data to have 82 percent of bachelor's degree holder.

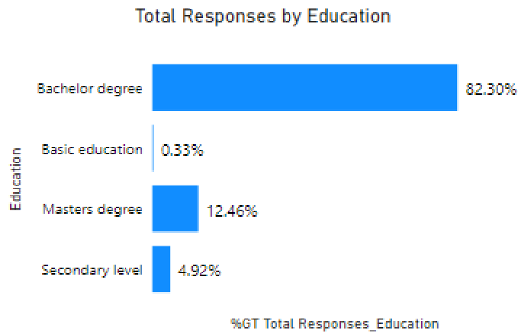

Figure 3.4: Respondents educations levels

Age	**%**	**Education**	**%**	**Flexible work time**	**%**
<20	2.90%	Basic level	0.30%	Yes	43.40%
20∼30	74.70%	Secondary level	4.90%	No	56.60%
30∼40	21.40%	Bachelor's level	82.30%		
40∼50	1.00%	Master and above	12.50%		
>50	0.00%				
Gender	**%**	**Commute time (min)**	**%**		
Male	50.50%	<30	46.30%		
Female	49.50%	30∼60	45.60%		
Marital status	**%**	>60	8.10%		
Not married	82.40%				
Married	17.60%				

Table 3.3: Statistics of valid respondents

4
Methodology

4.1 Logit model

In the analysis framework of commuters' behaviors while deciding how they are travelling to their destination, discrete choice models, centered on the random utility theory, have turned out to be one of the useful tools [42]. In transportation, they have essentially been used to mode choice, but moreover to the choice of route, destination, and other significant matters such as private car possession. In common practice, the often-used discrete choice models apply a linear fixed coefficient utility function in the parameters [40].

The charter for a discrete choice model is defined by a group of general hypothesis or assumptions; decision-maker, alternatives, attributes and decision rules. Decision-maker in discrete choice is considered to be a single individual because it is a desegregated model. assuming the decision-maker so called individual is governed by a specific application. For example, a household or a team of coworkers can be considered as a decision-maker. In this case only the decisions of a group of people is considered and the inner interactions in the group is ignored. The decision maker in this study is an individual person. To retain the diversity of the decision-makers preferences, the model includes the socio-economic variables of decision-makers gender, level of education, age range, marital status [42].

Alternatives are the available options to the decision-maker to choose from, this requires knowing not only the chosen option but all the options that was available before choosing. Therefore the assumptions should be made on all available options. The alternatives considered in this study are bus, car, moto and ibus altogether is the choice set. Further a distinction of the decision-maker with access to all or some alternatives is defined by deterministic criteria of having car or not having one.
Attributes is the characteristic of each alternative. Some attributes are generic to all alternatives such in-vehicle travel time and travel cost but other are alternative-specific, listing waiting time and crowding. Attribute are defined in two different form whether direct measure or a function of available data. In this study in-vehicle travel time, travel cost and waiting time are direct measure of their quantity contrary with the crowding which is the function of available data [42].

Decision rule is the procedure by which the decision-maker assess the attributes of different alternatives and make a choice. discrete choice model uses the utility theory. This assumes that a decision maker choose basing on a value, entitled utility. Then the decision maker choose alternative with high utility compared to other alternatives in the choice set. Discrete choice model has many forms such as binary logit model, multinomial logit model, hybrid logit model, nested logit and others. In this study, multinomial logit model is used. In multinomial logit model more than two alternatives is considered, it uses logistic distribution [42].

$$F(\varepsilon) = \exp\left[-e^{-\mu(\varepsilon-\eta)}\right],\ \mu > 0$$

$$f(\varepsilon) = \mu e^{-\mu(\varepsilon-\eta)} \exp\left[-e^{-\mu(\varepsilon-\eta)}\right]$$

[42]

Figure 4.1: Multinomial logit model

A commuter in Kigali referred as decision-maker can choose only one alternative from a choice set of n alternatives. Cn = 4 = 1 ,2, 3, 4 where (Alternative 1: Bus; Alternatives 2: Car; Alternatives 3: Moto; Alternative 4: iBus). The decision rule is governed by maximum utility, it means that the commuter will choose the alternative with maximum utility; The task is to define the alternative's utility functions (U1, U2, U3, U4). Constructing the utility function firstly depends on each alternative's observed and computed attributes.

- U1 = U (in-vehicle travel time, waiting time, cost, and crowdedness)
- U2 = U (in-vehicle travel time and cost)
- U3 = U (in-vehicle travel time and cost)
- U4 = U (in-vehicle travel time, waiting time, cost, crowdedness)

Assuming the utility function to be linear in terms of parameters representing the weight associated to each attribute which vary over different people, we get.

- U1 (bus) = $B\_TT * TT\_BUS + B\_WT * WT\_BUS + B\_CT * CT\_BUS + B\_CD * CD\_BUS$
- U2 (car) = $B\_TT * TT\_CAR + B\_CT * CT\_CAR$
- U3 (moto) = $B\_TT * TT\_MOTO + B\_CT * CT\_MOTO$
- U4 (iBus) = $B\_TT * TT\_IBUS + B\_WT * WT\_IBUS + B\_CT * CT\_IBUS + B\_CD * CD\_IBUS$

The theory of random utility explains that primarily the utility of an alternative depends on the defined observed attributes by the analyst as defined in the previous section and depends as well on unobserved attributes. unobserved attributes of each alternative are defined by random parameters [42]. therefore, the utility functions becomes:

- U1 (bus) = $ASC\_BUS + B\_TT * TT\_BUS + B\_WT * WT\_BUS + B\_CT * CT\_BUS + B\_CD * CD\_BUS$ (1)
- U2 (car) = $ASC\_CAR + B\_TT * TT\_CAR + B\_CT * CT\_CAR$ (2)
- U3 (moto) = $ASC\_MOTO + B\_TT * TT\_MOTO + B\_CT * CT\_MOTO$ (3)

- U4 (iBus) = $ASC\_IBUS + B\_TT * TT\_IBUS + B\_WT * WT\_IBUS + B\_CT * CT\_IBUS + B\_CD * CD\_IBUS$ (4)

Where ASC-BUS, ASC-CAR, ASC-MOTO, ASC-IBUS are the random parameters for bus, car, moto and iBus, respectively. B-TT is the parameter for in-vehicle travel time, B-WT is the parameter for waiting time, B-CT is the parameter for cost and B-CD is the parameter for crowdedness. TT-BUS, TT-CAR, TT-MOTO, TT-IBUS are the in-vehicle travel time attributes for bus, car, moto and iBus, respectively. WT-BUS and WT-IBUS are the waiting time attributes for bus and iBus. CT-BUS, CT-CAR, CT-MOTO, CT-IBUS are the cost attributes for bus, car, moto and iBus, respectively. CD-BUS and CD-IBUS are the crowdedness attributes for bus and iBus.

4.2 Estimation process

Maximum likelihood estimation is used to estimate the parameters in utility equations; ASC-BUS, ASC-CAR, ASC-IBUS, B-TT, B-WT, B-CT, B-CD. Maximum likelihood estimation is a method of determining the parameters values of a model in way that they maximize the probability that the described procedure by the model matches the observed real data [43]. The likelihood function for a whole data-set of choices scrutiny is the combined probability of the recorded observed series of choice decisions.

$$\mathscr{L}(\alpha,\beta) = P((c_1|C_1)\bigcap....\bigcap(c_N|C_N)|\alpha,\beta,X)$$

Figure 4.2: Likelihood function

Maximum likelihood method assumes that each time the observed choices are independent. This implies that the function of likelihood can be expressed as the product of single choice likelihood.

$$\mathscr{L}(\alpha,\beta) = \prod_{i=1}^{N} P(c_i|C_i)$$

Figure 4.3: Likelihood function

Maximum likelihood estimation is a nonlinear process. In this research, PANDABIOGEME is used, a programming package good in estimating discrete choice model using custom-built algorithms. For coding, a programming editor that uses python programming language called Jupyter is used see appendix D.

5

Results

The general results of the optimization process are presented in table 5.1, the generated coefficient of attributes for available transport modes altogether with statistical values. The t-test values show that the results of the coefficients are statistically significant. the t-test utilizes appropriate methodology to boil all the sample data to one value which is t-value. T-test compares null hypothesis to the sample data mean(s) and includes sample data variability and size. For statistical significance of the data, the absolute value of t-value should be greater than two [44]. This rule holds for all the coefficients except for car parameter coefficient (ASC_CAR) equals to 1.287007, this shows a sense of variance in respondents' choice but not large as the number is closer to two, this is the case as well for the coefficient of cost (B_CT) equals to 1.974205. The only coefficient that shows a large variance in respondents' choice is coefficient of waiting time (B_WT). The absolute value of $B_W T$ is 0.920344, this reveals a large weighting difference of waiting time of respondents.

	Value	**Std err**	**t-test**	**p-value**	**Rob. Std err **	Rob. t-test	Rob. p-value
ASC_BUS	-1.041553	0.132039	-7.888249	3.11E-15	0.13322	-7.818284	5.33E-15
ASC_CAR	-0.284613	0.221143	-1.287007	1.98E-01	0.219048	-1.299317	1.94E-01
ASC_MOTO	-0.373106	0.125661	-2.96914	2.99E-03	0.12574	-2.967286	3.00E-03
B_C2	-0.380006	0.118935	-3.845661	1.20E-04	0.121815	-3.754731	1.74E-04
B_C3	-0.457383	0.117207	-3.242186	1.19E-03	0.117861	-3.224199	1.26E-03
B_CT	-0.000173	0.000088	-1.974205	4.84E-02	0.000087	-1.990344	4.66E-02
B_TT	-0.015202	0.002847	-5.339853	9.30E-08	0.002838	-5.356859	8.47E-08
B_WT	-0.007402	0.008043	-0.920344	3.57E-01	0.008067	-0.91763	3.59E-01
IB_C2	-0.470477	0.132422	-3.552858	3.81E-04	0.131998	-3.56427	3.65E-04
IB_C3	-0.718427	0.14424	-4.980775	6.33E-07	0.144303	-4.978583	6.41E-07

Table 5.1: Coefficient of attributes for available transport modes altogether with statistical values

5.1 Behavioral interpretations

In-vehicle travel time and waiting time for public transits are among major attributes in travel behavior of commuters in the city of Kigali and a haunt problem to discover which is valued the most. The results show that the coefficients of in-vehicle travel time (B_TT) and waiting time (B_WT) are -0.015202 and -0.007402 respectively. In the utility functions calculations, B_TT causes bigger dis-utility of the mode than B_WT as the absolute value of the B_TT is larger than the absolute value of B_WT, therefore in-vehicle travel time weighs much than waiting time for the commuters in Kigali.

Coefficient	Value	Coefficient	Value	Coefficient	Value
B_CT	-0.000173	B_C2	-0.380006	IB_C2	-0.470477
B_TT	-0.015202	B_C3	-0.457383	IB_C3	-0.718427
B_WT	-0.007402				

Table 5.2: Attributes coefficients

Crowdedness in public transit is another important attribute, three levels of attributes are defined which correspondents to the real scenarios on ground. Level one is the base scenario, which makes its coefficient equal to zero. From there the results show that the coefficients of level two (B_C2) and three (B_C3) for normal are -0.380006 and -0.457383 respectively. For iBus the results show that the coefficients of level two (IB_C2) and three (IB_C3) are -0.470477 and -0.718427 respectively. Comparing the coefficient weather for normal bus mode or hypothetical iBus, in both modes the crowdedness level three (defined as the condition where the bus is crowded and with no seats available) causes more dis-utility in utility functions calculations than crowdedness level two (defined as not crowded with no seats available), because in both cases, $|B\_C3| > |B\_C2|$ and $|IB\_C3)| > |IB\_C2|$. Furthermore, if the comparison of two transit modes normal bus and the hypothetical iBus in terms of crowdedness reveals that the crowdedness in hypothetical iBus can cause more dis-utility than the crowdedness in normal bus in operation in Kigali. The judgement is based on the fact that the absolute values of coefficients of crowdedness of level two and three for hypothetical iBus are bigger than the absolute values of coefficients of crowdedness of level two and three for normal buses in operation.

From the generated attributes' coefficients of four transport modes made possible the computation of value of time for the travelers in Kigali. The value of time in transport is the equivalent monetary value a traveler is willing to spend to buy non-monetary attributes like travel time and waiting time in commuting or the monetary compensation if the time is lost [47]. The value of in-vehicle travel time in Kigali city is equal to the coefficient of travel time over the coefficient of travel cost, B_TT divided by B_CT = -0.015202 / -0.000173 = 87.87 Rwf / hr. (the unit of value of time is the currency by time. Rwf is Rwandan currency. 1 USD = 983.31 (Rwf). This means that a traveler in Kigali is willing to pay 0.089 USD to buy one hour of in vehicle travel time. The value of waiting time in Kigali city is equal to the coefficient of waiting time over the coefficient of travel cost, B_WT divided by B_CT = -0.007402 / -0.000173 = 42.78 Rwf / h. This means that travelers in Kigali are willing to pay 0.043USD to buy one hour of waiting time.

Marginal utility of attribute is the increase in utility due to the added unit value of that attribute [45]. In Kigali, if the travel cost increases by one Rwandan currency, the utility of travel time will be reduced by the coefficient of in-vehicle travel time (B_TT), -0.015202, the utility of waiting time will be reduced by the coefficient of waiting time (B_WT), -0.007402, the utility of travel cost will be reduced by the coefficient of travel cost (B_CT), -0.000173, for normal bus, the utility of crowdedness will be reduced by the coefficient of crowdedness depending level of crowdedness, level 2 is -0.380006 then level three is -0.457383 and lastly for the iBus the utility of crowdedness will be reduce by the coefficient of crowdedness depending as well on level of crowdedness, level 2 is -0.470477 and level 3 is -0.718427.

5.2 Policy implications

The study results reveal the travel behaviors and the mode choice of the commuters in Kigali city which can guide in policy development and transportation planning. Firstly, The Kigali public transport restructuring proposes the implementation of real time passenger information in the public transit, which is referred to as iBus in this study, while planning to implement this technology more attention can be given to travel time over the waiting time because the commuters in Kigali weigh the in-vehicle travel time more than the waiting time. Let take an illustrative example: The transportation organization plans to implement a public transit in Kigali from point A to B. Two options of buses are available to make a choice, the budget is the same for either option. The first option is to buy 20 normal buses with normal speed but with high frequency, the second option is to buy 15 faster buses. Assume all other factors are the same for the two options. The option is to take the bus system with less travel time as shown in the given table 5.3.

Table 5.3: Bus systems with less travel time

Options	Budget	No of buses	Waiting time	Travel time	Total time	Choice
Normal bus	Fixed	20	20 min	40 min	60 min	No
Faster bus	Fixed	25	10 min	50 min	60 min	Yes

Secondly, the dedicated bus lane in the case of Kigali can be a pre-implemented infrastructure before equipping the bus with RTPIS. The dedicated bus reduces the in-vehicle travel time being the crucial variable over waiting time in Kigali commuters, it is also one factor for the bus to reach the bus stops on time which make the RTPIS system work smoothly and the bus system more reliable. In transportation planning each project has the benefits and the cost, implementing infrastructure to reduce the travel time will require increasing to some extent the bus fare. This increase should be based on the willingness of the commuter to pay for those infrastructure, which is the value of travel time, 87.87 Rwf / hr (0.089 USD / hr).
The implementation of real RTPIS in public buses in Kigali can reduce the waiting time while increasing cost. The waiting time value is 42.78 Rwf / h (0.043 USD / h). In the implementation after estimating the amount of time that the system probably reduces to the usual waiting time. The bus fare can be increased based on the monetary value the commuters are willing to pay per unit time saved that is the waiting time value; 42.78 Rwf / hr (0.043USD / hr).

Once the buses with RTPIS are in operation, the crowdedness of the buses should be wisely regulated. Crowding measures must be developed to avoid the crowdedness in buses defined as level three (crowded with no seats). Crowding level three is six standees per m2. The coefficient of crowding level three is -0.718427, potentially causing more dis-utility for buses with RTPIS than the normal bus in operation because the rather has a lower crowding coefficient for crowding level 3; -0.457383.

5.3 Case study

The case study is an origin to destination case, from Kimironko Bus Park to Nyabugogo Taxi Park. A 11.9km trip from the main residential to a workplace areas in Kigali, illustrated in the given table 5.4. Commuter's choices among three transport modes available: Bus, Car and Moto bicycle. The hypothetical RTPIS is suggested as well, this mode will replace the buses according to the city authority in charge of transportation [46]. Attributes of bus mode are collected from the bus operator, as well as the attributes for moto are collected from the riders. The car attributes are collected from the car owners, except the travel cost, which is calculated from the data as follow: Average commuting car price in Kigali is 5,000,000 Rwf and taking a life span of 10 years, the daily usage is 1370 Rwf, considering two trips from home to work and from work in the evening, one trip cost 685 Rwf. In addition, there is fuel cost, 11.9km for fuel consumption of 16km/l with the fuel price of 1100 Rwf, fuel cost 818 Rwf adding 100 of parking fare the total travel cost for the car is 1603. The attributes for RTPIS buses are projected based on the normal bus attributes and the estimated coefficients. The travel demand is assumed to be to be 5000 people.

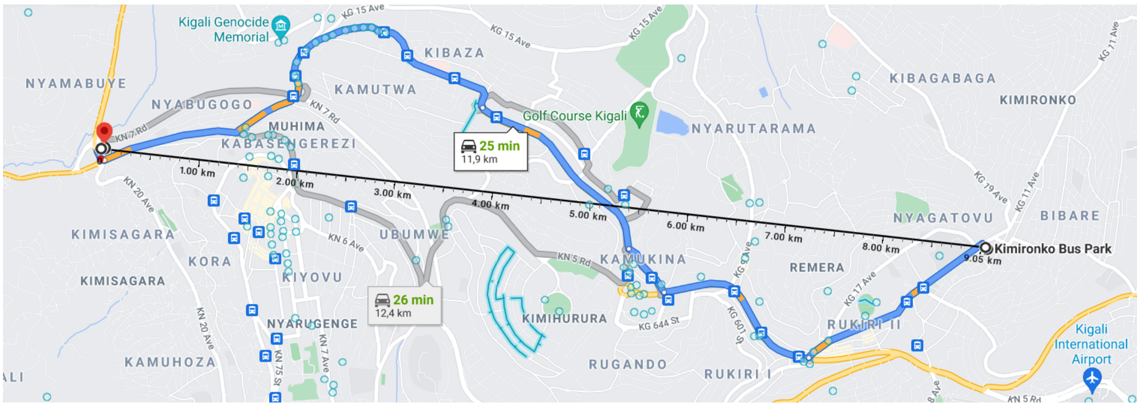

Figure 5.1: Kimironko Bus Park to Nyabugogo Taxi Park

Modes	Time	Waiting time	Travel time	cost	Crowding
Bus	Peak hours	15min	75min	370rwf	0.46/ft2
Car	Peak hours	0min	35min	1603rwf	0
Moto	Peak hours	0min	30	1200rwf	0
iBus	Peak hours	2min	45min	424	0.368/ft2

Table 5.4: Attributes of each transport mode

Utility functions of the current mode of transport:

- UBus = $ASC_$BUS + B_TT * TTBUS + B_WT * WTBUS + B_CT * CTBUS + B_C3*$Crowding\_bus\_level3$ = -1.041553 + (-0.015202 * 75) + (-0.007402 * 15) + (-0.000173*370) + (-0.457383 * 0.46) = -2.56

- UCar = ASC_CAR+(B_TT * TTCAR) + (B_CT * CTCAR) = -0.284613 + (-0.015202 * 35) + (-0.000173 * 1603) = -1.09
- UMoto = ASC_MOTO + B_TT * TTMOTO + B_CT * CTMOTO = -0.373106 + (-0.015202 * 30) + (-0.000173 * 1200) = -1.04

Probability of each mode:

- PBus = e-2.56 / (e-2.56 + e-1.09 + e-1.04) = 0.101 = 10.1
- PCar = e-1.09 / (e-2.56 + e-1.09 + e-1.04) = 0.438 = 43.8
- PMoto = e-1.04 / (e-2.56 + e-1.09 + e-1.04) = 0.461 = 46. 1

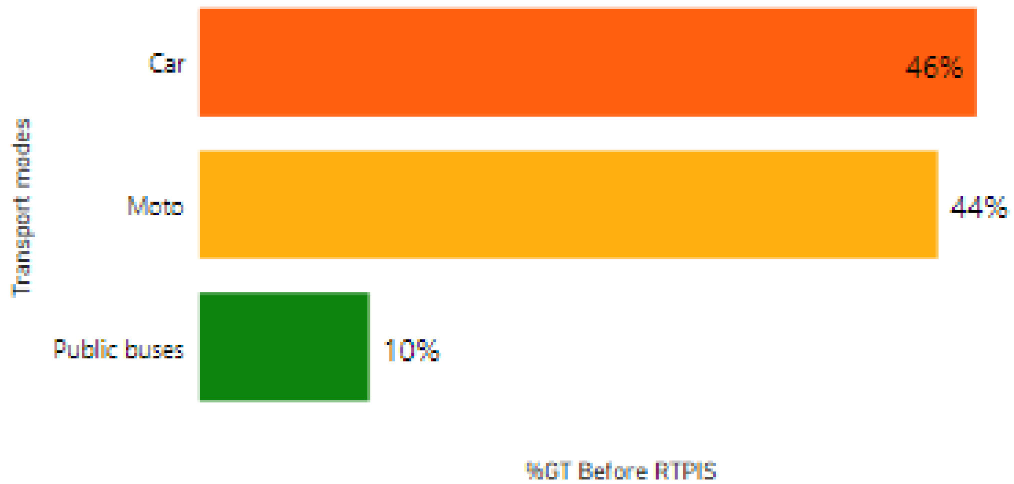

Figure 5.2: Transport mode shares before RTPIS

In the current situation, 46.1 percent of the population prefer commuting with private car and this makes the car the first attractive transport mode, the second mode of transport that attracts a large number is motor-bicycle with 43.8 percent and the public buses attract only 10.1 percent of the commuters.

Let check the mode share after implementation of buses with RTPIS.
Utility function when the buses are equipped with RTPIS:

- UCar = $ASC\_CAR + (B\_TT * TTCAR) + (B\_CT * CTCAR)$ = -0.284613 + (-0.015202 * 35) + (-0.000173 * 103) = -1.09
- UMoto = $ASC\_MOTO + B\_TT$ * TTMOTO + B_CT * CTMOTO = -0.373106 + (-0.015202 * 30) + (-0.000173 * 1200) = -1.04
- $ASC\_IBUS + B_TT$ * TTIBUS + B_WT * WTIBUS + B_CT * CTIBUS + IB_C3*Crowding_bus_level2 = 0 + (-0.015202 * 45) + (-0.007402 * 2) + (-0.000173*424) + (-0.457383 * 0.368) = -0.94

The probability of each mode

- PCar = e-1.09 / (e-0.94 + e-1.09 + e-1.04) = 0.311 = 31.1

- PmOto = e-1.04 / (e-0.94 + e-1.09 + e-1.04) = 0.327 = 32.7
- PiBus = e-0.94 / (e-0.94 + e-1.09 + e-1.04) = 0.362 = 36.2

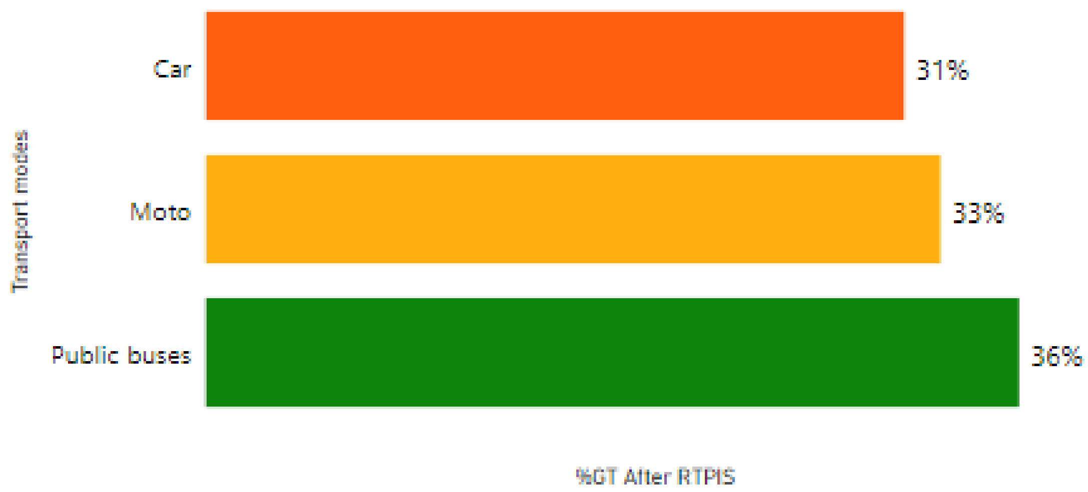

Figure 5.3: Transport mode shares after RTPIS

After the implementation of RTPIS in the Kigali bus system, the mode share will change in favor of a more sustainable mode, the public buses. Figure 5.5 shows that the public buses with RTPIS have a large share of 36.2 percent of the commuters while motor-bicycle and private car attracts 32.7 percent and 31.1 percent respectively.

By implementing the real-time passenger information system public buses mode will increase by 26 percent in terms of users as shown in 5.6 and private car and motor-bicycle will reduce by 15 percent and 11 percent respectively.

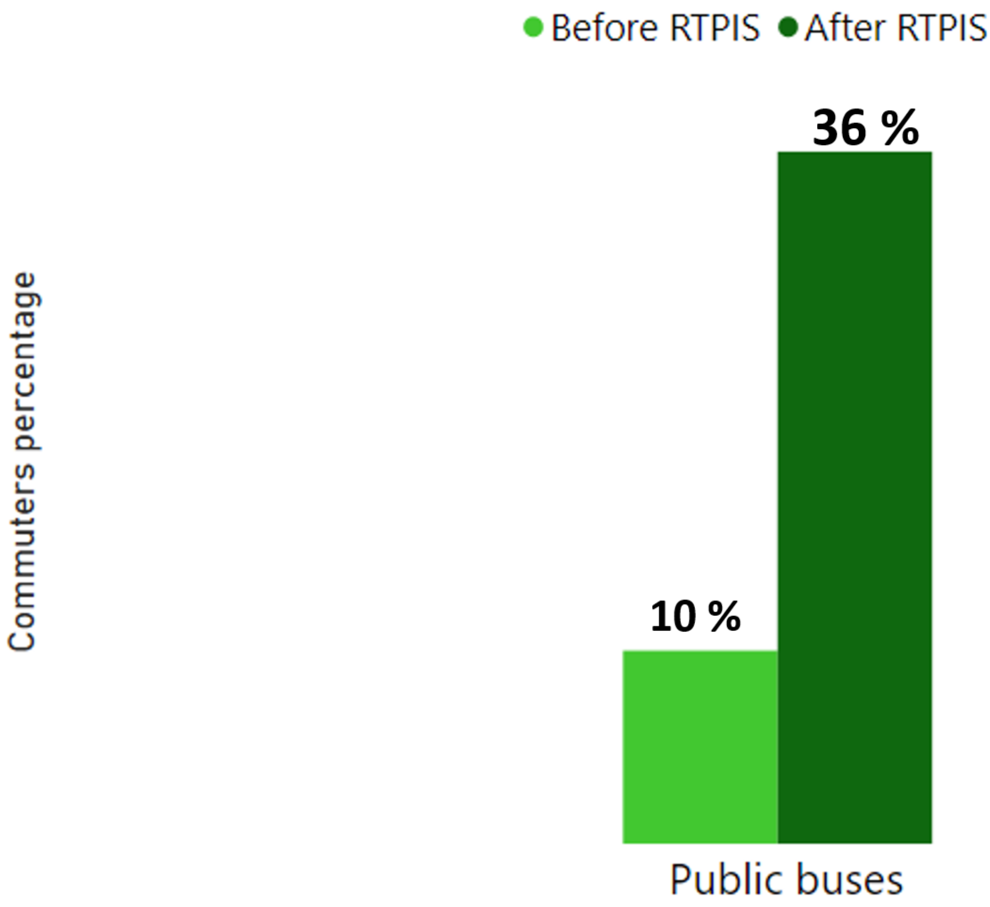

Figure 5.4: Public buses shift after implementation of RTPIS

6
Conclusion and limitations

6.1 Conclusion

In this thesis, a stated preference survey was conducted to scrutinize the transport mode choices of commuters in Kigali based on four attributes; in-vehicle travel time, waiting time, travel cost and bus crowding. The transport modes considered are composed of three existing modes i.e public buses, car, motor-bicycle and an hypothetical public buses equipped with real time passenger information system. Furthermore, travel behaviors of commuters in Kigali were studied to assess the impacts of installing the real-time passenger information system in public buses. A case study of commuters from one residential area to a workplace is studied.The main results and conclusions of this research are summed-up below:

- In-vehicle travel time, waiting time, travel cost and crowding are the main factors influencing transport mode in Kigali.
- In-vehicle travel time weighs more than waiting for Kigali commuters as the absolute value of in-vehicle travel time coefficient is larger than the absolute value of waiting time coefficient which are 0.015202 and 0.007402 respectively.
- The value of In-vehicle travel time is double the value of waiting as calculated. The value of in-vehicle waiting is USD 0.089 per hour while the value of waiting time is USD 0.043 per hour. As results, it is advisable to put in place infrastructure that reduces in-vehicle travel time like bus dedicated lane for the success of real-time passenger information system in public buses in Kigali.
- Commuters in Kigali choose to take less crowded bus both for the current public buses in operation and the planned bus system with RTPI system. The coefficients of bus crowding level two and level three are -0.380006 and -0.457383 respectively. The coefficients of bus with RTPIS crowding level two and three are -0.470477 and -0.718427 respectively.
- The comparison of the crowding coefficient for both bus systems shows that commuters in Kigali expect the planned buses with RTPIS to be less crowded in peak hours than the current bus system in operation. In addition the crowding level three i.e 5 person per square meter is to be avoided while implementing bus with RTPIS because it can create more dis-utility.
- According to the case study results, the current transport modes share in

terms of attracting commuters are; 46 percent for private car, 44 percent for motor-bicycle and 10 percent for public buses. After equipping the public buses with RTPIS, the transport modes share in terms of attracting users will be; private car: 31 percent, Motor-bicycle: 33 percent and public buses with RTPI system: 36 percent.

- The public buses equipped by RTPI system will attract more users more than any other transport mode currently in operation in Kigali i.e private car and motor-bicycle. The public buses will increase in attracting the commuters by 26 percent while the private car and motor-bicycle will decrease by 15 percent and 11 percent respectively.

6.2 Limitations

limitations observed while carrying-out this thesis are:

- Due to COVID-19 restrictions the data collection was carried online, which caused some bias in the data, if the conditions were favorable, face to face survey might have given better quality data.
- Rwanda as a developing country, the research sector is under-development, which made the data availability scarce while conducting this research.
- The time was short to touch the necessary aspects of this important topic in Kigali, we recommend more research to explore further the travel behaviors in Kigali.

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A
Orthogonal scenarios generated using SPSS statistics

Profile Number 1												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
1	30min	45min	500Rwf	2L	35min	3500Rwf	45min	1800Rwf	30min	5min	350Rwf	1L
Profile Number 2												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
2	45min	15min	300Rwf	2L	35min	3000Rwf	15min	1800Rwf	20min	5min	350Rwf	1L
Profile Number 3												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
3	60min	45min	650Rwf	2L	15min	1500Rwf	45min	1200Rwf	60min	5min	700Rwf	1L
Profile Number 4												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
4	60min	15min	400Rwf	3L	35min	3000Rwf	25min	500Rwf	30min	2min	450Rwf	1L
Profile Number 5												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
5	75min	45min	300Rwf	3L	25min	3000Rwf	45min	800Rwf	45min	5min	450Rwf	2L
Profile Number 6												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
6	45min	15min	650Rwf	2L	25min	1500Rwf	35min	800Rwf	20min	5min	450Rwf	1L
Profile Number 7												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
7	30min	45min	500Rwf	2L	35min	2500Rwf	25min	800Rwf	20min	2min	700Rwf	2L

Profile Number 8												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
8	60min	45min	650Rwf	2L	15min	3000Rwf	25min	500Rwf	45min	2min	350Rwf	2L
Profile Number 9												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
9	45min	25min	500Rwf	3L	15min	3000Rwf	15min	1800Rwf	60min	10min	450Rwf	2L
Profile Number 10												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
10	60min	25min	300Rwf	2L	45min	2500Rwf	35min	1800Rwf	30min	2min	700Rwf	2L
Profile Number 11												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
11	30min	15min	650Rwf	3L	45min	1500Rwf	15min	500Rwf	30min	5min	550Rwf	2L
Profile Number 12												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
12	30min	15min	300Rwf	3L	15min	2500Rwf	25min	800Rwf	60min	2min	550Rwf	1L
Profile Number 13												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
13	30min	25min	400Rwf	2L	25min	3000Rwf	35min	1200Rwf	60min	2min	350Rwf	2L
Profile Number 14												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
14	45min	15min	650Rwf	2L	25min	2500Rwf	45min	500Rwf	60min	10min	700Rwf	1L

Profile Number 15												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
15	30min	15min	300Rwf	3L	15min	3000Rwf	35min	1200Rwf	30min	5min	700Rwf	2L
Profile Number 16												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
16	60min	25min	300Rwf	2L	45min	3000Rwf	25min	500Rwf	60min	5min	550Rwf	1L
Profile Number 17												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
17	75min	15min	400Rwf	2L	15min	3000Rwf	45min	800Rwf	20min	2min	550Rwf	2L
Profile Number 18												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
18	75min	25min	650Rwf	3L	35min	1500Rwf	25min	1800Rwf	45min	5min	350Rwf	2L
Profile Number 19												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
19	75min	25min	650Rwf	3L	35min	2500Rwf	15min	1200Rwf	30min	10min	550Rwf	2L
Profile Number 20												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
20	30min	15min	300Rwf	3L	15min	3500Rwf	45min	1800Rwf	45min	10min	450Rwf	2L
Profile Number 21												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus

21	60min	15min	500Rwf	3L	25min	3000Rwf	25min	500Rwf	20min	10min	700Rwf	2L
Profile Number 22												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
22	45min	15min	300Rwf	2L	35min	1500Rwf	35min	800Rwf	30min	2min	700Rwf	2L
Profile Number 23												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
23	45min	25min	500Rwf	3L	15min	2500Rwf	45min	500Rwf	30min	2min	350Rwf	1L
Profile Number 24												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
24	75min	15min	500Rwf	2L	45min	3000Rwf	45min	800Rwf	30min	10min	350Rwf	1L
Profile Number 25												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
25	45min	45min	400Rwf	3L	45min	2500Rwf	45min	500Rwf	20min	5min	550Rwf	2L
Profile Number 26												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
26	30min	25min	400Rwf	2L	25min	3500Rwf	45min	1800Rwf	20min	2min	550Rwf	2L
Profile Number 27												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
27	30min	25min	400Rwf	2L	25min	2500Rwf	25min	800Rwf	30min	5min	450Rwf	1L
Profile Number 28												

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
28	75min	15min	400Rwf	2L	15min	1500Rwf	25min	1800Rwf	30min	10min	450Rwf	1L
Profile Number 29												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
29	30min	15min	650Rwf	3L	45min	3000Rwf	35min	1200Rwf	20min	2min	450Rwf	1L
Profile Number 30												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
30	60min	15min	400Rwf	3L	35min	3500Rwf	15min	800Rwf	45min	2min	700Rwf	1L
Profile Number 31												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
31	60min	15min	500Rwf	3L	25min	3500Rwf	15min	800Rwf	60min	5min	450Rwf	2L
Profile Number 32												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
32	75min	45min	300Rwf	3L	25min	2500Rwf	15min	1200Rwf	20min	2min	350Rwf	1L
Profile Number 33												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
33	75min	15min	400Rwf	2L	15min	3500Rwf	35min	500Rwf	60min	2min	350Rwf	2L
Profile Number 34												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
34	60min	15min	500Rwf	3L	25min	2500Rwf	35min	1800Rwf	45min	2min	550Rwf	1L

Profile Number 35

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
35	75min	45min	300Rwf	3L	25min	3500Rwf	35min	500Rwf	30min	10min	700Rwf	2L

Profile Number 36

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
36	60min	15min	400Rwf	3L	35min	1500Rwf	45min	1200Rwf	20min	10min	550Rwf	2L

Profile Number 37

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
37	45min	45min	400Rwf	3L	45min	3500Rwf	25min	1200Rwf	30min	2min	450Rwf	1L

Profile Number 38

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
38	60min	15min	400Rwf	3L	35min	2500Rwf	35min	1800Rwf	60min	5min	350Rwf	2L

Profile Number 39

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
39	30min	15min	300Rwf	3L	15min	1500Rwf	15min	500Rwf	20min	2min	350Rwf	1L

Profile Number 40

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
40	45min	15min	650Rwf	2L	25min	3000Rwf	15min	1800Rwf	30min	2min	550Rwf	2L

Profile Number 41

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
41	45min	45min	400Rwf	3L	45min	1500Rwf	35min	800Rwf	60min	10min	350Rwf	2L

Profile Number 42												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
42	60min	15min	500Rwf	3L	25min	1500Rwf	45min	1200Rwf	30min	2min	350Rwf	1L
Profile Number 43												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
43	30min	45min	500Rwf	2L	35min	1500Rwf	15min	500Rwf	60min	2min	450Rwf	2L
Profile Number 44												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
44	45min	15min	650Rwf	2L	25min	3500Rwf	25min	1200Rwf	45min	2min	350Rwf	2L
Profile Number 45												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
45	75min	15min	500Rwf	2L	45min	3500Rwf	35min	500Rwf	45min	5min	550Rwf	1L
Profile Number 46												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
46	45min	15min	300Rwf	2L	35min	3500Rwf	25min	1200Rwf	60min	10min	550Rwf	1L
Profile Number 47												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
47	75min	45min	300Rwf	3L	25min	1500Rwf	25min	1800Rwf	60min	2min	550Rwf	1L
Profile Number 48												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus

48	75min	25min	650Rwf	3L	35min	3500Rwf	35min	500Rwf	20min	2min	450Rwf	1L
Profile Number 49												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
49	60min	25min	300Rwf	2L	45min	3500Rwf	15min	800Rwf	20min	10min	350Rwf	1L
Profile Number 50												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
50	75min	25min	650Rwf	3L	35min	3000Rwf	45min	800Rwf	60min	2min	700Rwf	1L
Profile Number 51												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
51	45min	25min	500Rwf	3L	15min	3500Rwf	25min	1200Rwf	20min	5min	700Rwf	2L
Profile Number 52												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
52	60min	45min	650Rwf	2L	15min	2500Rwf	35min	1800Rwf	20min	10min	450Rwf	1L
Profile Number 53												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
53	30min	15min	650Rwf	3L	45min	3500Rwf	45min	1800Rwf	60min	2min	700Rwf	1L
Profile Number 54												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
54	30min	15min	650Rwf	3L	45min	2500Rwf	25min	800Rwf	45min	10min	350Rwf	2L
Profile Number 55												

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
55	45min	45min	400Rwf	3L	45min	3000Rwf	15min	1800Rwf	45min	2min	700Rwf	1L

Profile Number 56

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
56	45min	15min	300Rwf	2L	35min	2500Rwf	45min	500Rwf	45min	2min	450Rwf	2L

Profile Number 57

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
57	60min	45min	650Rwf	2L	15min	3500Rwf	15min	800Rwf	30min	2min	550Rwf	2L

Profile Number 58

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
58	45min	25min	500Rwf	3L	15min	1500Rwf	35min	800Rwf	45min	2min	550Rwf	1L

Profile Number 59

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
59	75min	15min	400Rwf	2L	15min	2500Rwf	15min	1200Rwf	45min	5min	700Rwf	1L

Profile Number 60

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
60	30min	25min	400Rwf	2L	25min	1500Rwf	15min	500Rwf	45min	10min	700Rwf	1L

Profile Number 61

ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
61	75min	15min	500Rwf	2L	45min	1500Rwf	25min	1800Rwf	20min	2min	700Rwf	2L

Profile Number 62												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
62	60min	25min	300Rwf	2L	45min	1500Rwf	45min	1200Rwf	45min	2min	450Rwf	2L
Profile Number 63												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
63	30min	45min	500Rwf	2L	35min	3000Rwf	35min	1200Rwf	45min	10min	550Rwf	1L
Profile Number 64												
ID	TT Bus	WT Bus	CT bus	CD bus	TT car	CT car	TT moto	CT moto	TT iBus	WT iBus	CT iBus	CD iBus
64	75min	15min	500Rwf	2L	45min	2500Rwf	15min	1200Rwf	60min	2min	450Rwf	2L

B

Utilities average differences of scenarios in ascending order

The eighteen first scenarios are used of questionnaires of the survey in Kigali.

Scenarios	U_Bus	U_Car	U_Moto	U_iBus	U avergae difference
56	-8.789	-5.4815	-6.221	-7.6396	1.890183333
15	-7.8688	-3.9885	-6.623	-6.824	1.97365
27	-8.44	-4.5225	-4.605	-4.973	2.020083333
22	-8.789	-4.6315	-5.743	-6.4826	2.202016667
46	-8.789	-6.3315	-5.485	-9.176	2.255083333
54	-8.6388	-6.4405	-4.605	-8.33	2.331816667
40	-9.559	-4.9475	-5.667	-6.1526	2.386683333
13	-8.44	-4.9475	-6.623	-9.1266	2.392383333
44	-9.559	-5.3725	-5.485	-7.4196	2.415683333
20	-7.8688	-4.4135	-9.081	-8.55	2.447283333
26	-8.44	-5.3725	-9.081	-5.0146	2.54445
39	-7.8688	-2.7135	-2.807	-3.2736	2.655416667
63	-10.936	-5.9065	-6.623	-7.469	2.65575
12	-7.8688	-3.5635	-4.605	-8.2656	2.895016667
62	-11.634	-5.5905	-7.761	-7.6396	3.041983333
14	-9.559	-4.5225	-6.221	-9.506	3.06575
11	-8.6388	-5.5905	-2.807	-6.494	3.066483333
7	-10.936	-5.4815	-4.605	-5.3446	3.188316667
6	-9.559	-3.6725	-5.743	-3.835	3.26125
38	-11.5028	-5.4815	-7.943	-9.468	3.264816667
51	-11.1538	-4.4135	-5.485	-5.686	3.40365
60	-8.44	-3.6725	-2.807	-7.799	3.50425
24	-12.643	-6.8655	-6.881	-6.623	3.012583333
36	-11.5028	-4.6315	-7.761	-5.925	3.74165
55	-13.2098	-6.8655	-5.667	-6.8886	3.77525
34	-11.7228	-4.5225	-7.943	-6.5586	3.830883333
45	-12.643	-7.2905	-5.083	-6.9	3.845083333
25	-13.2098	-6.4405	-6.221	-5.356	3.963483333
4	-11.5028	-5.9065	-3.945	-4.6316	3.991383333
23	-11.1538	-3.5635	-6.221	-4.4116	4.096716667
21	-11.7228	-4.9475	-3.945	-6.255	4.106816667

30	-11.5028	-6.3315	-3.467	-6.8886	4.11075
16	-11.634	-6.8655	-3.945	-9.908	4.351583333
9	-11.1538	-3.9885	-5.667	-10.257	4.34765
58	-11.1538	-2.7135	-5.743	-6.5586	4.356083333
41	-13.2098	-5.5905	-5.743	-10.037	4.525316667
17	-12.423	-3.9885	-6.881	-5.0146	4.528316667
49	-11.634	-7.2905	-3.467	-5.485	4.384416667
64	-12.643	-6.4405	-4.347	-9.3466	4.63235
33	-12.423	-4.4135	-5.083	-9.1266	4.678683333
50	-14.8978	-5.9065	-6.881	-8.5956	4.781416667
31	-11.7228	-5.3725	-3.467	-9.688	4.84715
43	-10.936	-4.6315	-2.807	-9.3466	4.85035
59	-12.423	-3.5635	-4.347	-7.23	4.91025
28	-12.423	-2.7135	-6.805	-5.542	5.06525
18	-14.8978	-4.6315	-6.805	-7.761	5.292483333
19	-14.8978	-5.4815	-4.347	-7.063	5.538983333
57	-14.68	-4.4135	-3.467	-6.1526	5.89635
5	-16.4038	-4.9475	-6.881	-7.981	5.911483333
8	-14.68	-3.9885	-3.945	-7.4196	5.93935
35	-16.4038	-5.3725	-5.083	-7.393	5.99715
52	-14.68	-3.5635	-7.943	-4.404	6.148083333
32	-16.4038	-4.5225	-4.347	-3.2736	6.59435
47	-16.4038	-3.6725	-6.805	-8.2656	6.609083333

C

Survey responses

The one hundred observations extracted from a one thousands six hundred and seventy one observations data sets.

<	ID_Sc	AV_BUS	TTBUS	WTBUS	CTBUS	CDBUS	AV_CAR	TTCAR	CTCAR	AV_MOTO	TTMOTO	CTMOTO	AV_IBUS	TTIBUS	WTIBUS	CTIBUS	CDIBUS	CHOICE
3	1	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
7	2	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
21	3	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
24	4	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
25	5	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
27	6	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
34	7	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
36	8	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
40	9	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
53	10	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
55	11	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
62	12	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
64	13	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
68	14	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
70	15	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
73	16	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
74	17	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
76	18	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
91	19	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	3
1	20	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
5	21	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
6	22	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
9	23	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
13	24	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
23	25	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
47	26	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
60	27	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
69	28	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
79	29	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
80	30	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
82	31	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
84	32	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
87	33	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
89	34	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
90	35	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	2
22	36	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	4
31	37	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	4
48	38	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	4
50	39	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	4
54	40	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	4
72	41	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	4
92	42	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	4
98	43	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	4
17	44	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	1
65	45	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	1
85	46	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	1
95	47	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	1
100	48	1	45	15	300	2	1	35	2500	1	35	500	1	45	2	450	2	1
2	49	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
4	50	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
10	51	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
15	52	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
18	53	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
19	54	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
28	55	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
29	56	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
30	57	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
32	58	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
33	59	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
39	60	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
41	61	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
45	62	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
46	63	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
49	64	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
51	65	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
56	66	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
57	67	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
58	68	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
61	69	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
66	70	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
71	71	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
75	72	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
78	73	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
83	74	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
86	75	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
96	76	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
101	77	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
102	78	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
93	79	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	3
11	80	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	4
12	81	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	4
16	82	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	4
20	83	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	4
35	84	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	4
37	85	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	4
52	86	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	4
59	87	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	4
63	88	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	4
88	89	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	4
97	90	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	4
26	91	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	1
38	92	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	1
44	93	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	1
67	94	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	1
81	95	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	1
94	96	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	1
99	97	1	45	15	300	2	0	35	2500	1	35	500	1	45	2	450	2	1
7	98	1	30	25	400	2	1	25	2500	1	25	800	1	30	5	450	1	4
13	99	1	30	25	400	2	1	25	2500	1	25	800	1	30	5	450	1	4
22	100	1	30	25	400	2	1	25	2500	1	25	800	1	30	5	450	1	4

D

Coefficients estimation process

Maximum likelihood estimations using PandaBiogeme package. With the help of Jupyter a programming editor that uses Python language.

```
In [25]: import pandas as pd
         import biogeme.database as db
         import biogeme.biogeme as bio
         import biogeme.models as models
         from biogeme.expressions import Beta
```

```
In [26]: df = pd.read_csv(r"C:\Users\Bertin Irakoze\Desktop\kigali/kigali.dat", '\t')
         database = db.Database('kigali', df)
```

```
In [27]: globals().update(database.variables)
```

```
In [28]: Crowding_bus_level1 = (CDBUS == 1)# reference group
         Crowding_bus_level2 = (CDBUS == 2)
         Crowding_bus_level3 = (CDBUS == 3)

         Crowding_ibus_level1 = (CDIBUS == 1)# reference group
         Crowding_ibus_level2 = (CDIBUS == 2)
         Crowding_ibus_level3 = (CDIBUS == 3)
         #CDBUS
         #CDIBUS
```

```
In [29]: ASC_BUS = Beta('ASC_BUS', 0, None, None, 0)
         ASC_CAR = Beta('ASC_CAR', 0, None, None, 0)
         ASC_MOTO = Beta('ASC_MOTO', 0, None, None, 0)
         ASC_IBUS = Beta('ASC_IBUS', 0, None, None, 1)
         B_TT = Beta('B_TT', 0, None, None, 0)
         B_WT = Beta('B_WT', 0, None, None, 0)
         B_CT = Beta('B_CT', 0, None, None, 0)
         #B_CD = Beta('B_CD', 0, None, None, 0)
         B_C2 = Beta('B_C2', 0, None, None, 0)
         B_C3 = Beta('B_C3', 0, None, None, 0)
         IB_C2 = Beta('IB_C2', 0, None, None, 0)
         IB_C3 = Beta('IB_C3', 0, None, None, 0)
```

```
In [30]: U1 = ASC_BUS + \
              B_TT * TTBUS + \
              B_WT * WTBUS + \
              B_CT * CTBUS + \
              B_C2*Crowding_bus_level2+B_C3*Crowding_bus_level3
         U2 = ASC_CAR + \
              B_TT * TTCAR + \
              B_CT * CTCAR
         U3 = ASC_MOTO + \
              B_TT * TTMOTO + \
              B_CT * CTMOTO
         U4 = ASC_IBUS + \
              B_TT * TTIBUS + \
              B_WT * WTIBUS + \
              B_CT * CTIBUS + \
             IB_C2*Crowding_ibus_level2 + IB_C3*Crowding_ibus_level3
              #B_CD * CDIBUS
```

Figure D.1: Coding using Jupyter part 1

```
In [31]: U = {1: U1,
              2: U2,
              3: U3,
              4: U4}

In [32]: av = {1: AV_BUS,
               2: AV_CAR,
               3: AV_MOTO,
               4: AV_IBUS}

In [33]: logprob = models.loglogit(V, av, CHOICE)

In [34]: biogeme = bio.BIOGEME(database, logprob)
         biogeme.modelName = '01logit'

In [35]: results = biogeme.estimate()

In [36]: pandasResults = results.getEstimatedParameters()
         print(pandasResults)
```

Figure D.2: Coding using Jupyter part 2

E

Survey questionnaires

Kigali public transport survey 1
Kigali public transport survey igamije kwiga ku ngaruka nziza zo gushyira ikoranabuhanga rya RTPIS muri busi rusange. RTPIS itanga amakuru y' ingendo ku mugenzi y' igihe bus igerera ku cyapa, igihe iribukoreshe kugera aho agiye kugirango umugenzi ategure urugendo rwe neza. ayo makuru y' ingendo umugenzi ashobora kuyareba kuri telephone ye, kuri tabulo zishyirwa ku byapa, muri busi igihe ayirimo. Ubu bushakashatsi bushyigikiwe na RTDA.

This survey aims to to study the impacts of implementing real time passenger information technology in public buses. Real time information systems provides departure and arrival times, enabling passengers to plan their journey and use their time efficiently. This survey is supported by Rwanda transport development agency (RTDA).

Wabona imodoka iri pirive wakoresha ugenda? (Do you have access to a private car that you can use for commuting?)

Yego
Oya

Questions 1: Guhitamo uburyo ugenda (Travel choice scenario)
Tekereze ko wabonye akazi gashya ugahindura aho ukorera. hari uburyo butandatu bushoboka. Hitamo icyo wategа ujya ku kazi.
(Assume that you find a new job and change the workplace. From your home to the new workplace, we assume six different possible situations. Please answer the below question as per your own preference.)

Hari uburyo bune bushoboka wakoresha uva mu rugo ujya ku kazi. Igiciro, Igihe wakoresha ugenda, igihe wamara utegereje busi, ubucucike muri busi birazwi nk' uko bigaragazwa hepfo. uzahitamo gutega iki?

(Assume that you Can use below four transport modes from home to workplace. The cost, travel time, waiting time and crowdedness of each mode is known as shown below. which mode will you choose for commuting?)

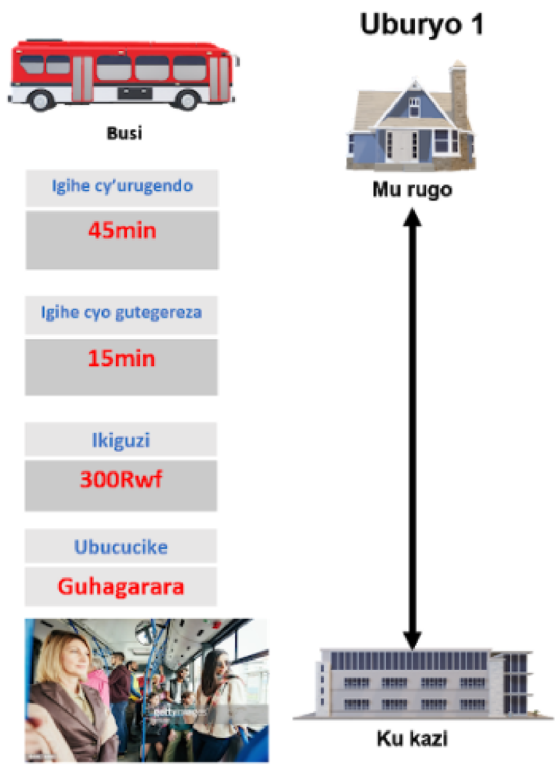

Figure E.1: Scenario 1

Busi
Imodoka
Moto
Busi ifite ikoranabuhanga

Questions 2: Hari uburyo bune bushoboka wakoresha uva mu rugo ujya ku kazi. Igiciro, Igihe wakoresha ugenda, igihe wamara utegereje busi, ubucucike muri busi birazwi nk' uko bigaragazwa hepfo. uzahitamo gutega iki?

(Assume that you can use below four transport modes from home to workplace. The cost, travel time, waiting time and crowdedness of each mode is known as shown below. which mode will you choose for commuting?)

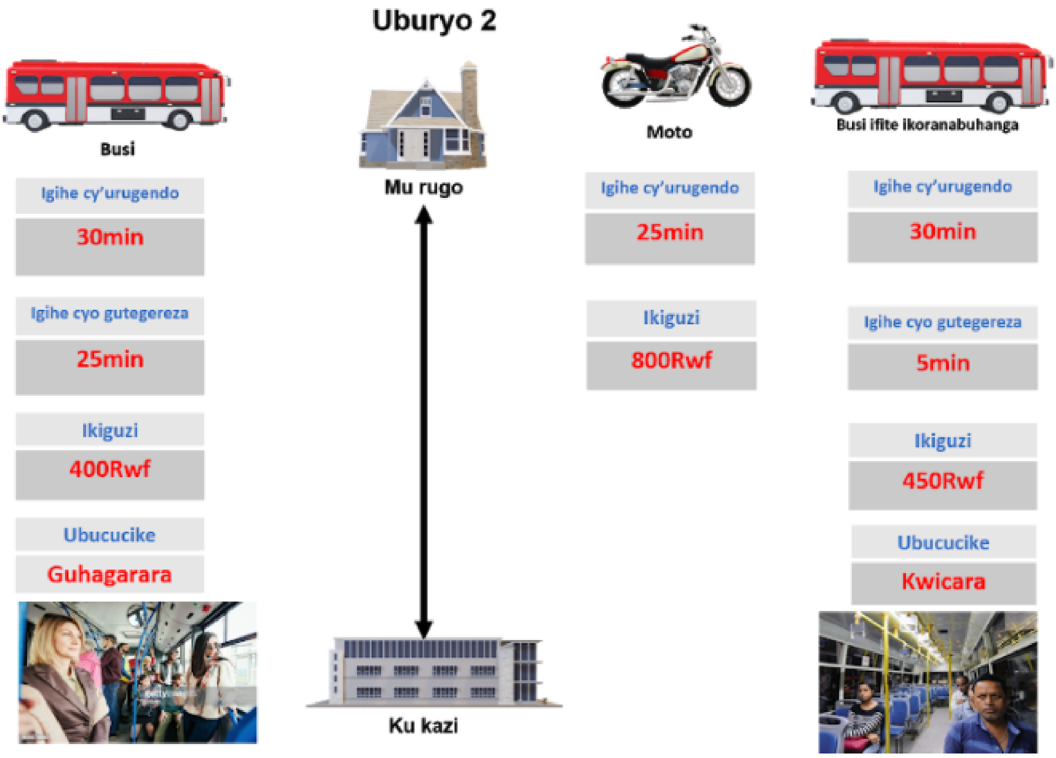

Figure E.2: Scenario 2

Busi
Imodoka
Moto
Busi ifite ikoranabuhanga

Question 3: Hari uburyo bune bushoboka wakoresha uva mu rugo ujya ku kazi. Igiciro, Igihe wakoresha ugenda, igihe wamara utegereje busi, ubucucike muri busi birazwi nk' uko bigaragazwa hepfo. uzahitamo gutega iki?

(Assume that you can use below four transport modes from home to workplace. The cost, travel time, waiting time and crowdedness of each mode is known as shown below. which mode will you choose for commuting?)

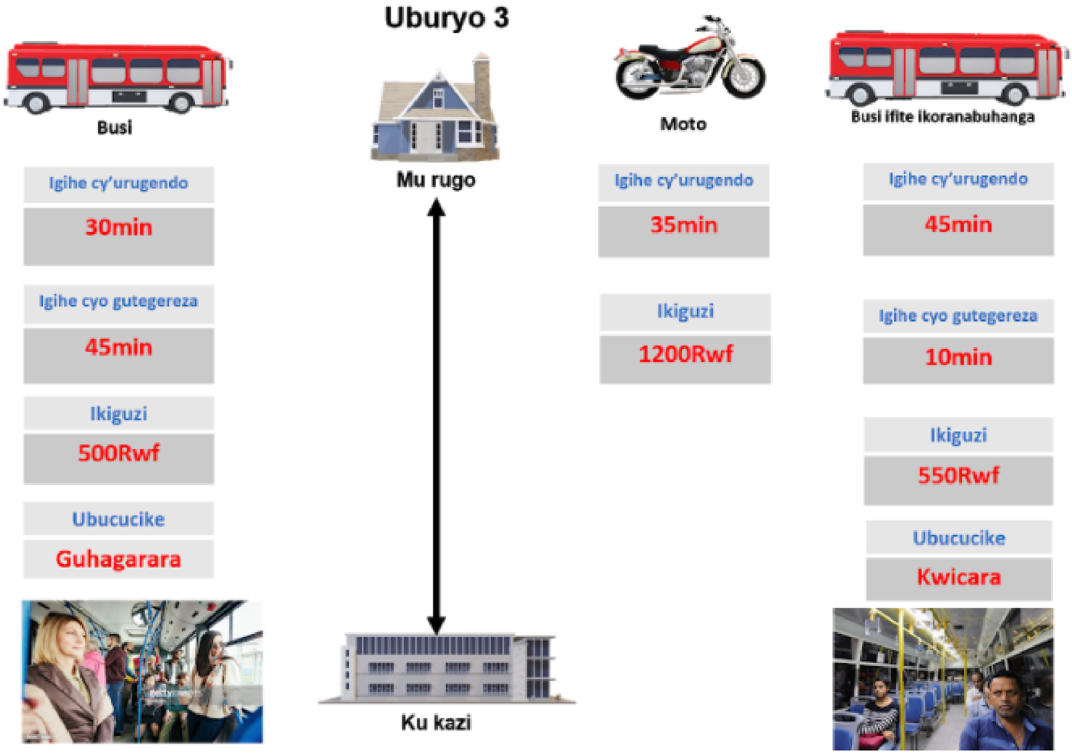

Figure E.3: Scenario 3

Busi
Imodoka
Moto
Busi ifite ikoranabuhanga

Question 4: Hari uburyo bune bushoboka wakoresha uva mu rugo ujya ku kazi. Igiciro, Igihe wakoresha ugenda, igihe wamara utegereje busi, ubucucike muri busi birazwi nk' uko bigaragazwa hepfo. uzahitamo gutega iki?

(Assume that you can use below four transport modes from home to workplace. The cost, travel time, waiting time and crowdedness of each mode is known as shown below. which mode will you choose for commuting?)

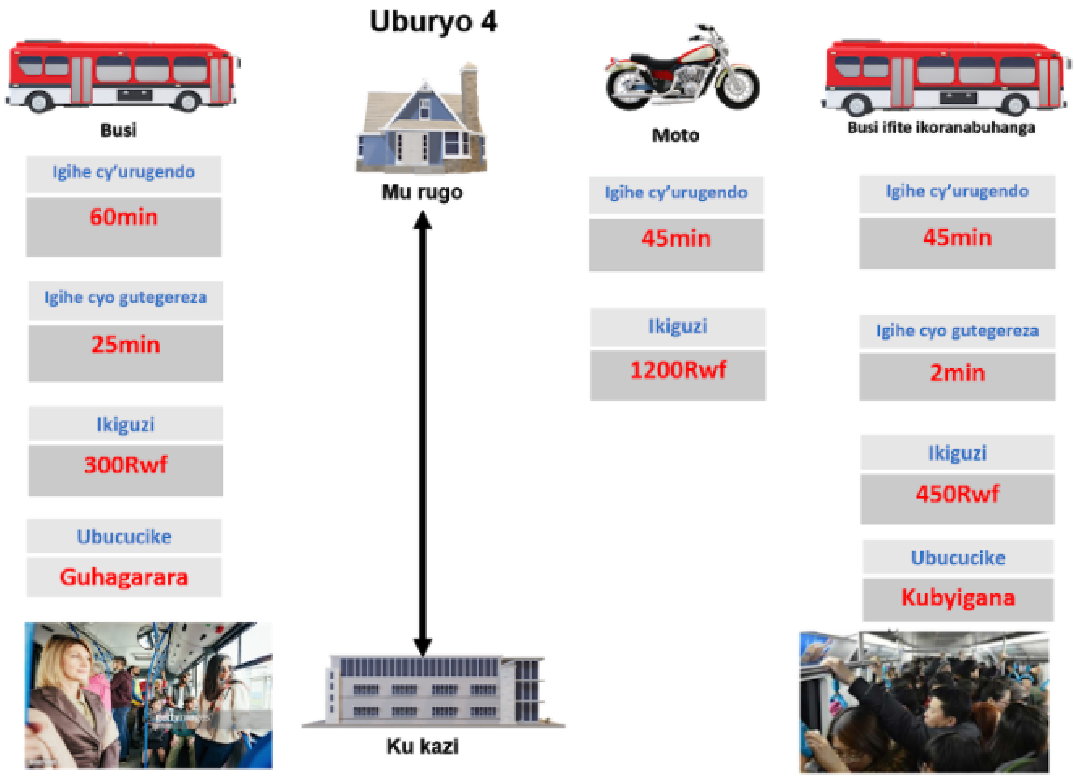

Figure E.4: Scenario 4

Busi
Imodoka
Moto
Busi ifite ikoranabuhanga

Question 5: Hari uburyo bune bushoboka wakoresha uva mu rugo ujya ku kazi. Igiciro, Igihe wakoresha ugenda, igihe wamara utegereje busi, ubucucike muri busi birazwi nk' uko bigaragazwa hepfo. uzahitamo gutega iki?

(Assume that you can use below four transport modes from home to workplace. The cost, travel time, waiting time and crowdedness of each mode is known as shown below. which mode will you choose for commuting?)

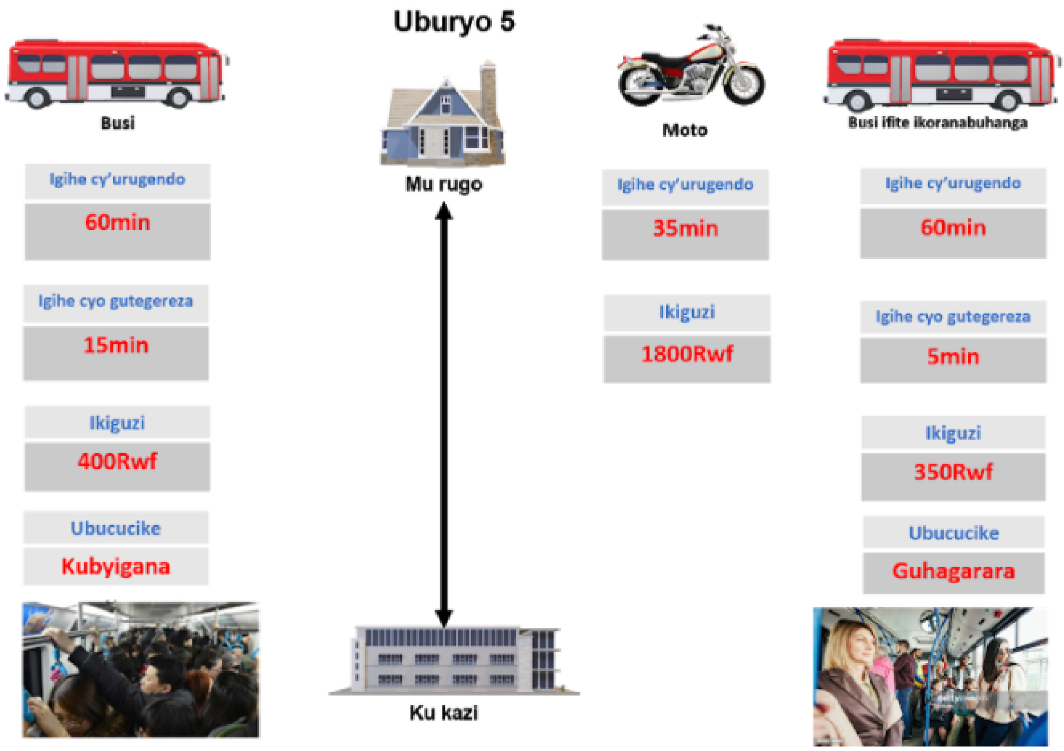

Figure E.5: Scenario 5

Busi
Imodoka
Moto
Busi ifite ikoranabuhanga

Question 6: Hari uburyo bune bushoboka wakoresha uva mu rugo ujya ku kazi. Igiciro, Igihe wakoresha ugenda, igihe wamara utegereje busi, ubucucike muri busi birazwi nk' uko bigaragazwa hepfo. uzahitamo gutega iki?

(Assume that you can use below four transport modes from home to workplace. The cost, travel time, waiting time and crowdedness of each mode is known as shown below. which mode will you choose for commuting?)

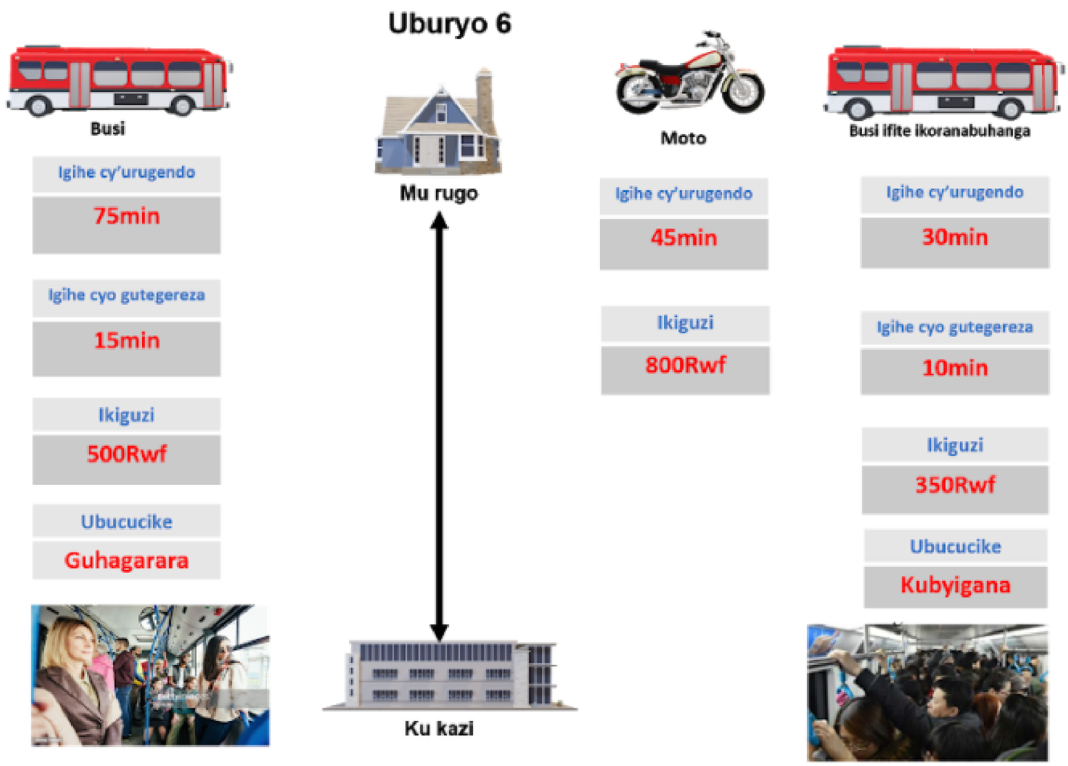

Figure E.6: Scenario 6

Busi
Imodoka
Moto
Busi ifite ikoranabuhanga

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