“QUANTIFICATION OF TRANSPORT DEMAND OF HYBRID LIGHTER THAN AIR IN RWANDA THROUGH STATED PREFERENCE METHODS”

By

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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

February, 2015

DEDICATION

This thesis is dedicated to:

God Almighty; have your way Lord, to you be the glory forever, for great things you have done for me.

And

My lovely family, especially to my late mother Mrs. Margaret MUKAGASANA for her inspiration that had made my endeavour a success.

ABSTRACT

Today, development of innovative modes of transport is taking place in order to accelerate the economic growth of transport users as well as reducing the environmental pollution, through an improved transport system. These new transport modes are associated with advances in modern technologies that are able to provide solutions to different problems in the transport industry of developing countries. This research was motivated by the cost reduction and environmental benefits, accruing from the use of new technology of Hybrid Lighter Than Air (HLTA) transport mode. The intention then, was to evaluate the modes choice preference of transport users in the case where the HLTA is introduced in Rwanda. The new mode of HLTA is believed to make a contribution in solving transport challenges stemming from the fact that Rwanda is a landlocked country. The landlockedness is associated with lack of access to seaports, remoteness and isolation from major markets. This continues to impede the development of the country and the problem is exacerbated by the fact that, road transport mode dominates the transport operations in Rwanda. From an economic point of view, road transport causes high transport economic costs for both passengers and freight, and increases, to a large extent, environmental pollution.

In order to achieve the transport users' modes choice preferences, this study has developed and used an efficient survey design process of Stated Preference. Drawing from current literature, Stated Preference is an accurate tool for data collection of studies that relate to choice preferences. This technique made it possible to design questionnaires by hypothetically creating choice games using three attributes; i.e. In Vehicle Travel Time, Waiting Time and Travel Cost for available alternative modes of transport. Thereafter, the collection of data took place by interviewing the transport users of three routes that accommodate heavy traffic in the study area, Rwanda.

The SPSS version 21 computer programme was used to analyse mode choice preference data and then for a matter of checking the results, STATA S/E 11.1 was used. Among the results, these computer programmes reported coefficients of attributes and these were applied in the Binomial logistic regression mathematical structure in the model building process. The model refinement and validation processes that followed, have suggested a removal of Waiting Time from the explanatory variables. This was due to poor performance that Waiting Time has demonstrated in terms of prediction and significance. Then, magnitudes of utilities of models were determined based on the two remaining variables. The choice probability value of each alternative on different routes was calculated; and thus transport demand of each mode was quantified.

According to the results, transport users in Rwanda would prefer and use HLTA in case it starts operating. For both cargo and passenger transport, HLTA was chosen above other modes set into choice process, with probabilities of 79.7%, 86.1%, and 58% for HLTA-Passenger on long, medium and short routes respectively and 71%, 56% and 77% for HLTA-Cargo on long, medium and short route respectively. The passenger transport volume share of HLTA-Passenger projected in the year 2014 was found to be 6269256 passengers against a total annual passenger traffic demand of 7941752 passengers on the three routes considered. The annual freight volume of HLTA-Cargo was 10947921 tonnes against a total of 16935637 tonnes on all the routes considered. These high demand volumes of HLTA were due to high choice probabilities which in turn, were due to small values of attributes that HLTA has got compared to those of other modes. It is, therefore, proposed that more research should be conducted to study the viability of HLTA use in Rwanda. While doing so, such studies should consider issues of economic viability, environmental benefit research and other studies engaging demand data, since these data items would be published as the main results of this current work.

OPSOMMING

Die ontwikkeling van innoverende vervoermiddels vind deesdae plaas ten einde die ekonomiese groei van die gebruikers van vervoer te versnel, asook om maniere te soek om omgewingsbesoedeling te bekamp deur die verbetering van vervoerstelsels. Hierdie nuwe vervoermiddels word geassosieer met vooruitgang in moderne tegnologie, wat ten doel het om oplossings te voorsien vir verskeie probleme in die vervoerindustrie van ontwikkelende lande. Hierdie navorsing is gemotiveer deur kostevermindering en omgewingsvoordele, wat uit die gebruik van die nuwe tegnologie van Hibriede Ligter as Lug vervoermiddels (lugskip) voortspruit. Die bedoeling was dan om die keuse van vervoermiddelvoorkeure deur gebruikers, te evalueer ingeval die bogenoemde lugskip in Rwanda as vervoermiddel implementeer sou word. Daar word beweer dat hierdie nuwe lugskip vervoermiddel ‘n aandeel sal hê om die vervoeruitdagingsprobleme van Rwanda, wat landingeslote is, te help oplos. Hierdie landingeslotenheid word geassosieer met ‘n gebrek aan toegang tot seehawens, afstand en afsondering van groot markte. Voorts belemmer dit die ontwikkeling van die land en die probleem word vererger deur die feit dat padvervoer die vervoer bedrywighede in die land oorheers. Padvervoer veroorsaak hoë vervoer onkoste in die land se ekonomie, vir beide passasiers- en vragvervoer, en daar is ‘n aansienlike toename in omgewingsbesoedeling.

Ten einde die vervoergebruikers se vervoermiddelkeuse voorkeure te bereik, het hierdie studie 'n doeltreffende opname-ontwerp proses van Verklaarde Voorkeur ontwikkel en gebruik. Uit kennis van huidige literatuur, word aanvaar dat Verklaarde Voorkeur 'n akkurate instrument is vir data-versameling vir studies wat verband hou met die keuse van voorkeure. Hierdie tegniek het dit moontlik gemaak om vraelyste te ontwerp deur die hipotetiese skepping van keuse speletjies wat drie eienskappe gebruik, naamlik In-Voertuig Reistyd, Wagtyd en Reiskoste vir beskikbare alternatiewe vervoermiddels. Daarna het dataversameling plaasgevind deurdat onderhoude met vervoergebruikers van drie swaar-verkeerroetes in Rwanda gevoer is.

Die SPSS weergawe 21 rekenaarprogram is gebruik om die vervoermiddel-keuse voorkeurdata te analiseer, en daarna, ten einde die uitslae te ondersoek, is die STATA S/E 11.1 program gebruik. As deel van die uitslae het hierdie rekenaarprogramme berig oor eienskappe van koëffisiënte. Hierdie uitslae is toegepas in die Binomiale logistieke regressie wiskundige struktuur in ‘n modelbou-proses. Die model validasieproses wat gevolg het, het voorgestel dat wagtyd weggelaat word as een van die verklarende veranderlikes. Dit was as gevolg van swak prestasie wat wagtyd getoon het in terme van voorspelling en betekenis. Daarna is groottes van modelle se nuttigheid bepaal op grond van die twee oorblywende veranderlikes. Laastens is die keuse waarskynlikheidswaardes van elke alternatief op verskillende roetes bereken, en sodoende is die vervoeraanvraag van elke vervoermiddel gekwantifiseer.

Volgens die uitslae sou vervoergebruikers in Rwanda die lugskip as vervoermiddel verkies en gebruik, indien dit implementer sou word. Vir beide vrag- en passasiersvervoer, is die lugskip bo ander vorme gekies wat in die keuse proses beskikbaar was, met waarskynlikhede van 79.7%, 86.1%, en 58 vir lugskip-passasier op 'n lang, medium en kort roete onderskeidelik, en waarskynlikhede van 71%, 56% en 77% vir lugskip-vrag op die lang, medium en kort roetes onderskeidelik. Die projeksie van die passasier vervoer volume gedeelte van lugskip-passasier vir die jaar 2014 het bevind dat 6269256 passasiers uit 'n totale passasiersverkeer aanvraag van 7941752, geprojekteer vir 2014, op die drie oorweegde roetes voorspel was. Die vrag volume van lugskip-vrag was 10947921 ton, teenoor 'n totaal van 16935637 ton op al die oorweegde roetes. Hierdie hoë aanvraag volumes van lugskip vervoer was as gevolg van hoë keuse waarskynlikhede wat op hul beurt, as gevolg van die klein waardes van eienskappe van die lugskip in vergelyking met dié van ander vervoermiddels veroorsaak is. Die voorstel is dus dat meer navorsing gedoen moet word om die lewensvatbaarheid van die gebruik van lugskip vervoer in Rwanda te bestudeer. Terselfdertyd moet sodanige studies kwessies oorweeg wat die ekonomiese lewensvatbaar van die vervoermiddel ondersoek, voordele vir die omgewing inhou en ander studies waar aanvraagdata oorweeg word, aangesien sulke data alreeds gepubliseer sal wees as die belangrikste resultate van hierdie huidige studie.

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I am whole heartedly thankful to the Almighty God, for having been with me, in each single step of this work. It wouldn't had been successful, if the Lord had not led me. Glory be to him.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

ADT	Average Daily Traffic
AfDB	African Development Bank
BL	Binary Logit
Bu	Bus
DAI	Discovery Air Innovation
GDP	Gross Domestic Product
GHG	Green House Gas
HAV	Hybrid Air Vehicle
HLTA	Hybrid Lighter Than Air
ILTP	Integrated Local Transport Plan
ISR	Intelligence, Surveillance, and Reconnaissance
IVT	In Vehicle Travel Time
IWW	In Land Water Way
IET	Institution of Engineering and Technology
LLDCs	Land Locked Developing Countries
LEMV	Long Endurance Multi-intelligence Vehicle
MSL	Mean Sea Level
Mininfra	Ministry of infrastructure
MNL	MultiNomial Logit
MT	Metric Tonne
MSL	Mean Sea Level
NTS	New Transit System
Pr	Probability

Rwf	Rwandan francs
RP	Revealed Preference
RTDA	Rwanda Transport Development Agency
RUM	Random Utility Maximisation
RURA	Rwanda Utilities Regulation Agency
SC	Stated Choice
SP	Stated Preference
TDM	Transport Demand Model
TC	Travel Cost
TDF	Travel Demand Forecasting
Tr	Truck
USD	United States Dollar
VKT	Vehicle Kilometres Travelled
VTOL	Vertical Take-Off Landing
WT	Waiting Time

Chapter 1 INTRODUCTION

1.1 GENERAL BACKGROUND

The system of transportation in Rwanda is based on road transport (AfDB, 2013; Christian & Ryan, 2011). The result of a transport system dominated by road is an inefficient transport operation that is expensive in terms of economic and environmental costs. Normally as part of a transportation system, the efficient movement of both freight and passengers plays a great role in terms of economic development of any nation (Eddington, 2006). But when a transport system fails to fulfill its intended function, of creating place and time utility, businesses become less productive; which causes transport costs to increase. In order to ensure that passengers and freight movement remains enjoyable and competitive, transportation professionals should include creation of place and time utility in the planning activities. Ideally, planners must incorporate it in an integrated manner into the overall planning process. It is, therefore, important to understand the transport users' preferences in terms of choice of transport modes, in order to satisfy their needs.

Lebo and Schelling (2001) argue that resources are scarce and should therefore be allocated where there is greatest economic potential. This means, for example, that building a paved road must not be taken as a straightforward decision in Rwanda due to high economic investment, maintenance costs and the inherited high transport economic cost that roads require. In addition to these, the hilly topographical lands and heavy rain climate of Rwanda exacerbate the problem. All these reasons taken together lead to some parts of the country being underserved in terms of mobility and accessibility by a transport facility. It is, therefore, clear that there is a need of an approach that brings into consideration an innovative technological mode of transport other than road to solve these issues. Fortunately, the challenges that are in the current transport operation, are recognised by the government of Rwanda. This is evidenced by the different programmes undertaken by the government in search for remedial measures for transport improvement. These programmes include: Economic Development and Poverty Reduction Strategies (EDPRS I and II), transport strategic policy, the Rwanda strategic transport master plan and Vision 2020. All these programmes are mindful of environmentally friendly transport systems.

According to Christian and Ryan (2011), the achievement of efficiency in transport operations in Rwanda should be based on different options, from changing technology to altering consumer demand. Speaking about Rwanda's transportation challenges, Christian and Ryan (2011) pointed out that "another option which may be viable, is the use of Hybrid Lighter-Than-Air in the transport system". They argued that this transportation approach can help to solve the problems of high economic costs and environmental pollution encountered by the users of the existing transport system and then help to overcome the problems of the fact that naturally Rwanda is a land locked country.

HLTA uses a combination of lighter-than-air airships and traditional fixed-wing and rotorcraft working systems. As per an industry report by HAV Ltd (2014), the technology is based on the combination of buoyancy and aerodynamic power to generate lift. Normally fixed-wing and rotor craft systems rely on dynamic lift, such as aerodynamic forces or vectored thrust, and airships rely on static lift due to buoyancy of lifting gasses. HLTA systems have the ability to lift large payloads, delivering them point-to-point, over long distances with minimum requirements in infrastructure, capital cost and most importantly, energy requirements (Christian & Ryan, 2011). Extensive benefits of HLTA appear to be obvious, but the critical issue is the acceptance of the mode by transport users as it is a new mode to be introduced in Rwanda. This is a great concern since, for any mode of transport to function, there might be a required demand to motivate its use. Travel demand is typically defined as the amount of goods and passengers willing to travel between two locations (Myer, 2004). In normal transport operations, travel demand is considered as a derived demand, which means that travelers have a purpose without which, they cannot travel. Based on their purposes and different characteristics of the available transport modes, travelers are able to choose among alternative modes for their trips.

The aim of this research is to determine the choice preference probabilities of transport users on different modes engaged in the study. Resulting probability values of transport modes were used to predict the amount of traffic demand volume of each existing mode and that of HLTA (a new and non-existing mode in Rwanda). In order to do so, an effort was made to examine the preferences of people among different modes, and from this data, a mode choice model of a binary logistic regression type was developed. The results reveal that HLTA has strong preferences in the transport users than other modes and should, therefore, be considered for further studies.

1.2 PROBLEM STATEMENT

Rwanda is a landlocked country, and it is far from the maritime ports through which all overseas goods pass. Therefore, it requires travelling long distances for importing and exporting of goods at the sea ports. Thus, the import and export operations cost a lot in terms of economic and environmental expenditure since road transport is the dominant mode available. For example, it takes almost a week for a truck to carry goods from the nearest port (Dar-Es-Salaam) to reach Kigali, the capital of Rwanda (Refer to Figure 1-1 below); the two cities being at a distance of 1457km from one another (Mininfra, 2012b). Since Rwanda's terrain is hilly, road transport becomes even more challenging. The hills and valleys result in a highly dense road network equivalent to $0.56km/km^2$, the maintenance of which consumes the majority of the government transport budget. When investment does occur, the physical characteristics of roads add significantly to the expense, such as construction of earthworks and the cost of importing supplies and equipment. The climate is an aggravating factor, with intense rainfall washing out road surfaces and requiring damage mitigation strategies, like drainage channels and slope stabilisation, which are in turn very high in terms of cost dependency. According to Christian and Ryan

(2011), over 40% of the cost of businesses is attributed to high transportation costs in Rwanda, against 12% and 36% for Kenya and Uganda respectively. In addition to this, the Green House Gas (GHG) emissions from transport are very high, approximately 5.4% of Rwanda's total emissions, 269.9Gg of CO_2 equivalent. The 2007 UNDP report says that, the high transport costs incurred, undermine the competitiveness of land locked developing countries on international markets. It also reduces the capability of these countries in terms of production. The first factor highlighted is a trade reducing effect, and the second is the purchasing power reduction which together reduces the GDP. Finally, they decrease the rate of return on capital required by investors to finance a project within the country. New technologies in transport rather than road, are therefore required to solve all these problems.

Hybrid Lighter Than Air, is able to improve the quality of transport conditions by reducing the transport economic costs and simultaneously by promoting environmental mindful transport activities. Therefore, it can solve the problems stemming from the fact that Rwanda is landlocked. Having the potential to pick and deliver point to point services, HLTA would also enable rural development by helping small farmers, those currently in areas too far from markets and thus increase the GDP. So, the main problem in this research is to find out whether there is sufficient demand to motivate the development of HLTA in Rwanda. The study, therefore, set out to evaluate people's preferences among transport modes. Then, based on the population preferences, the modelling process carries on, to figure out the amount of transport demand available for the use of HLTA both in the freight and passengers transport. This provides an opportunity to do further researches on the viability of HLTA in Rwanda, since these research projects strongly require transport demand volumes involvement.

1.3 OBJECTIVES OF THE STUDY

1.3.1 Main objective

The overall objective of this study is

"To develop modes choice preference models to use in the quantification of transport demand of modes and to determine the share of HLTA for its development in Rwanda".

1.3.2 Specific objectives

1. Description of the current status of the transportation practice in Rwanda.
2. Explanation of the working technology of HLTA and its different potential features.
3. Conducting a Stated Preference experiment for an evaluation of transport users' preferences among alternative modes, including HLTA.

4. Formulation of models' utility functions, and determination of magnitudes of utilities and probabilities for transport alternative modes.

5. Quantification of traffic demand for different modes and HLTA particularly.

6. Determination of monetary value of Travel Time related attributes from the models' results.

7. Demonstration of the resultant models' applications.

1.4 JUSTIFICATION AND RATIONALE

The government of Rwanda is keen to explore innovative transport technologies that may offer a competitive advantage in the transport system. This is observed in the key principles for public transport services, set out by the ministry of infrastructure (Mininfra, 2012a). However, these innovative technologies must fall within the green growth strategy; a condition that HLTA fulfils.

The key theme that HLTA technology supports is energy efficiency. According to IET (2014), the operating costs of HLTA are lower, their fuel burn is 50% – 65% less than conventional fixed wing aircraft, when compared on a tonne per km basis. Fuel burn is even lower when compared to normal rotary wing aircrafts and road vehicles. The socio-economic and environmental benefits of the use of HLTA are numerous, to name a few:

- A sharp drop in the economic costs of imported and exported goods at national level. This results in a reduction of the trade deficit, an increase in foreign exchange earnings and, ultimately, increased economic growth;
- A fall in the costs of exporting mine and agricultural products, and encouragement of private operators to promote and diversify exports;
- Promotion of productive activities (primary and secondary sectors);
- Efficiency in transport of perishable products like flowers, and
- Environmental improvement. (IET, 2014).

The working technology of HLTA matches with the Government of Rwanda's aims to promote effective transport as well as other environmentally sound principles. Furthermore, the climatic conditions in Rwanda are conducive for the operation of HLTA vehicles. This is justified by a recent study on wind energy potential in Rwanda. On average, the mean wind speed is low lying between 3.7-10.7m/s (World Health Organisation, 2010), while newly developed Hybrid airships are tested successfully in the wind speed of 25m/s (HAV Ltd, 2013). Moreover, the formation of storms and wind gusts seem to be quite localised, easily observable, and predictable a few hours in advance, in Rwanda. These elements indicate that using the airway can be reasonably easy. An additional motivation for working with hybrid air transport is the need to reduce GHG emissions. Rwanda can have improved logistic processes when using such a low carbon emitting transport mode, and this would position Rwanda's agricultural products in a high value niche market.

As far as the economic development of Rwanda is concerned, the use of HLTA would also provide an opportunity for private investment in the transportation industry currently constrained by the road infrastructural development challenges. Moreover, HLTA can be used in disaster relief like intervention in fire breaks and flood escape mechanisms. This study would also make an academic contribution in the field of transport in the country.

1.5 SCOPE OF THE PROJECT

This project has been carried out in the country of Rwanda (see the map of Rwanda on Figure 1-1); but it has concentrated on three different categories of routes. The reasons of choice of these routes are discussed in Section 3.2.3 of this report. The following sections provide only the information of these routes.

1.5.1 Long distance route

The long distance route in this study, refers to the route between Kigali (Capital of Rwanda) and Nairobi (Capital of Kenya), Dar-Es-Salaam (Capital of Tanzania, there exists a port that connect Rwanda to the international shipments from all over the world) and Mombasa (a region in Kenya, where the main port that links East African landlocked countries to the international markets is located). Section S1 indicated on the map (See Figure 1-1 below) shows a part of this route in Rwanda. This route passes through Rusumo border and enters Tanzania and then it extends to Kenya. The average driving and flight distances are respectively: 1470 km and 1101.6 km.

1.5.2 Medium distance route

The medium distance subject to this study is the route between Kigali and Kampala (Capital of Uganda). The sections S2, S3 and S4 on the Figure 1-1 indicate different roads that, together compose this route. The average driving and flight distances are 580 km and 377 km respectively.

1.5.3 Short distance route

This is an intercity route, between Kigali and Rusizi cities in Rwanda. This route is indicated by section S5 on the Figure 1-1 below. The average driving and flight distances are respectively 290 km and 200 km.

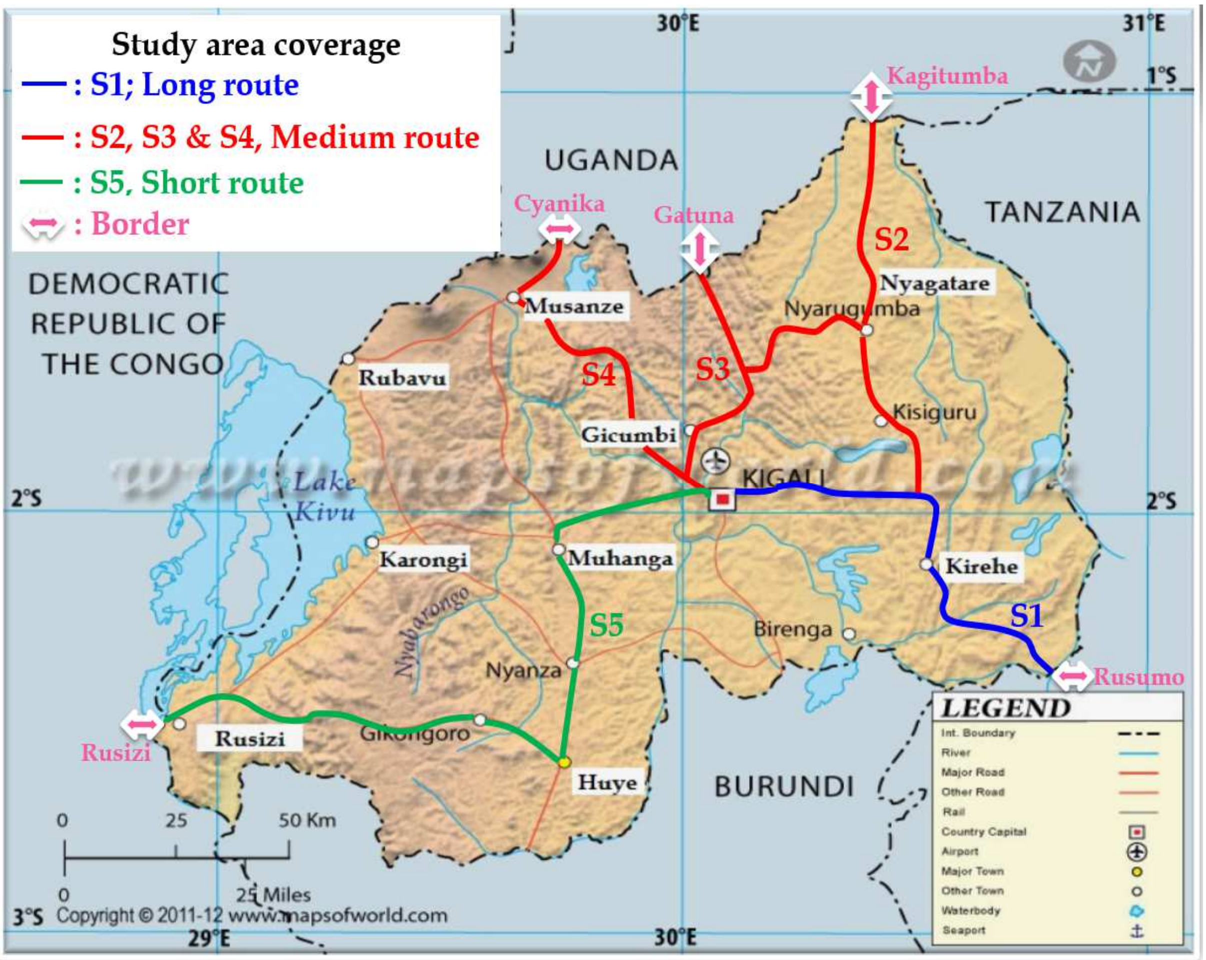


Figure 1-1: Study area coverage (Maps of World, 2014)

The technical part of this study has covered the following research elements:

- General information on HLTA transport technology;
- Development of Stated Preference experiment and choice preference data collection;
- Application of Multinomial/Binomial logistic regression modeling process;
- Determination of utility functions and magnitude values and hence the probabilities assigned to different modes;
- Calculation of monetary value of time attributes as part of models' outcomes;
- Determination of the transport demand volumes as shares of each mode based on the probabilities from the concepts of Multinomial Logit;
- Direct and indirect application of the resultant models.

1.6 RESEARCH STRUCTURE

The design of this study is based on different components that it comprises. Each part has got its specific elements and when taken together, these elements summarise the process that has been followed to achieve the objectives. The following Figure 1-2 demonstrates a sequential structure of different components starting from the overall objective.

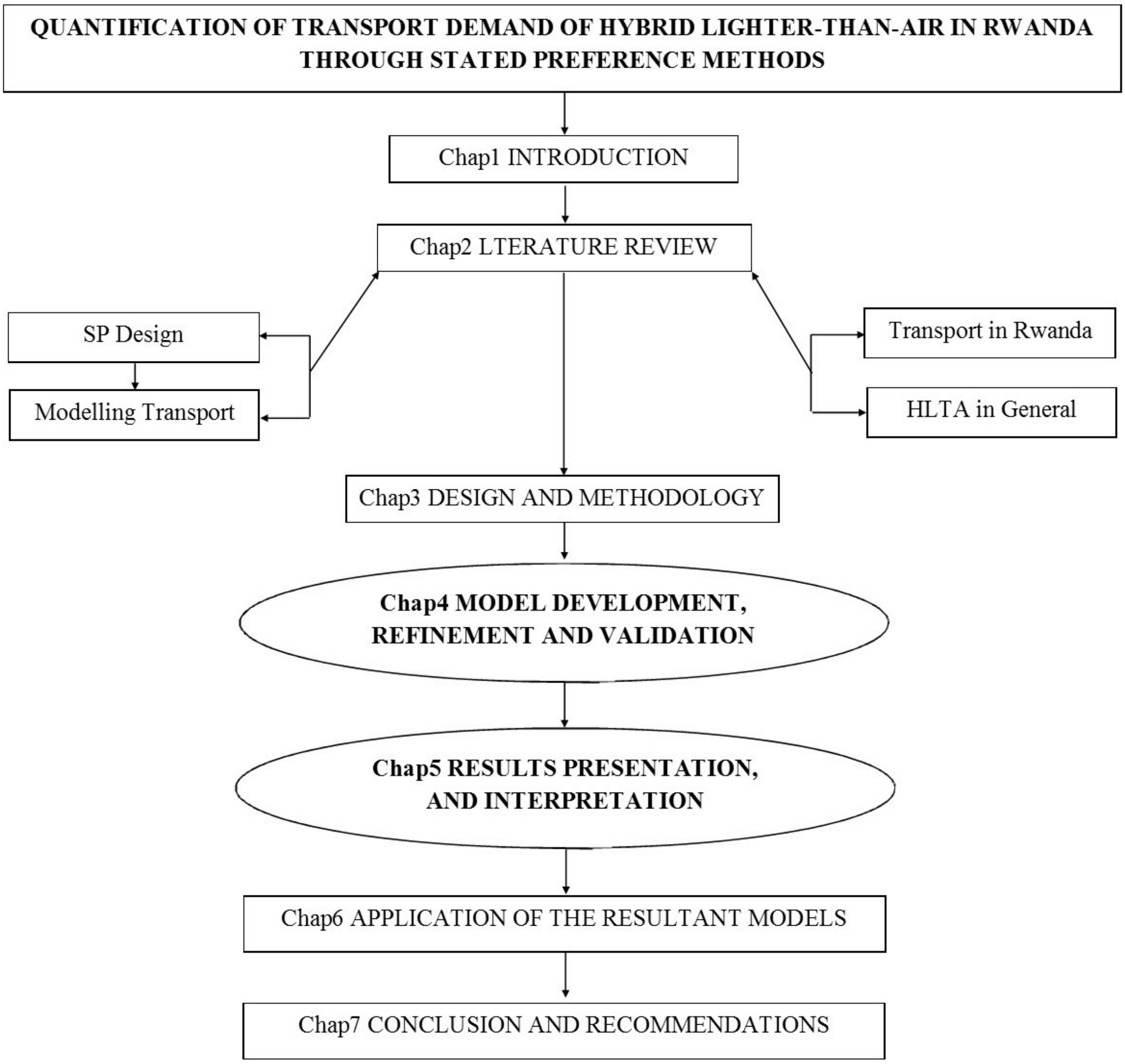


Figure 1-2: Structure of the thesis

1.7 OUTLINE OF THE STUDY

Chapter 1 consists of the background of the study, articulation of the problem; objectives of the study; the justification and rationale resulting from the use of HLTA, Scope, Structure and Outline of the study. It also includes a section of discussion of key terms used.

The remainder of the study is organised as follows:

Chapter 2 is the review of literature pertaining to the current problem and objective. The literature was reviewed under the following subsections: Transport model competition and the challenges encountered by Rwanda's transport systems, basic principles of working technology of HLTA and its environmental compliance, and the possible uses and capabilities of HLTA. In addition, the conceptual framework of the efficient designs of Stated Preference experiments and questionnaire writing principles. This chapter includes also discussion on the running of SPSS computer program in the analysis of binary logistic regression modelling, the application of principles of Multinomial/Binary logistic regression processes to determine the utility functions and probabilities of modes. Lastly, the discussion of the models refinement and validation, and then the determination of monetary value of indirect cost attributes.

Chapter 3 in turn, presents the conceptual design and methodology used; including the discussion on the sampling and data collection methods.

Chapter 4 comprises of presentation of data and analysis processes, the details on the main work of this study: models' development, refinement, and validation for this study.

Next is chapter 5, in which the presentation of the results takes place, and also the interpretation of findings.

Chapter 6 discusses the possible direct and indirect applications of the results.

Finally, Chapter 7 presents the conclusions and recommendations.

1.8 DEFINITION OF KEY TERMS

Hybrid Lighter Than Air

This is a new air transport mode that uses a mixture of buoyancy energy from lighter than air gas like helium and aerodynamic lift for its operations. Barry & Shelley (2002) argue that it has a lot of applications and will reach all parts of the globe in the near future.

Transport Modes: These are the means by which people and freight achieve mobility. According to Rodrigue, Slack and Comtois, (1998), transport modes are categorised in three basic groups depending on what surface they use: land (road, rail and pipelines), water (shipping), and air transport.

Stated Preference

This is a survey technique used to assess preferences in hypothetical situations (Sanko, 2001). It is used extensively in marketing studies to evaluate the willingness of the clients on use of a new products or services.

Alternatives

In the context of this study, an alternative transport mode is an option that can be used, for example: for road transport: Bus, Truck and for Air: HLTA and Air transport

Attributes

Also called variables, attributes are characteristics of an alternative transport mode (Koppelman & Bhat, 2006). For example: travel cost, travel time, service frequency, etc.

Combination

This term was used a number of times in this report where it means an arrangement of numbers (called here attributes' levels) in order to make a Stated Preference statistical design (Sanko, 2001).

Modelling

Modelling is the act of making models. A transportation model is a formal representation of the relationships between transportation system components and their operations (Myer, 2004).

Utility

A utility of an alternative in the choice process is interpreted as a usefulness of that alternative over the other alternatives in the choice set. Kumar, Basu and Maitra (2004) state that individuals assign the utilities to different alternatives and then they choose an alternative with the highest utility, a principle known as Random Utility Maximisation in different literature.

Probability

This is a measure of the likeliness that an event will occur. In the context of this study, probability is used to show how likely people would prefer an alternative mode of transport amongst the available alternatives.

Transport demand

Transport demand is expressed in terms of number of people, or tonnes of freight that travel per unit of time and space. According to Rodrigue, Slack and Comtois (1998), "Transport demand is a derived demand" which means that a traveller has got a determined purpose from which trip making demand is derived.

Chapter 2 LITERATURE REVIEW

2.1 INTRODUCTION

Transportation is considered as the act of moving people and goods from one location to another, guided by a determined purpose (Myer, 2004). The first point is the so-called origin, and the last is the destination. Taken together, transportation studies involve a branch of engineering that uses scientific facts to plan, design, execute, and manage transportation systems. A transport system consists of means and equipment necessary for the movement of passengers and goods. According to Eckhardt and Rantala (2012), "most of the worldwide transport systems currently in use, are the ones that had been created in the 20th century, but the appearance of the fast increasing transport demands are stressing these transportation systems at their capacity". Eckhardt and Rantala (2012) added that "the start of new transportation systems being developed, require significant planning, funding, governmental backing, and construction activities". Therefore it is important for transportation organizations to find appropriate modes of transport to best handle people's transportation needs.

Different literature references have made an emphasis of this fact. Examples include Myer (2004); arguing that, "the transport planning approaches are continuously being developed and transport modeling techniques have been improved to account for a variety of alternative modes and pricing incentives". In addition to these, an increasing portion of transport funds are flexible. This means that, they can be spent on various types of programmes and projects rather than just roadways. One of these programs that literature refers to, is the use of HLTA (Christian & Ryan, 2011).

This chapter provides a background of the literature on transport systems in Rwanda as the study area covered in this research. It examines the constraints available by providing different reports and conference proceedings. HLTA comes in as one of the possible solutions proposed. The details on the working technology of Hybrid Lighter Than Air Transport are presented as per the reports published by Hybrid Air Vehicles Ltd and other authors interested in this new technology. The last parts of this chapter consist of methods of survey and modeling approaches in the transportation field. The multi-model transport modes are emphasised, as they include Binary Logistic regression, applied in the analysis of the choice preferences data in this research.

2.2 TRANSPORT AND NATIONAL ECONOMY

Transport is an indispensable item in the business logistics channel. Without transportation, the movement of goods and services from one place to another would be impossible. This means that transport is a key element in the economic development of a nation, (Refer to Figure 2-1 below). According to Sivakumar, Yabe, Okamura and Nakamura (2006), enhancement of transport operation within a region would potentially improve routes that are located between markets, companies and industrial areas. Transport improvement would also relax constraints on access to the city centre and, therefore, increasing overall national employment and also productivity. However, when the traffic jam increases in the area, the effect goes beyond economic welfare and attack productivity. This as a result, reduces GDP (Graham, 2007).

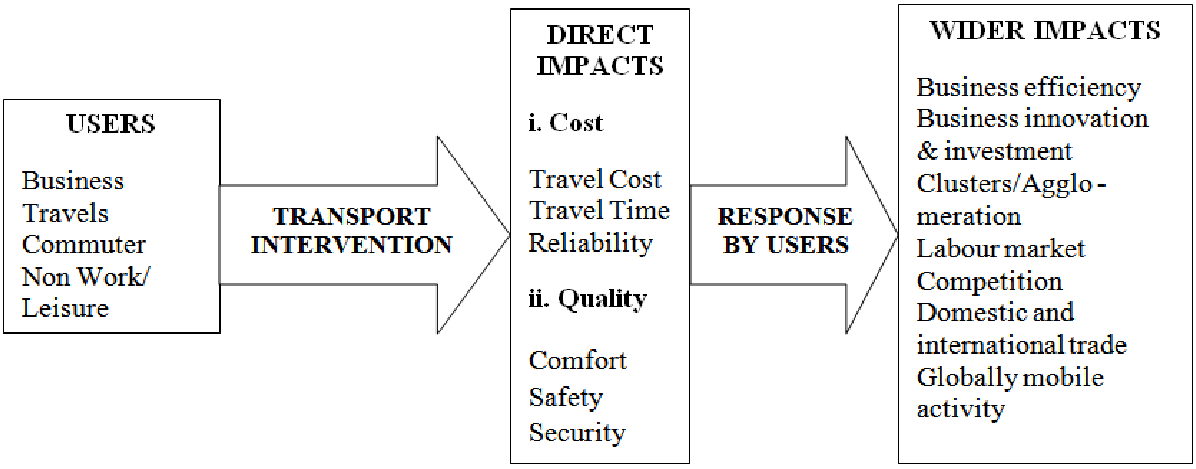


Figure 2-1: Links between transport and economic performance (Eddington, 2006)

The above figure demonstrates the impacts of transport on the economy. It shows that the intervention of transport in the users' business would have a good direct impact on the cost efficiency. This would be achieved by an efficient transport system with a reduction of travel time, the delivery reliability and would consequently increase the quality of business by ensuring safety, security and comfort. In the end, the impacts are widened by business innovation, increase of international trade and finally, the national economy.

2.3 OVERVIEW OF TRANSPORT SECTOR IN RWANDA

The transport sector is a strategic tool for the economic development for Rwanda. The transport sector contributes considerably towards poverty reduction and economic growth, and serves as a strong support to other economic sectors. This sector contributes approximately 7% to the GPD and represents approximately 15% of total service delivery (Mininfra, 2012b).

However, in Rwanda, the transport costs are exceptionally high at national as well as international levels. There are also insufficient modes of transport in terms of affordability and accessibility by people, in urban and rural areas. These two major constraints must be taken into account in the effort to achieve the short, medium and long-term development goals. In line with improving the transport sector, the ministry of infrastructure has set the following main objectives, which are mostly based on the reduction of economic costs for the transport users (Mininfra, 2012b):

- Strengthening the institutional framework and capacity of transport institutions and stakeholders, in planning and management of the subsector;

- Reducing and managing transport costs;
- Ensuring quality and sustainability of the rural, urban and international transport networks;
- Improving safety for goods and passengers on the principal modes of transport;
- Facilitating access to cost-effective transport services. (Mininfra, 2012b)

2.3.1 Transport modal competition in Rwanda (STATUS QUO)

The economic cost of transport per passenger or per tonne-km of freight of different modes differs significantly due to the operating cost of the mode itself. It is this factor that determines the transport modal competition. The following modes of transport are available in competition in Rwanda:

2.3.1.1 Road transport mode

Globally, road transport outweighs other motorised transport modes. In each of the East African Community countries, roads provide the dominant mode of freight and passenger movements and carry between 80% and 90% of the region's total trade in goods and services (PADECO Co. Ltd, 2011). The transport sector in Rwanda is no exception; for both passengers and freight, the national and international transportation is dominated by roads. The freight movements alone account for approximately, 7,100 tonnes per day by road (Aurecon, 2012).

According to Mininfra (2012a), the Rwanda road transport network consists of 14,000 km of National, District, Feeder and Urban roads. On this network, 1172 km (equivalent to 8.4%) is classified as paved national roads, 1688 km (equivalent to 12%) is classified as unpaved national roads and 1836 km (equivalent to 13%) is classified as gravel district roads. The remaining 9300 km (equivalent to 66.6%) of the network consists of unclassified gravel roads (Mininfra, 2012a). This dominant mode continues to cause losses in economy where 40% of the costs of businesses are attributed to transport (Christian & Ryan, 2011).

2.3.1.2 Air transport mode

The Aviation sector is currently characterised by scattered and limited public investment across the sub-sector. The national carrier (RwandAir) is currently at a start-up phase and the general aviation and cargo businesses are yet to be established in the country. RwandAir has a limited route network and, therefore, it does not enjoy economies of scale in the transport model competition. RwandAir depends on the government financial support to maintain its operations, because the private investment in the sub-sector is still very low (Mininfra, 2012a).

2.3.1.3 Rail transport mode

At present, there is no rail network in Rwanda; but two potential railway routes connecting both Central and Northern corridors are currently under research. The first line is Gisenyi-Kigali which could be extended to connect Goma in the Democratic Republic of Congo. The second is Dar -Es Salaam-Isaka-Kigali-Keza-Musongati railway line (Mininfra, 2012a).

2.3.1.4 Water transport mode

Being a landlocked country, Rwanda offers limited opportunity to the water transport mode. The inland waterway is very limited to operations in Lake Kivu. In the case of the Akagera river, transport operations are carried out over shorter distances and with smaller non-professional vessels and the amount of freight and passenger traffic is very low (Mininfra, 2012a).

2.3.2 Domestic freight transport status

Domestic distribution in Rwanda has all different categories of goods that are globally considered, based on the levels of processing and manufacture. These are raw materials, semi-finished goods, and finished goods. All these freight categories are almost all carried by road transport as it is the main mode available in Rwanda. According to Aurecon (2012), the domestic road freight industry is deregulated in the sense that there are no requirements for transport operators to be licensed to carry on their operations, although this is an area that RURA (Rwanda Utilities Regulation Agency) is investigating to formalise the industry. Road freight transport operations are all private, with rates set on a negotiated basis. Services are all non-scheduled, i.e. delivered on an as-required basis.

Kigali is the central distribution hub for all the cargo movement in Rwanda; see Figure 2-2 which gives an indication of different destinations. The reasons that make Kigali a central distribution hub are summarised, but not limited to the following:

- Most of the import cargo comes through the Northern and Central corridor to Kigali for customs clearance;
- Kigali is the largest consuming market in Rwanda and therefore, goods congregate at Kigali;
- Geographically speaking, Kigali is in the very centre of Rwanda, which makes it easy for distribution in the provinces. See Figure 2-2.

In rural areas, where the freight movements are particularly dominated by crops transport, the system lacks transportation from small plots of farms to provincial intermediary warehouses and from these intermediaries to Kigali and other towns in provinces and districts for final consumption.

Currently, small pick-up trucks are used for movements of short distance delivery. For larger consignments from provincial intermediary warehouses to Kigali, as well as for export purposes, larger trucks are used.

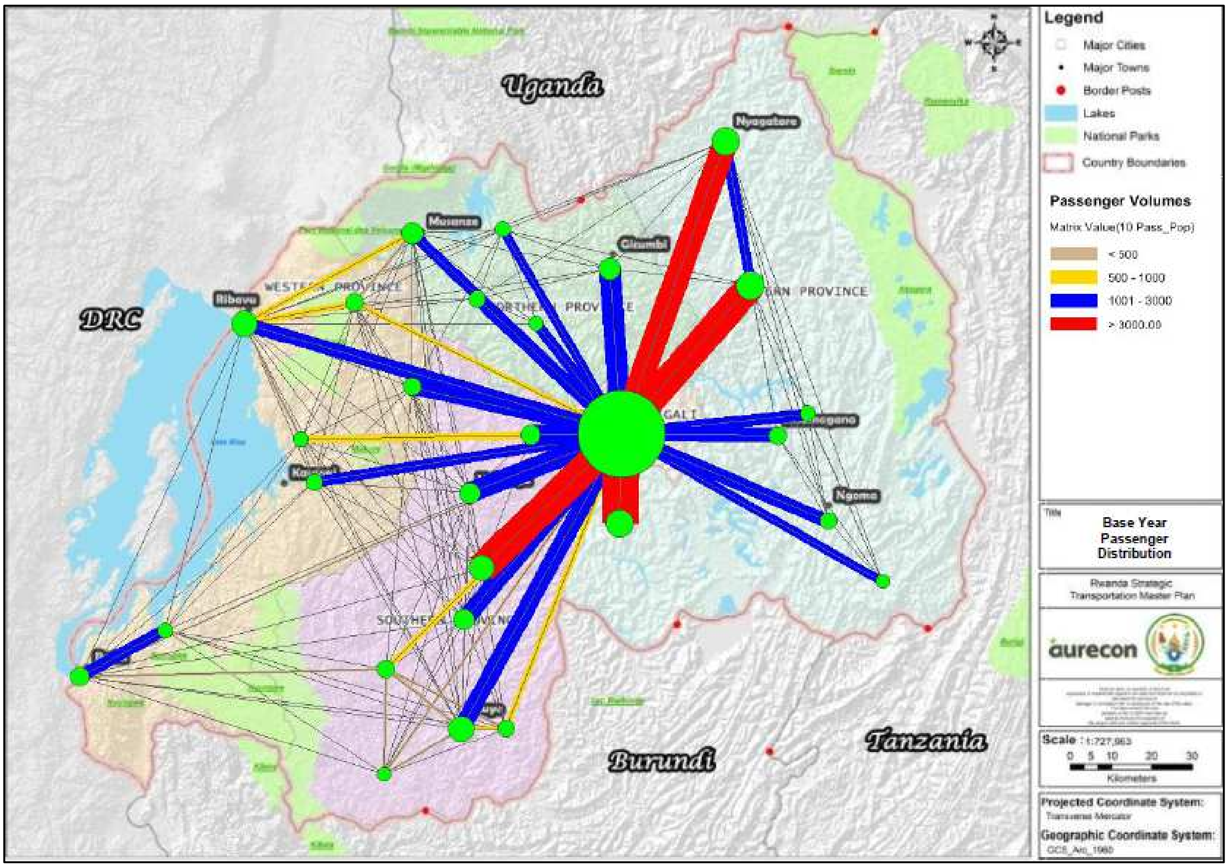


Figure 2-2: Freight volume distribution in Rwanda (Aurecon, 2012)

2.3.3 International movements

Rwanda depends on two main transport corridors for trade, namely: the Northern corridor and the Central corridor (Mininfra, 2012b) . The Northern corridor connects the landlocked countries of East and Central Africa, i.e.: Burundi, Democratic Republic of Congo, Rwanda and Uganda to the Kenyan seaport of Mombasa. Based on the 2009 public expenditure review on the transport sector, approximately 70% of Rwanda's external trade utilises this corridor. The central corridor links Rwanda to Dar-Es-Salaam seaport. This corridor accommodates approximately 30% of the country's external trade.

The main mode of transport for passengers on both corridors is bus and for the goods transport, truck is the main mode (Mininfra, 2012b). Air-cargo exists but, with, by very far less popularity, as compared to Truck.

2.3.4. Issues on Air Corridor

As compared to the port corridors which carry relatively higher volumes of traffic, the air corridor is at a nascent stage and carries very low volumes. It is not being utilised to its full potential, owing to difficulties in cargo consolidation, and also the very high costs associated with air transport. While critical imports are made through the corridor, the export volumes are usually low and dominated by agricultural products, mostly coffee and tea (Aurecon, 2012).

Most of the freight forwarders and operators who handle air cargo are located far away from the airport and closer to the city. Moreover, the air freight tariff is high as compared to tariffs available at other airports in East Africa, particularly to Entebbe which is the main competing airport because the trade is dominated by imports. Airlines also charge higher tariffs on inbound cargo, due to lack of outbound cargo from Kigali (Mininfra, 2012b).

2.3.5 Status of intercity road passenger services

The condition of national paved roads is very good, with a rate of 98% in 2011 (Mininfra, 2012b). However, there is a lack of network continuity, low capacity and low Level Of Service (LOS) for national and district roads. The Rwanda national road network is operating at undesirable LOS with 11.1% and 88.9% of the critical links of road network operating at a LOS E and F respectively (Mininfra, 2012b). This is against the standard given by Litman (2011), who argues that a typical transport planning process defines the minimum level-of-service considered acceptable as typically LOS C or D. Litman (2011) continues to argue that roads that exceed these values are bound to fail and so, deserve expansion or other interventions. It is, therefore, a clear indication that the road network of Rwanda is not satisfactory in terms of service and has to undergo interventions. The LOS of the bus route network has a significant impact on ensuring quality services for intercity bus travelers (Mininfra, 2012a). Unfortunately, despite all these challenges related to road transport, the movement is still dominated by bus for passengers and trucks for the freight transport.

2.3.6 Visionary aims for transport in Rwanda

Rwanda plans to develop the transport sector by the best technological modes of transport possible. The vision projected in the year 2050, is according to Christian and Ryan (2011), that "Rwanda will possess an efficient inclusive integrated transport system, which is fully energy secure and resilient to both climate change and increasing demand". This will be achieved by:

- A fully sustainable multi-model transport system that is based on efficient technology and operational systems;
- A low cost to entry;

- A fully secure domestic energy supply;
- Socially inclusive encompassing the majority of the Rwandan nation;
- Robust in terms of adaptation to climate change and future demand;
- Regionally competitive domestic transportation industry supporting the national economy;
- Sufficient access to capacity in terms of finance, knowledge and governance.

HLTA technology is believed to have abilities to handle most of the challenges described above, in the following sections different features of HLTA technology are discussed.

2.4 HYBRID LIGHTER THAN AIR TECHNOLOGY

2.4.1 Introduction

The term “Hybrid” refers to the use of both aerodynamics and propulsion power from non-combustible and lighter than air gas such as helium, to generate a lift. According to United States Government Accountability Office (2012), “The use of airships may hold the potential for significantly increasing capabilities in the areas of persistent Intelligence, Surveillance, Reconnaissance, Communications, as well as lowering the costs of transporting cargo over long distances and to austere locations”. The HLTA can be operated like a helicopter with vertical take-off, landing and hovering (Canadian Standing Committee on Transport, Infrastructure and Communities, 2013).

Today's airships could conceivably be used to transport everything from ripe pineapples to heavy industrial equipment directly to the customer. Shippers, for example, could roll tractors, backhoes, and road graders onto a 50 tonnes hybrid vehicle at a factory and roll them off at the job site, easing logistics and reducing costs (Bruce & The daily climate, 2011). A lot of applications are being developed today on this technology of HLTA. Different literature, including Barry and Shelley (2002), believe that airships of this type are going to reach all parts of the globe. The following sections discuss the working principle of HLTA and give an overview about its uses, capabilities, cost rates and its environmental competitiveness against ordinary aircraft.

2.4.2 Airship basics

There exist three types of Hybrid Lighter Than Air and they are classified in terms of rigidity. According to HAV Ltd (2012b), an airship can be rigid, semi-rigid, or non-rigid. Non-rigid airships are based on the pressure for its stability; it makes use of air that is filled into the bags (ballonets) to maintain hull pressure. As the airship ascends, the helium expands and forces the air out, maintaining pressure and in the same way when the airship descends, the helium contracts and air is forced into the ballonets. In case of empty ballonet the airship has currently attained the top pressure, and therefore going any higher would require helium to be vented to prevent over pressurising the hull. Semi-rigid airships have the same structure but are pressure stabilised. Rigid airships have a metal framework that makes up the hull and the lifting gas is contained in large gas bags (HAV Ltd., 2012). From these principles, the following relationships apply:

- Heaviness = Total Mass (Including Gas Mass) minus Displaced Mass;
- If Total Mass > Displaced Mass, then the vehicle is 'Heavy';
- If Total Mass < Displaced Mass, then the vehicle is 'Light';
- If Total Mass = Displaced Mass, then the vehicle is at equilibrium, (HAV Ltd., 2012).

Typical Hybrid Air Vehicles are presented in the Figure 2-3, and Figure 2-5, for demonstration purposes.

Figure 2-3: Typical Hybrid Lighter Than Air Vehicle: SkyCat (HAV Ltd, 2012b).

2.4.3 How a Hybrid Lighter Than Air works

The working principle of HLTA is a combination of two different sources of energy, the first, which is the dominant, is Buoyancy, providing approximately 60% of the lift given by the use of helium gas. The second is the aerodynamic and propulsive lift to provide extended endurance in a vehicle that is easier to operate than traditional lighter-than-air aircraft. This provides the remaining 40% and is privileged also by the vehicle's shape (HAV Ltd, 2012). Additionally, powered lift is used during takeoff and landing by vectoring the thrust from four ducted propulsors. This minimises ballasting and allows transfer and winching of heavy logistics, landing on unprepared surfaces, and enhancing stability on the ground. A full hover craft landing system allows operations from austere fields and provides amphibious capability (HAV Ltd, 2012). Figure 2-4 below, demonstrates the sources of energy used for the operation of HAV. The helium filled hull creates lift, which, when combined with the vectored thrust engine, enables Vertical Take-Off / Landing (VTOL), as well as precision hover. The hovercraft landing system's suck down allows for multi-surface operation and load transfer on land, water, ice and snow (HAV Ltd, 2014).

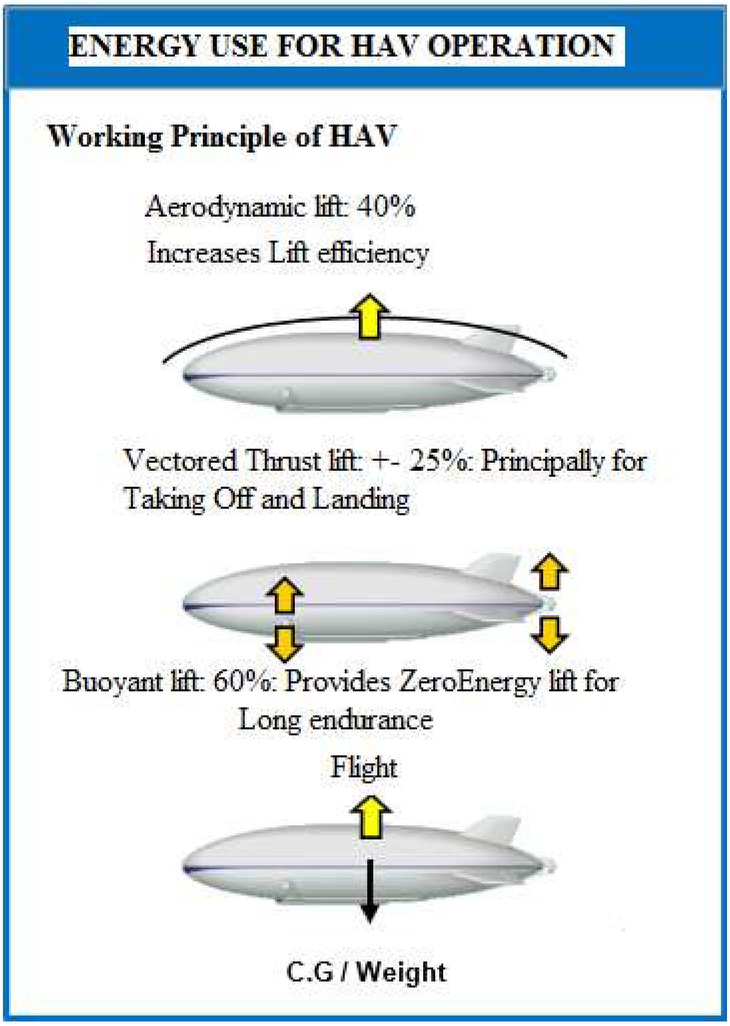


Figure 2-4: Combination of different sources of energy of HAV (HAV Ltd, 2014)

In the case of a new model of AirLander 50, the airship is optimised for carrying freight. It has the power to carry 50 metric tonnes of payload during conventional take-off and landing and over 550 m^3 of internal space. Using vector thrust, the vehicle can also be operated in helicopter mode, with a payload capacity of 20 metric tonnes. Looking at helicopters' capability, one will realise that this is higher than the normal values. A further benefit is that once the loading / off-loading had been completed, the vehicle reverts back to operating like a fixed wing aircraft, offering much lower operating costs and longer range than a helicopter (HAV Ltd., 2012). Depictions of AirLander50 and its inferior supporting parts can be seen in Figure 2-5 and Figure 2-6 below.

Figure 2-5: Typical Hybrid Lighter Than Air: AirLander 50 (HAV ltd, 2014)

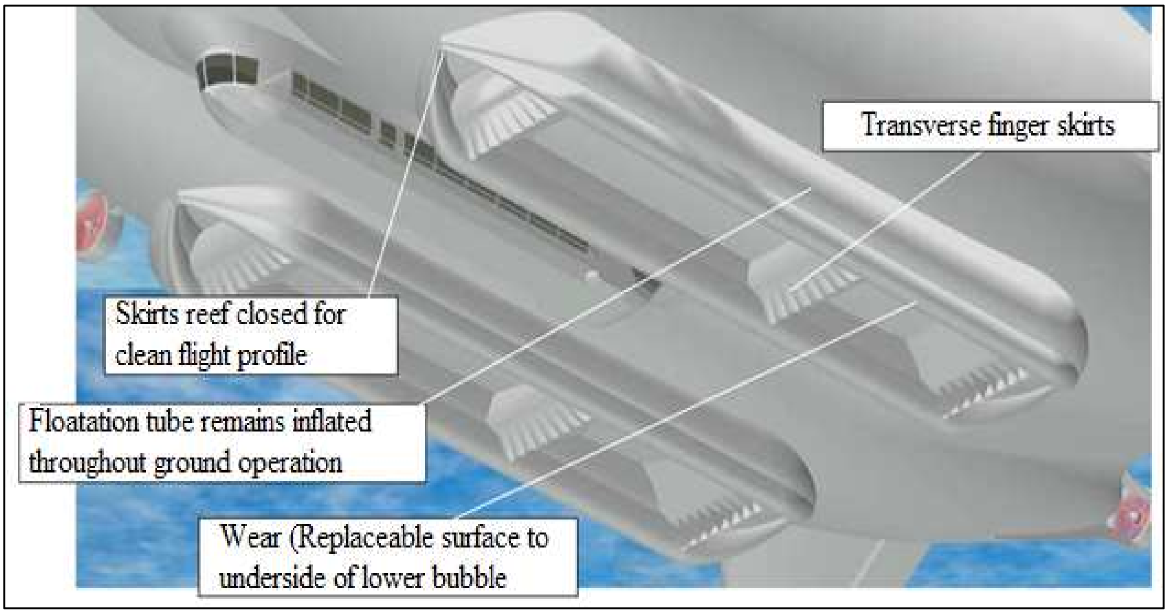


Figure 2-6: Inferior supporting parts of HAV: AirLander 50 (HLTA Ltd, 2011)

2.4.4 Status Quo, Hybrid Lighter Than Air

Currently the use of HLTA is progressing successfully. The success of HLTA is being promoted by Hybrid Air Vehicles Ltd, a company that is based in Cranfield in the United Kingdom. Hybrid Air Vehicles Ltd is a pioneer and world leader in the design, manufacture and support of innovative Lighter-

Than-Air (LTA) aircraft products, known as "Hybrid Air Vehicles". This firm has improved the airship technology by bringing together a long legacy of Lighter Than Air design and delivery experience. HLTA Ltd has combined airship technology with modern technologies to create a major new, cost effective, low carbon emission aerospace business, focusing initially on the surveillance and heavy lift markets.

Recent improvements in manufacturing technology, such as advanced fabrics, control technology and simulation have enabled the team to build a hybrid air vehicle that has significant advantages over the original airship concept. This resulted in the development of AirLander 50, an aircraft that has substantial applications in Canada today. This hybrid aircraft can land on any reasonably flat surface; including snow, ice, water or land. It requires no prepared runway and virtually no infrastructure. Connecting remote communities in a cost effective way in all four seasons suddenly has become a reality. According to IET (2014), the use of HLTA potentially supports strategic objectives and programs such as Arctic Sovereignty, the Enbridge Northern Gateway Pipeline, The Quebec Northern Development Program and Arctic Watch programs in Canada. For some, AirLander 50 offers more than just a more flexible, cost-effective mode of transport. Mining companies see this as a game changer, reducing the need for extensive access infrastructure and the extensive capital investment that the infrastructure requires. Assets that were previously deemed economically unviable are currently being reassessed with AirLander 50 being deployed as “mobile infrastructure”, (HAV Ltd., 2012). The first batch of AirLander 50 will be available for commercial application in 2015 (IET, 2014).

HAV Ltd (2012) argues that, engaging with the energy and mining sectors has enabled an understanding of their requirements in detail, and delivers an aircraft that is optimised for their operations. Hybrid Air Vehicles Ltd has also made an inauguration of the heavy lift operation in the commercial activities by their airships. The launch of Discovery Air Innovations (DAI) took place in London and Pointe Claire, Quebec. Then, on August, 12^{th} , 2011 Discovery Air Innovations, the owner of Discovery Air Inc and Hybrid Air Vehicles Ltd made a signature of agreement in which DAI will be the first customer for HAV’s commercial heavy lift program. Discovery Air Innovation Inc is a specialty aviation company based in Canada, with operations approximately in the whole world. The services offered include: cargo transport, rotary wing, and fire escaping services, logistics and military aviation services. DAI president, Paul Bouchard, has stated that, “HAV’s heavy lift and cargo market will be a tremendous addition to DAI’s range of aviation services”. With a cargo capacity of 50 tonnes at speeds up to 105 knots (194 km/h), DAI believes that, this capability will enable economic development of remote, stranded resources with a low environmental impact. The ability to deliver cargo point-to-point without the need for a runway, means the infrastructure costs of clients are reduced substantially.

2.4.4.1 SkyCat HAV for Canada

The SkyCat HAV in Canada has different features that outweigh other modes of transport in comparison:

- Minimum Infrastructure Operations: VTOL operations on land, water, marsh, ice and snow;
- Wide ranging capabilities: Multiple applications, including: prospecting, oil/mine/gas hardware supply, logistic supply to communities, Arctic sovereignty support;
- Environmentally benign: No requirement for prepared runways or ice roads, greatly reduced CO_2 ($\frac{1}{4}$ that of airplanes);
- Scalable: Initially planned for Canada at 50 and 200 tonnes payload capacity, but with potential to extend to 1000 tonnes with further development HAV Ltd (2009).

In Canada, a study was conducted by HAV Ltd (2009) on the SkyCat1000, where it was referred to as strategic freight-SkyCat1000. The HAV was found to have:

- Little cost: The cost of this HAV, was calculated to be equal to sea freight. This conclusion confirms the findings of ATG group that was presented by (Prentice, Beilock, Phillips & Thomson, 2010) that "for the very largest volumes up to 1,000 metric tonnes capacity, freight rates of HAV would be comparable to marine shipment". (Refer to Table 2-3 to come);
- End to end delivery times;
- The larger the SkyCat, the more efficient;
- Point to point delivery with choke points;
- Low emissions: lower environmental impact.

In the same study, the transportation costs have also been compared between different modes of freight transport. Figure 2-7 below demonstrates the results of this study done by HAV Ltd (2009) in Canada. It shows that transportation cost is very high for air freight compared to that of HAV. The figure also shows that end to end delivery cost is small compared to sea freight.

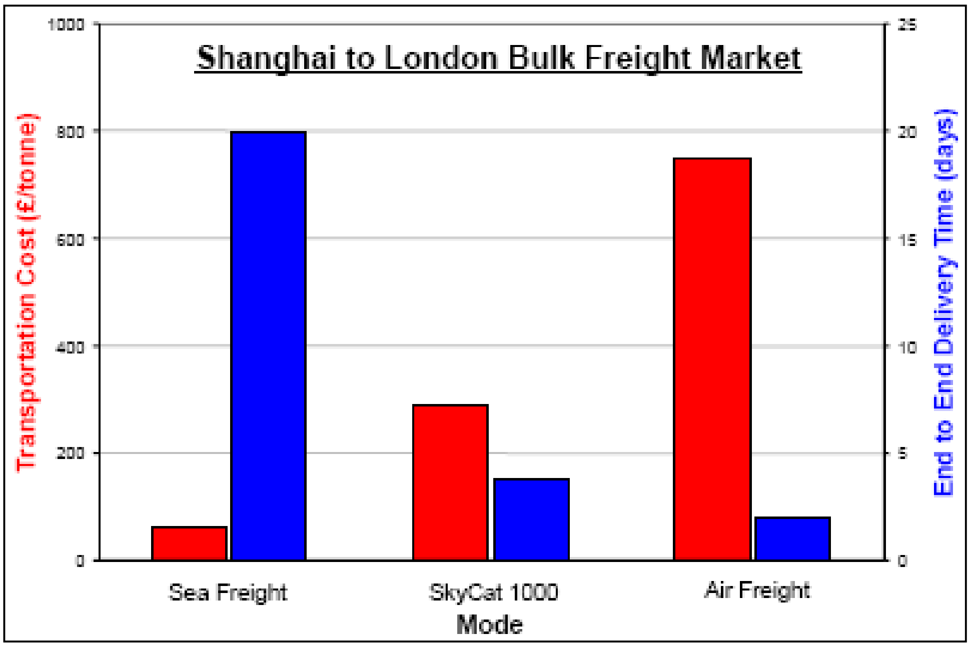


Figure 2-7: Transport cost for sea freight, air freight and SkyCat1000 (HAV Ltd, 2009)

Another study has also been conducted in the North of Canada on SkyCat20/50. The conclusions were:

- HAV has low environmental impact;
- SkyCat50 is cheap and its cost is equivalent to a third of the cost of fixed wing aircrafts (Refer to the Figure 2-8 below);
- Point to point delivery-all terrain landing;
- No specialised ground infrastructure required.

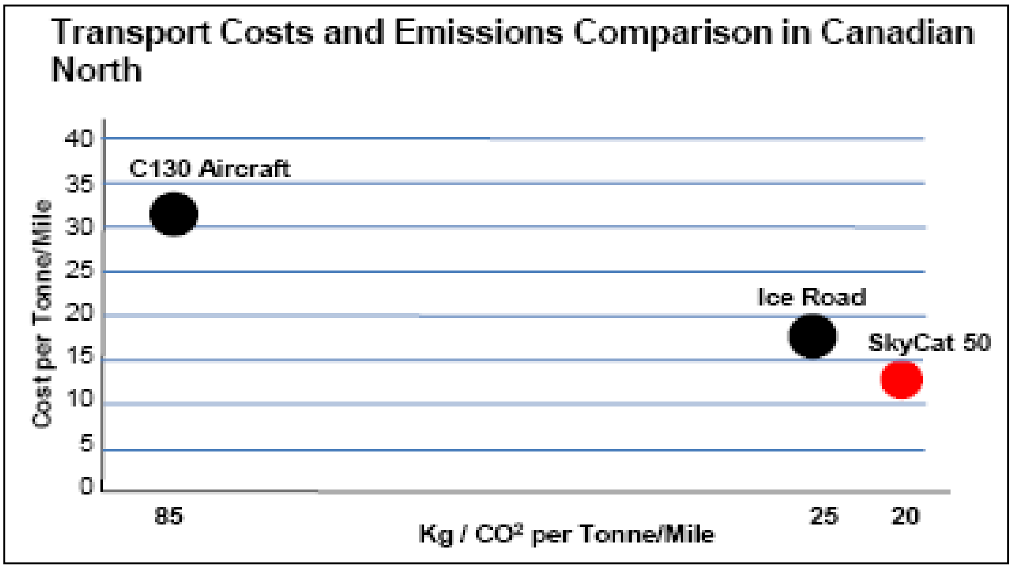


Figure 2-8: SkyCat50 and Ordinary aircraft costs and emissions in Canada (HAV Ltd, 2009)

The challenge of the use of ground transport in Canada was the main reason that HAV Ltd (2009) has based on in conducting the study of HAV application in this country. The hypothesis was that an HAV like SkyCat200 can reduce shipping costs and speed-up delivery for hardware. So, in order to prove this, a 134km segment of pipeline surrounding little Chicago has been used as the baseline for comparison. Then SkyCat 200 delivers 160 tonne loads of 30" and 10" diameter pipe (80ft long) to Norman Wells and 80 tonne loads onwards to the pipe trench. The following applied method was reported to practically demonstrate the working procedure (see also Figure 2-9):

- Airlifts pipe bundles from mill in Regina to Norman Wells staging site;
- Unloads long haul loads at stockpile site / reloads short haul loads to the trench (Deployed from air hover at 250ft);
- Year round shuttles from mill corridor;
- Lowers bundles along corridor for welders to disassemble and move to the trench.

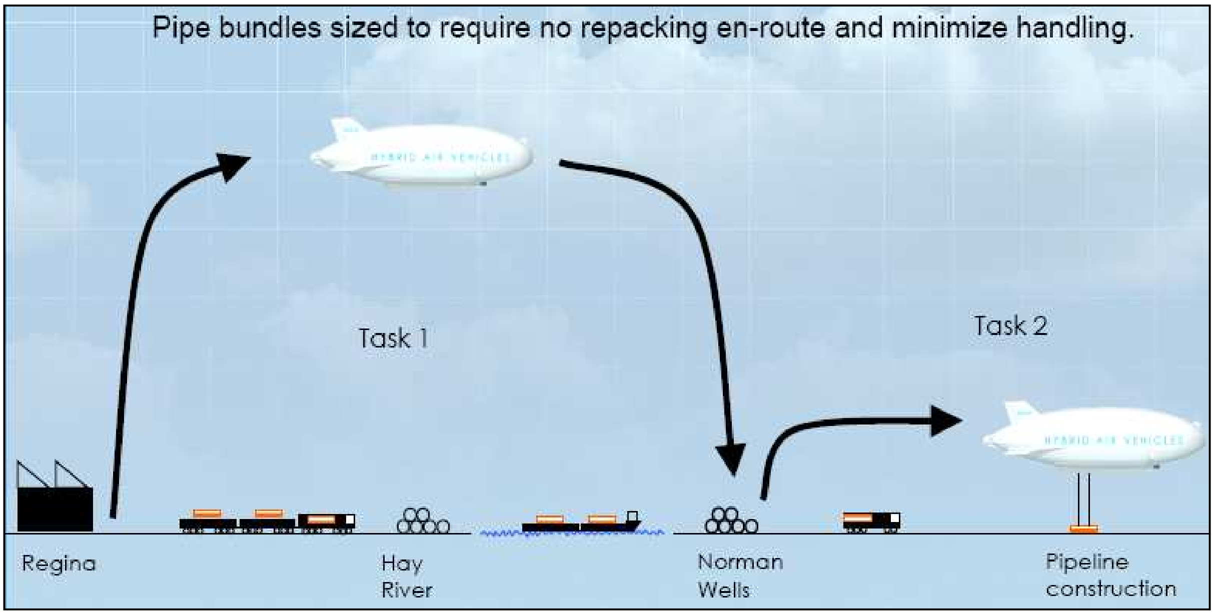


Figure 2-9: Demonstration of methods used to show the use of HAV (HAV Ltd, 2009)

The Figure 2-10 below shows a map of the routes and distances followed, whereby:

Task 1

- Pipe bundled at factory into circa 40 tonnes handing units for transportation;
- Each return flight to Norman Wells takes 28 hours (4,000km) carrying 4 bundles;
- 30" pipe takes 250 flights, 10" pipe takes 50 flights.

Task 2

- Pipe bundles collected from Norman Wells for delivery to trench;
- Each return flight to pipe trench takes circa 4 hours (500km) carrying 2 bundles;
- 30" pipe takes 500 flights, 10" pipe takes 100 flights.

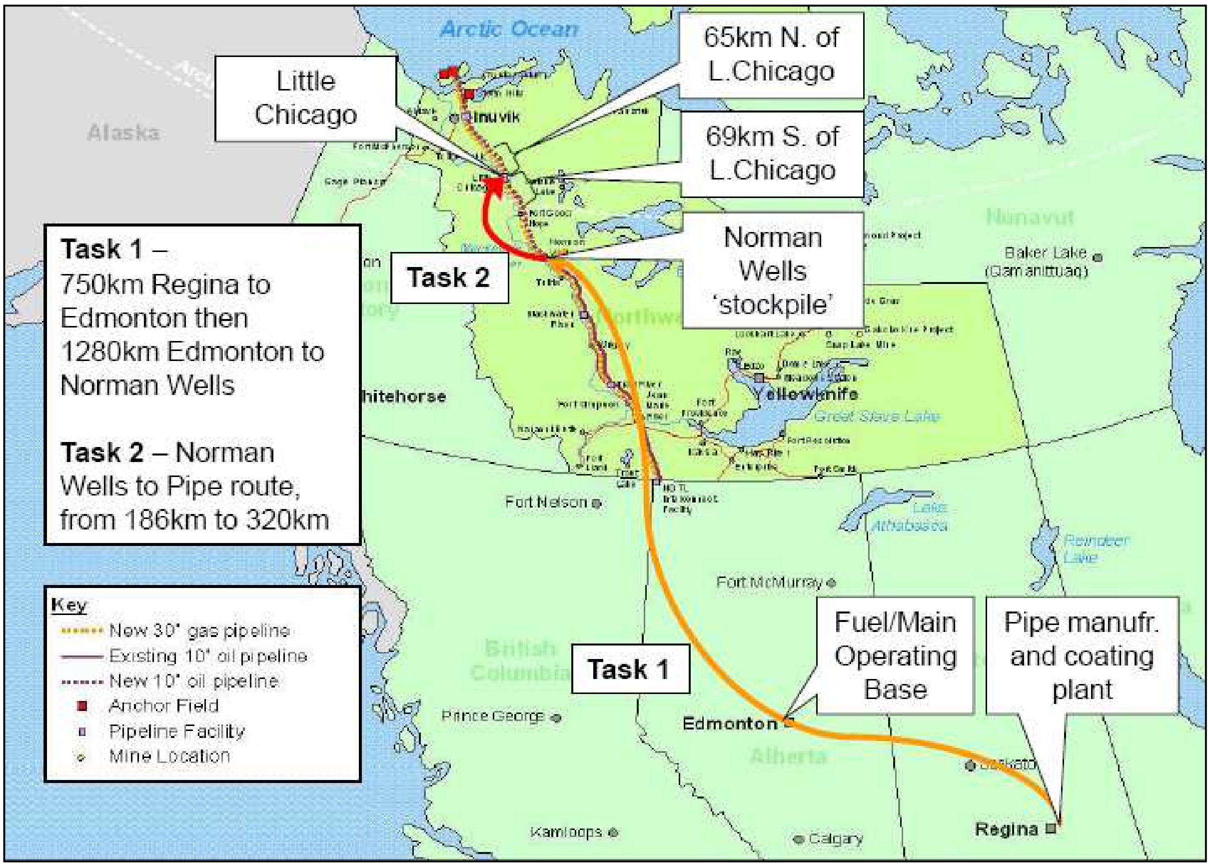


Figure 2-10: Mapping the tasks undertaken to show the use of HAV (HAV, 2009)

The team of HAV has been responsible for design, manufacture, flight test, maintenance and operation of the majority of the different programmes in Canada. They also had to certify the flight testing. Different programmes and flight tests can be seen in Figure 2-11 below:

Figure 2-11: Different programmes and flight tests of HAV (HLTA Ltd, 2009)

2.4.4.2 HLTA progress in the USA

In the United States of America, there are projects with regards to the use HLTA. In 2010, partnering with Northrop Grumman, HAV Ltd won a $517 million U.S. Army contract to develop the Long Endurance Multi-intelligence Vehicle (LEMV) for deployment into theatre in 2012. This vehicle is able to operate above 20,000 feet (MSL) with up to 21 days endurance.

2.4.4.3 Hybrid Lighter Than Air in near future

Today, Hybrid Air Vehicles Ltd plans to establish regional centres in almost all the parts of the world for the operation and support of its aircrafts. Some of these centres will also provide design, development and production aspects for the aircraft and become centres for innovation about the core technology (HAV Ltd, 2014). By supporting the development of this compelling aircraft solution, interested federal, provincial and municipal governments will benefit from acquiring a market lead for the technology. Business plans generated for current negotiations with federal and provincial governments in Canada have indicated that each regional centre is likely to create 500 net new jobs. In addition, an estimated 2,000 jobs will be created in the supply chain. Since the advanced materials and systems used in AirLander 50 require high skill levels, these new jobs are anticipated to generate high average tax incomes for the state (HAV Ltd, 2013). The next section describes the capabilities of different types of HLTA vehicles available.

2.4.4.4 Hybrid Air Vehicles' main uses

The main uses of HLTA range from short haul passenger services and extend to military services and public cargo transport. These uses, stem from its flexibility in reducing or eliminating transshipments and fuel consumption is equally impressive, saving up to the maximum of 75% on equivalent payload alternatives. Table 2-1 below shows some of the HAV aircrafts and their main uses.

Table 2-1: Capabilities and main uses of Hybrid Air Vehicles (HAV Ltd, 2011)

CAPABILITIES					**MAIN USES**
Aircraft	**Payload (tonne)**	**Max Range (miles)**	**Max Altitude (ft)**	**Max Speed (knots)**	
HAV 266	20	5200	9000	92	▪ Short haul passenger transport. ▪ Re-supply of hardware, consumables, fuel/oil, personnel etc. Palletised or loose equipment.

HAV 366	50	6000	9000	104	▪ Commercial point to point cargo/ Freight short haul operations. ▪ On/off shore oilfield support. ▪ Crane/winch type operations, vertical lift and precision hover. ▪ Roll on/Roll off loading and unloading plus winch and craneage. ▪ Humanitarian aid delivery: unprepared runway operations. ▪ Military type logistics support. ▪ Special events/Tourism, etc.
HAV 606	200	6500	9000	90	▪ Delivery of balanced fighting units, ammunition transportation. ▪ Commercial long range and outside cargo/freight delivery. ▪ Roll on/Roll off and unloading ▪ Crane/winch type operations, Vertical lift, and precision hover. ▪ Humanitarian aid delivery rescue/ evacuation, mobile field hospital. ▪ Cruise liner type operation.

2.4.4.5 Heavy lift capabilities and operational benefits of HLTA

The operational benefits and capabilities can be explained in terms of load/lift capacity, low cost, rapid deployment, reliability and ease in operation. Ground loading offers roll-on-roll-off capability, while the precision hover allows pick-up and delivery of cargo from ships or other austere locations. HLTA can carry cargo whose size and weight are highly unsuitable to other modes of transport. HLTA can also avoid the rehandling of cargo along the way. More details about the capabilities and their related operational benefits are found in the following Table 2-2.

Table 2-2: Capabilities and related operational benefits for HLTA (HAV Ltd, 2011)

CAPABILITIES	OPERATIONAL BENEFITS
Load/lift capacity	▪ Winches vertical loads larger than any other air vehicle can do. ▪ Loiter, precision hover and craneage of heavy loads capabilities. ▪ Roll on/roll off loading and unloading. ▪ Primary load area developed as an industrial rather than aerospace structure.
Low cost	▪ Low fuel consumption/gas emissions. ▪ Low asset cost and ongoing operating and maintenance requirements.
Rapid deployment	▪ Rapidly deployable, into extreme environments with minimal support infrastructure. ▪ By passing traditional road/sea infrastructure resulting in substantial time savings. ▪ True point to point transportation of machinery personnel to industrial fields avoiding choke points and dangers at close to fixed wing aircraft time.
Reliable	▪ Up to 105 knots airspeed with high reliability. ▪ -50C to +55C temperatures, resistance in wind speeds of up to 50 knots.
Easy to operate	▪ Can launch, land, load from gravel airstrips, water, or snow / ice surfaces. ▪ Neither infrastructure upgrades nor specialist handling equipment required.

According to the Hybrid Air Vehicles Ltd (2011), the AirLander 50 particularly, has the following benefits:

- Cargo flexibility: The large payload is ideal for carrying large equipment, such as drill rigs or mining equipment. See Figure 2-12 below (HAV Ltd, 2011);

Figure 2-12: Lifting flexibility of AirLander50 (HAV Ltd, 2011)

- A useful rectangular shape, large rear hatch can accommodate a variety of containers. It can, for example, hold six ISO containers. Using it in the trade heavy lift will therefore be successful (HAV Ltd, 2014);

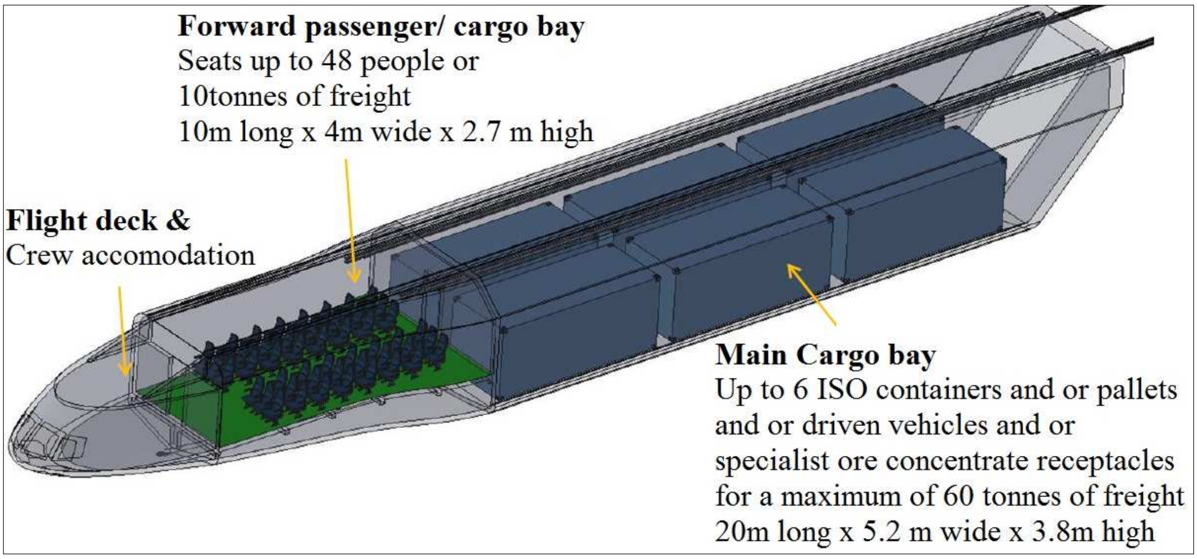


Figure 2-13: Operational features of AirLander 50 (HLTA Ltd, 2014)

- It is designed to be the safest aircraft. It does not stall, has slow approach and take-off speeds (45 knots), it has four engines located far apart (less risk of damage to more than one unit), and can fly on one propulsion unit. It also has the Air Cushion Landing System (ACLS) to absorb impact in the extremely unlikely case of full propulsion power failure;

- In addition to all these merits, Airlander50 can also mix the cargo and passenger transport, as demonstrated in Figure 2-13 above.

2.4.4.6 Cost rates of Hybrid Air Vehicles

Being a new technology, limited research on HLTA has been performed. This is why most of the publications have been done by the manufacturing company itself. The cost rates of HAV are said to be commercially confidential until now. On a comparison basis, HAV Ltd (2014) says that AirLander50 fuel burn is approximately one quarter and costs half of the same task undertaken by a C130.

As far as the cost is concerned, a research that was done by Advanced Technologies Group Ltd and presented in Prentice, Beilock, Phillips and Thomson (2010), had come up with estimates about the costs rates of HAV. In this report, the authors compared the cost per tonne-km, considering different carrying capacity (refer to the following Table 2-3.)

In publishing these values, the authors also had pointed out that the more the carrying capacity, the lesser the cost per tonne-km. The low values of cargo would be costly, but up to 200 Metric Tonnes, rates would be comparable to trucking and for the very largest volumes up to 1,000 MT capacity, freight rates would be comparable to marine shipment. See also Table 2-3.

Table 2-3: Freight rates of HLTA (Presented by Prentice *et al.* 2010)

AIRSHIP CARGO CAPACITY	FREIGHT RATES ($/Tonne-Kilometre)
20MT	$1.5
200MT	$0.2
1,000MT	$0.06

2.4.5 Hybrid Lighter Than Air and Environment

The hybrid air vehicle is one of the most environmentally friendly modes of transport available worldwide. This is so, since, HLTA provides an opportunity to meet the growing demands of an interconnected world while reducing the environmental impact that humanity imposes upon the planet. This is demonstrated in the reduction of the carbon emissions that it exhibits. Historically airships have been extremely energy efficient and modern airships are even more so (HAV Ltd., 2014). The environmental friendship facts of Hybrid Air Vehicles are summarised in the following statements:

- Airships have extremely low emissions of both greenhouse gases and other pollutants. When less fuel is burnt, fewer emissions result. The consumption of the fuel usage of HAV is demonstrated in Figure 2-14 comparing it to the one of the normal airplanes.

- Airships are much quieter than other forms of aerial transportation. This improves the quality of life for those served by airship transport, and opens airships for use in ecotourism without jeopardising the tranquility of remote biomes. With the capability to fly at variable speeds, including hovering, airships can allow eco-tourists to observe sensitive monuments and natural wonders from a spectacular vantage point, with little to no impact upon these treasures.
- Airships require very little to no ground infrastructure, allowing operations in austere locations without the need to build or maintain costly roads, ports, or airports, which themselves are disruptive to sensitive ecosystems. This opens remote developing regions to the global marketplace. Perishable, organic produce can find willing buyers on the world stage, facilitating sustainable fair trade, where before, lengthy complicated logistics made such efforts infeasible.
- The Green House effect of the Hybrid Air Vehicles is very small as compared to other Aircraft doing the same activity per tonne-km/h. Refer to the Figure 2-15: Environmental impacts of HAV and normal aircrafts (HAV Ltd, 2014).

2.4.5.1 Fuel consumption versus productivity for HAV and normal airplanes

The following Figure 2-14 demonstrates a comparison of the existing technology level and expected future improvements in fuel consumption and productivity for both HLTA and fixed-wing aircraft. It can be seen from the graph that the more the weight carried by HLTA, the more the productivity and the less the fuel consumed per a unit basis. It can also be seen that normal aircrafts consume much more fuel than the HLTA. The Airplane C-130 (20 tonnes payload) consumes high fuel (0.28 kg-fuel/tonne-km payload) as compared to HLTA-20 (20 tonnes payload) that consumes (0.12 kg-fuel/tonne-km). But when it comes to productivity, the normal aircraft still compete HLTA.

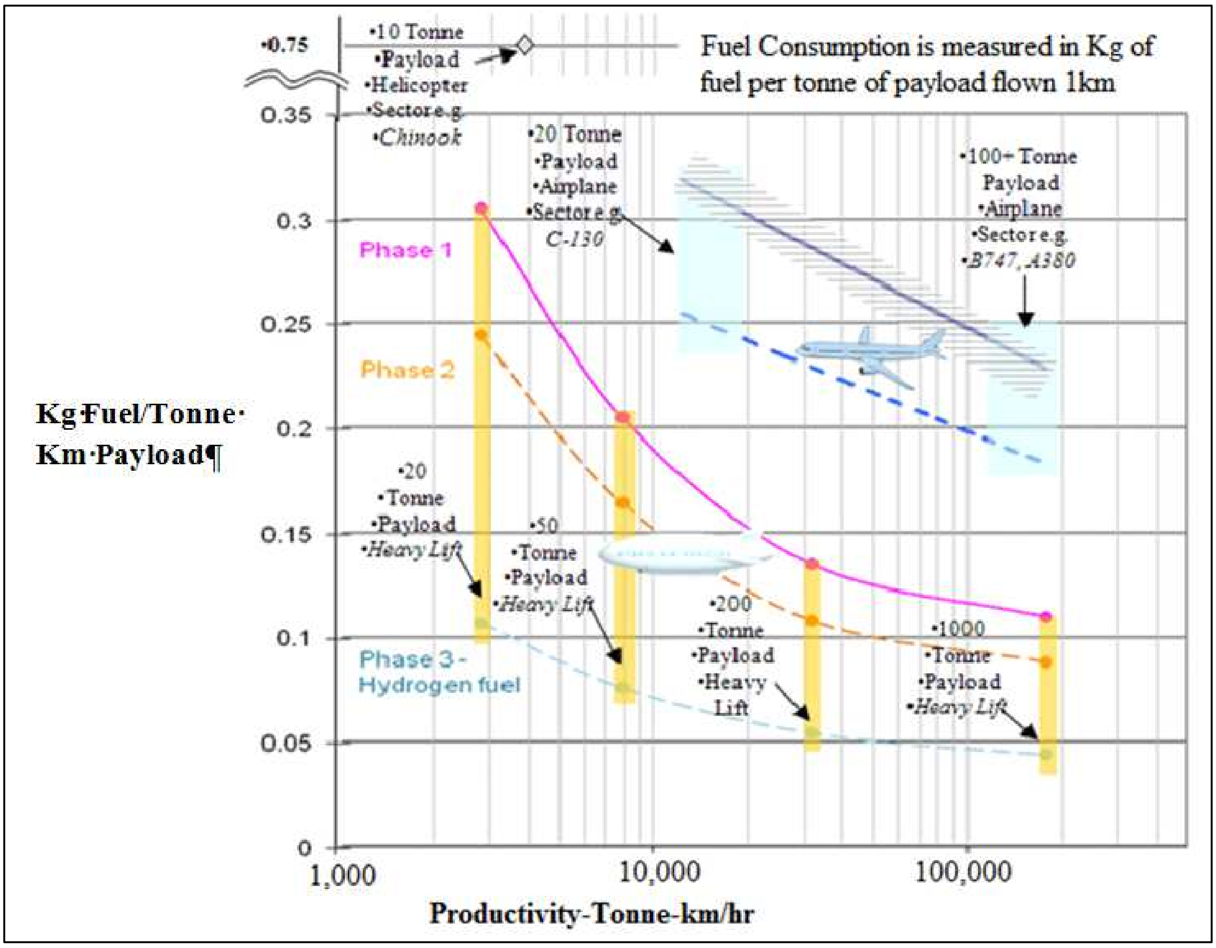


Figure 2-14: Fuel consumption of HAV and normal Airplanes (HAV Ltd, 2014)

2.4.5.2 Greenhouse effect due to aircraft productivity

The Green effect index reflects the negative impact of the vehicle on the atmosphere taking into account fuel consumption and flight altitude. The following Figure 2-15, indicates the existing technology level and expected future improvements in Greenhouse Gas emissions for both hybrid and fixed-wing aircraft. Hybrid aircraft have lower greenhouse gas emissions because they consume less fuel and operate at a lower altitude. This can be seen from Figure 2-15 below, where the Green effect index of normal aircraft is 3x, and 1x for heavy lift HLTA.

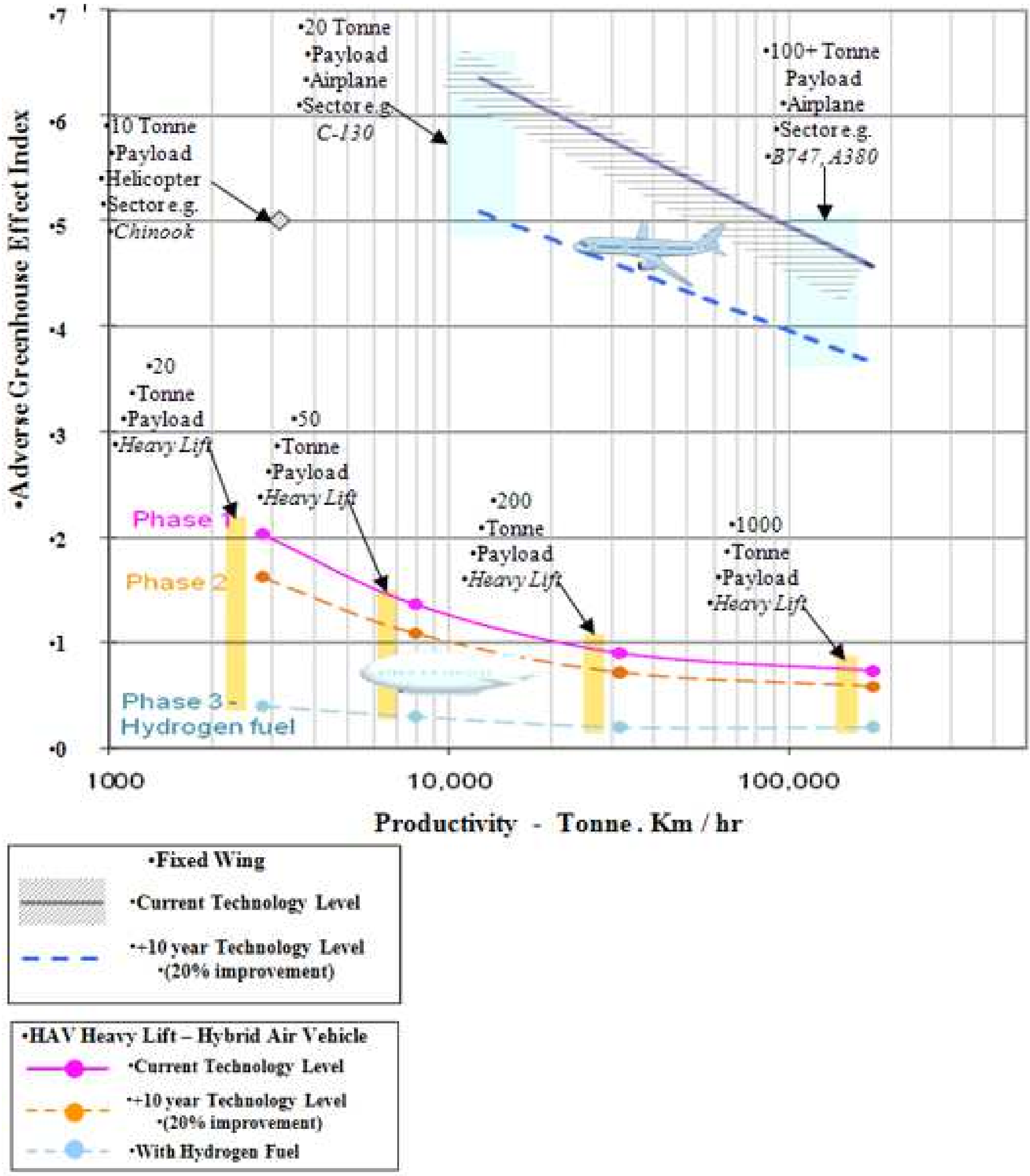


Figure 2-15: Environmental impacts of HAV and normal aircrafts (HAV Ltd, 2014)

2.4.6 Market opportunities of Hybrid Lighter Than Air

The following are the areas that benefit from Hybrid Air Vehicles' technology:

1. Surveillance.

- Geo surveying: e.g.: Photogrammetric surveying;
- ISR: Intelligence, Surveillance and Reconnaissance: Military applications.

2. Cargo transport.

- Commercial freights;
- Point to point deliveries of materials and equipment;
- Mining oil and gas support;
- Humanitarian aid.

3. Passenger transport: e.g.: Long trip passengers, short haul passengers.
4. Search and rescue: e.g.: in Floods and fire breaks and in accidents.
5. Coastal Patrol.
6. Advertising and filming. (HAV Ltd, 2012).

HLTA has many new features and advantages, but these would be valuable only if this mode has adequate transport demand to motivate its use. The following section describes literature on modelling transport, which will be used later to develop models, that will be used to determine the preferences of HLTA and other modes, and thus their transport demand shares.

2.5 MODELLING TRANSPORT

2.5.1 Introduction

Transport demand is typically defined as the volume of freight and passengers that moves between two positions. The demand of travel, strongly depends on land use and on economic conditions of the area (Myer, 2004). Modeling is the act of making models, while a transportation model is a formal description of the relationships between transportation system components and their operations. Knowledge of these relationships allows for estimating or predicting unknown quantities (outputs like demand of traffic on routes, demand of traffic to assign on modes etc.), from quantities that are known (inputs, like mode's travel time, cost, etc.). Todd (2013) argues that transport demand analysis is based on various models in order to predict the outcomes of a specific project, programme or policy. He continues defining models as simplified representation of the real world. In particular, transport demand models are designed to simulate the number and types of trips that people would make; and most importantly the mode of transport they would choose in a determined situation (Todd, 2013). Due to the fact that models are vast and can tackle a lot of things at once, the awareness of the models' limitations facilitates using them according to the need, required accuracy, and budget available. The following are the application of transportation models available:

- Demand models (econometric models, short-term traffic prediction, traffic generation, etc.);
- Network models (modal split, traffic assignment, scheduling);

- Traffic models (advanced traffic and control representation, interaction between vehicles);
- Performance models (traffic quality perception, safety performance models, fuel consumption, air-pollution generation, noise generation, signal optimisation, etc.); and
- Choice preference models (Mode choice models, route choice models, etc.) (Myer, 2004).

All these types of models are developed from the historical and or direct survey related records for the region and then are applied to predict future transportation features (examples can be found in Banzhaf, Johnson & Mathews (2001). Based on the level of data available, the above classes of model can be broadly combined in the aggregate or disaggregate model types.

2.5.2 Aggregate models

The aggregate models are the most former representations of travel demand features, with a simple mathematical structure. They were able to represent travel as based on the size of a zone. The amount of trips produced from a zone was taken to be directly proportional to the size of the population in a given zone, while the number of trips attracted to a zone was considered to be proportional to the number of sources of attraction in the zone. Moreover, the travel between zones was considered to be inversely proportional to the distance between the zones, also referred to as "impedance" (Sivakumar, 2007). A typical type of this process is known in literature as: Four steps travel demand modelling.

The aggregate models present only general findings of the demand or any other targeted parameter but do not tackle specifically the effects of the inputs. This aggregation of data brings in problems of model’s inaccuracies due to the denial of the travelers’ behaviours. In other words the decision maker is not consulted to know the reasons for executing trips and or to choose a mode of transport from those available. This weakness of aggregate models has pushed different researchers to make preoccupations on studies that include decision makers’ behaviours in transportation studies. The researchers had then achieved new methods able to include decision makers' behaviours and these were called disaggregate models.

2.5.3 Disaggregate models

When the techniques advanced and the data became available in the transport sector, the aggregate models were shifted into disaggregate models. The new element that disaggregate models had come with, is the use of a disaggregated level data on the trips that are made by individuals in a considered zone. From this data, it became possible to practice the modelling methodologies like: Constrained optimisation and Random Utility Maximisation (RUM). According to Sivakumar (2007), the fundamental difference behind the development of aggregate and disaggregate models is that the disaggregate models are based on the individual, household or firm as the decision making entity. This means that the disaggregate models consider the effects of individual socio-demographics or firm characteristics, on travel-related decision making, while aggregate models use the general socio-economic characteristics of the area. The behavioral nature of disaggregate models, and the associated advantages over aggregate models, have led to the widespread use of disaggregate discrete choice methods in travel demand modeling.

A few of these application contexts are presented below with references to recent work in these areas: destination choice (Bhat *et al*., 1998; Train, 1998), route choice (Yai, Iwakura & Morichi, 1997) and (Cascetta, Russo, Viola & Vitetta, 2002), air travel choices (Proussaloglou & Koppelman, 1999), activity analysis (Wen & Koppelman, 2001), auto ownership, brand and model choice (Bhat & Pulugurta, 1998) and choice of mode of transport (discussed in details later in this report). Choice models have also been applied in several other fields such as purchase incidence and brand choice in marketing (Kalyanam & Putler, 1997) and housing type and location choice in geography, (Sermons & Koppelman, 2001).

For the purposes of this research, the modelling process is based on the choices of people's preferences in amongst the presented modes of transport and also a new mode to be introduced (HLTA). This is classified in the disaggregate models since they are based on the travelers' preferences. The next section discusses a typical disaggregate model called Multi attributes preference models.

2.5.3.1 Multi-attributes preference models

This is a typical case of the disaggregate models, which makes use of the consumer preferences. When consumers are faced with different choice alternatives in the real markets, they make their own choices based on different characteristics (attributes) of the alternatives. Therefore, much of the marketing research as elaborated in Koppelman, Bhat and Schofer (1993) is directed toward predicting how consumers would react to changes in available choice sets. In fact the prediction done is mostly oriented to understanding what will happen in the market when new products or services are added to the existing ones. Researchers are currently able to study the consumers' preferences of the new products that do not exist in the market.

The choice alternatives and their utilities are formulated as being an integration of the evaluation of all the attributes and, therefore, the utility value of each alternative is figured out. In Khan (2007) for example, the utility of the alternative is represented as a weighted function of the various attributes. Multi attributes preference models are also known in the literature as decomposition models or conjoint choice models. However, the term "conjoint choice models" is typically used for all types of representations that use Stated Preference data. These ones include multinomial logit representations based on Random Utility Maximisation. One of the specific applications of the multi-attributes preference models is found in the mode choice modelling. This was explained particularly in details below as it matches with the objective of this current study.

2.5.3.2 Mode choice models

Mode choice models are in a wide range depending on the number of modes engaged in the choice process. The two most used categories are the multinomial choice model and the binomial choice model (Koppelman & Bhat, 2006). However, literature suggests that both are the same at an exception of binary choice models having two alternatives and multinomial having more than two. The multinomial (polytomous) logistic regression model is a simple extension of the binomial logistic regression model. As its name indicates, the polytomous is used when the dependent variable has more than two nominals.

The binary choice responses are frequently not numerical values. This is emphasised by some authors arguing that the response is simply a designation of one of two possible outcomes (a binary response), like: alive or dead, success or failure, yes or no and choices between two alternatives. In mode choice studies, binary choice includes choosing between two modes such as: automobile or train, self-drive or public transport, bus or HLTA, etc. The mode choice modelling process has recently been developed using Revealed Preference and Stated Preference survey techniques. These are state-of-the practice survey methods found in almost all of the disaggregate modelling. For details of these techniques, refer to the following sections.

2.5.4 State-of- the practice survey techniques for mode choice modelling

In order to get information about individual choice behaviors in the transportation, there are two methods most commonly used: Revealed Preferences (RP) and Stated Preferences (SP) (Sanko, 2001). RP concerns what is observed, or what persons have done in the real world while SP survey looks for preferences on hypothetical situations. The former is based on the existing items in the market while the latter is concerned on a new item that is not yet observed in the market. RP survey is, for example, a household survey, asking people about their origins, destinations, purposes for the trips they have made or that they regularly make. SP is, for example, a survey of a new mode of transport to be introduced in a transport modal competition.

Based on survey works and experimental design to be developed in these two techniques, SP data is likely to provide more flexibility than RP data. But on the other hand RP information would in many ways complement an SP experiment. A detailed discussion on the comparisons of SP and RP is presented in the Table 2-4 below. The comparisons are based on the strong and weak points of each.

Table 2-4: Comparison of RP and SP (Morikawa & Ben-Akiva, 1992)

CRITERIA	RP DATA	SP DATA
Preference	▪ Choice behavior in actual market. ▪ Cognitively congruent with actual behavior. ▪ Market and personal constraints accounted for.	▪ Preference statement for hypothetical scenarios. ▪ Possibly cognitively congruent with actual behavior ▪ Market and personal constraints possibly not considered.
Alternatives	Actual alternatives responses to non-existing alternatives are not observable.	Generated alternatives can elicit preference for new alternatives.
Attributes	▪ Potential measurement errors. ▪ Attributes are correlated. ▪ Ranges are limited.	▪ No measurement errors. ▪ Multicollineality can be avoided by experimental design. ▪ Ranges can be extended.
Choice set	Ambiguous in many cases	Pre-specified
Number of responses	To obtain multiple responses from an individual is difficult.	Repetitive questioning is easily implemented.
Response form	Only choice is the available format	Various response formats are available (e.g.: ranking, rating, and choice).

From the above table, it can be seen that an SP survey technique has got a number of advantages as compared to its rival, RP. This is based on the fact that "RP models assume that it is only in the act of existing choice that people reveal their preferences". But, the question exists whether people are really willing to choose in that way or whether it is because they have no other options. If different options are available, people would choose differently from when only limited choices are available. Therefore, a negative response to this question is an obvious deduction. The next 4 sections discuss an SP exercise in detail, providing its experimental design procedure and applications.

2.5.5 Stated Preference exercise

The origin of the Stated Preference is rooted in the mathematical psychology. In this science, people's choice of one of the alternatives (or the ranking or rating of them) is used to derive importance of the attributes describing the alternatives. SP technique started being used in the 80s, from that time until now, it has been achieving good results. Some good examples can be found in Louviere, Hensher and Swait (2000). In some applications, SP has to do with the valuation of environmental assets (Bateman, Carson and Day, 2002) .

Stated Preference (SP) method is becoming a popular tool in the travel demand modelling field. The motivational factor behind its use is the ability to identify the behavioural responses of the population to the introduction of new travelling modes in the study area. These new travelling modes are generally presented to the transport users in the form of SP travel choice scenarios. In these sets of scenarios also called choice games, the users are requested to state their choices, bearing in mind the information about the recent trips they had executed, or that they are going to execute, and then they are compared to the hypothetical alternatives not available yet (Richardson, 1995).

2.5.5.1 SP survey for new modes and services

Innovative new technological modes may compete with existing travel modes and affect people's choices of travel modes. According to Yang (2010), the emergence of new travel modes can influence the market shares of existing travel modes and also induce new travel demand. SP surveys are used in some instances for evaluating the effects of innovative travel modes and services, such as high speed rail, cycling facilities, and congestion pricing (Yang 2010).

In the following example, a new mode of transport, i.e. TRAM was to be introduced in the transport system of an area. So, given the hypothetical attributes' values of TRAM, respondents were asked to choose among the existing travel modes (car and rail) and the new mode (TRAM). See Figure 2-16 by Sanko (2001).

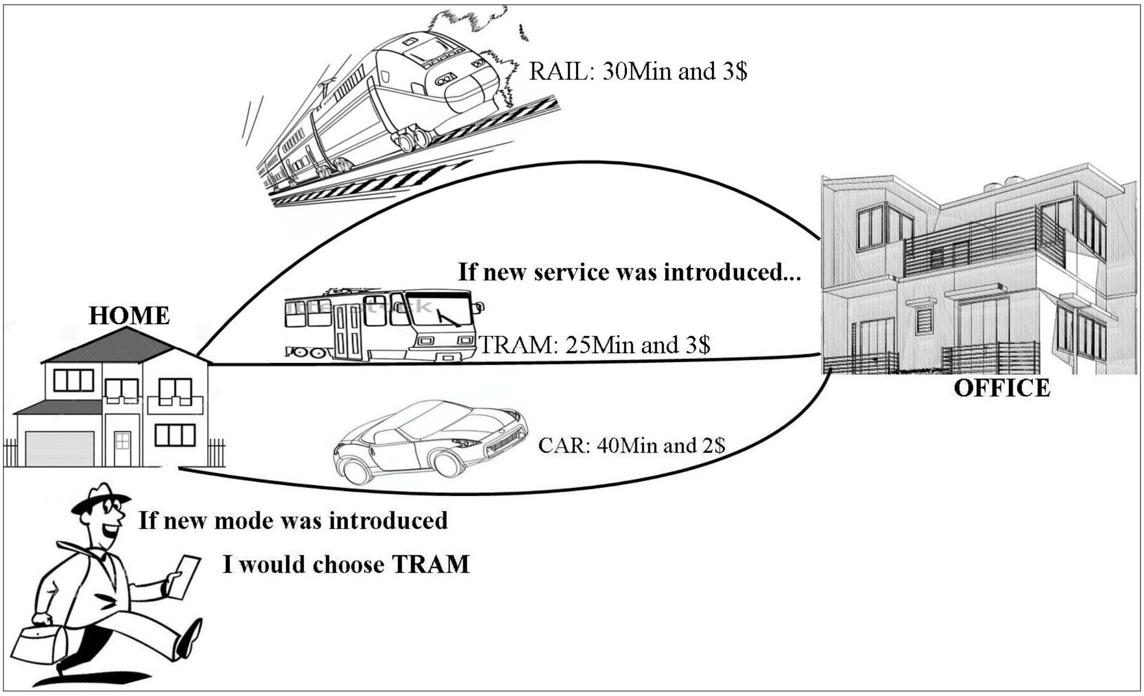


Figure 2-16: Demonstration of Stated Preference survey; adopted after Sanko (2001)

Good results were also achieved by Khan (2007) who has analysed the implementation of the Integrated Local Transport Plan (ILTP). In his study the problem to be resolved in the area was the high rising urban sprawl in the region which was inflating the demand for better public transport infrastructure and service. Therefore the ILTP target was primarily focusing on reducing the car dependency and increasing the market shares of sustainable travelling modes such as walking, cycling and public transport. The success of this work has been made possible by making use of an SP exercise.

Another application of SP is found in Gunn, Bradley and Hensher (1992) who considered a new high speed rail system proposed to connect Sydney, Canberra, and Melbourne in South-Eastern Australia. The system is electrically powered and reaches the speed of 350 kilometres per hour. This new high speed rail system has the advantage of providing much of the speed and luxury of air travel as well as the frequency, reliability, convenience and egress of rail travel. In order to forecast the travel demand and market shares in the future years, an RP survey was conducted in their work for current travels (car, air, coach, and rail) in the corridor, and an SP survey was conducted to investigate the generation of new travel demand and the travel diversion of the new high-speed rail from competing travel modes.

An important issue related to the successful use of SP techniques has to do with the design of the SP experiments. Efficient designs of SP experiment lead to making a successful model. Standard and approved procedures for the SP experiment are discussed in the next section based on the review of different literatures, including Louviere *et al*. (2000) and Sanko (2001). However, other alternative approaches based on optimisation had been suggested by Toner, Wardman and Whelan (1999).

2.5.6 Design of SP experiment

Reed (2013) says that SP experimental design is based on conceptualising a systematic plan which helps in the determination of the content of choice questions to produce the variation in the attributes' levels that are required to elicit a choice response.

In the SP experimental design, Orthogonality is a key issue to look at. Orthogonality means making a zero correlation between attributes. This is kept so because it would prevent the bias in the data.

The process of developing SP experiment engages different steps that all require attention in order to arrive at the successful results (Reed, 2013). The main elements to cover in the SP experiment are presented in Figure 2-17 below. The elements presented in this figure were assembled from different literatures and suggestions of different authors like Louviere, (1988); Sanko (2001); Koppelman and Bhat (2006) and Ahern and Tapley (2008).

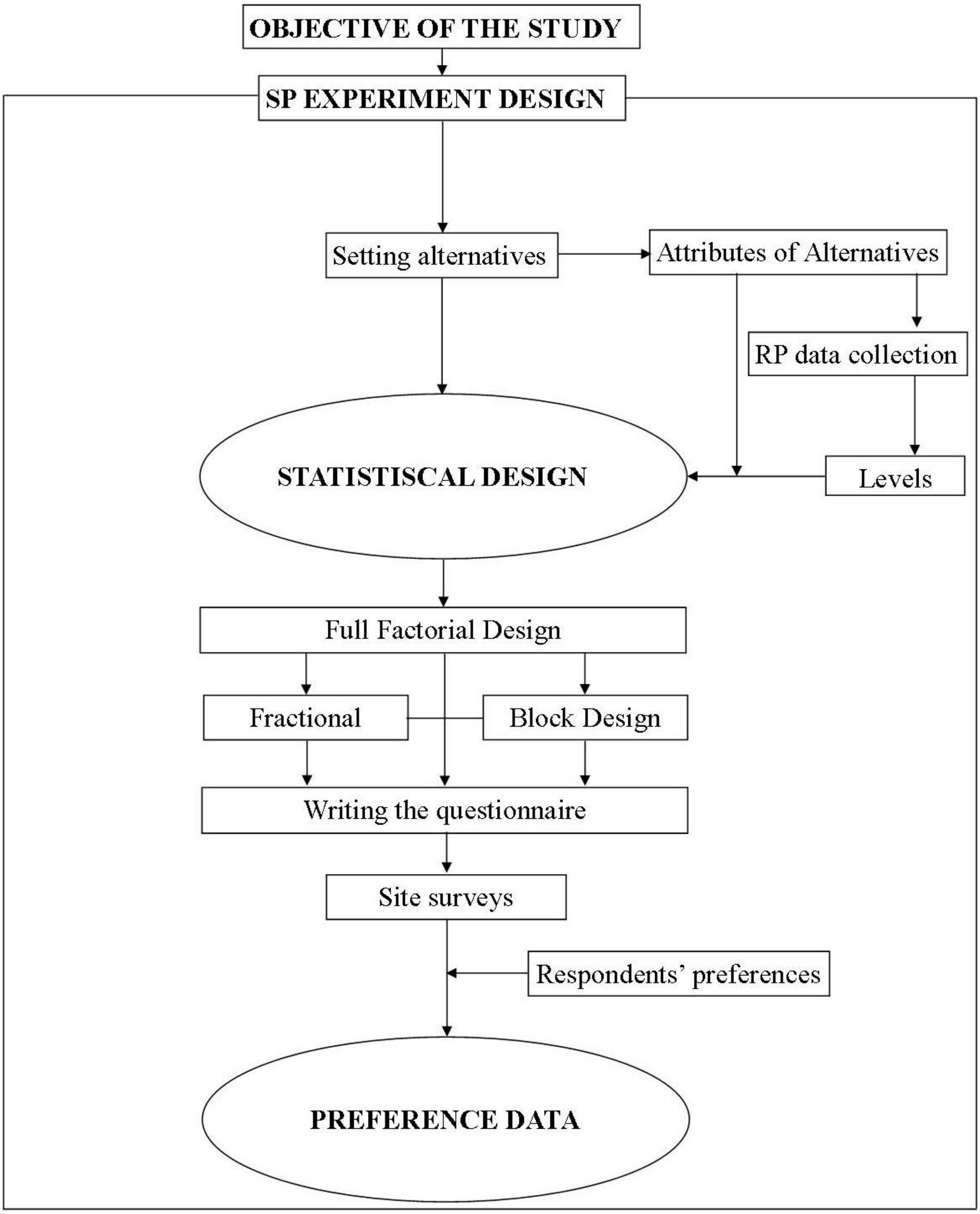


Figure 2-17: Stated Preference experiment procedure (Sanko, 2001)

Each element on the above figure has its specific role in the SP experiment design, and each step has to be performed carefully for the overall efficiency. The remaining part of this SP design section discusses in detail the elements presented in Figure 2-17 above, by giving tips towards a successful SP design and data collection.

2.5.6.1 Setting up the alternatives

The choice decision is made by individuals among available alternatives. The set of available alternatives may be constrained by the environment for their impact on the choice making ability. According to Koppelman and Bhat (2006), a bus mode can only be an alternative if there is a road connecting the two cities. Feasibility of an alternative for an individual in the context of travel mode choice may be determined by legal regulations; for example a person cannot drive alone until the age of 16 in some countries. This means that a person under 16 cannot be involved in choice decision making in the exercise where drive alone is an alternative.

Finally, not all alternatives in the feasible choice set may be considered by an individual in her/his choice process. For example, transit might be a feasible travel mode for an individual's work trip, but the individual might not be aware of the availability or schedule of the transit service; therefore, that one is not a feasible option to him or her (Koppelman & Bhat, 2006).

Generally, in the travel mode choice studies, the modeler makes a preliminary study to find out available potential transport modes in the study area in order to set alternatives. After this step, the modeler should identify the attributes appropriate to the alternative modes identified.

2.5.6.2 Setting up the attributes and their levels

Attributes are the components of the alternatives in a choice process to characterise them. Following Lancaster (1971), it can be postulated that choosing an alternative is based on its characteristics (values of its attributes). These are in fact the ones that determine its utility magnitude.

Based on which alternatives an attribute applies to, there are two types of attributes in the choice modelling. A generic attribute that applies to all alternatives equally and alternative-specific attribute that applies to one, or a subset of, alternatives (Koppelman & Bhat, 2006). In the travel mode choice context, In Vehicle Travel Time (IVT) time attribute is usually considered to be specific to all motorised modes because it is relevant to motorised alternatives. But, sometimes travel time can be onerous due to overcrowding of bus or truck. In that case IVT time can be included in the process as distinct variable with a distinct parameter (Koppelman & Bhat, 2006).

Other time related attributes like Waiting Time (WT) at a transit stop, transfer time at transit transfer point and packing time for transit goods are relevant only to the transit modes, not for the non-transit modes. It is also common to consider the travel times for non-motorised modes of bike and walking as specific to only these alternatives (Koppelman & Bhat, 2006).

Concerning attributes' identification, currently, there is no rule of thumb about the number and types of attributes that are required for the SP experimental design. Although, missing a certain influential attribute would be violent and lead to an inaccurate model, it cannot be possible to include all possible attributes in the process. Marshall and Ballard (1998) have studied attributes setting up and concluded that, an estimate of 70% of the studies used three to seven attributes.

Recent work done by Rasouli and Timmermans (2013) has developed a method called "factor listening" that can be used in order to set up attributes of alternatives. According to this method, the modeler has to list out as many attributes as possible and then ask the travelers to pick what they use in their choice processes. Then, the more an attribute is chosen, the more it is influential in their choice decision process. Therefore, the attribute in question should be included in the modelling process.

Koppelman and Bhat (2006) have elaborated on listing out different attributes from which to choose what to include in the modelling process. They explain that the first step towards choice model analysis is to gather relevant data. In the context of travel mode choice, such data includes:

- Traveler and trip related variables that influence the traveler's assessment of modal alternatives (e.g., income, automobile ownership, trip purpose, time of day of travel, origin and destination of trip, and travel size);
- Mode related variables describing each alternative available to the traveler (e.g., travel time, travel cost and service frequency for carrier modes); and
- The observed or reported mode choice of the traveler.

The first two classes are chosen to describe parameters that lead a decision maker while in the choice process of an alternative. These are, therefore, independent and can change based on the trip purpose. According to Gunn *et al*. (1992), the mode choice models use the following common explanatory variables based on the purpose of the study:

Traveler (decision maker) related variables.

- Income of traveler or traveler's household;
- Number of automobiles in traveler's household;
- Number of workers in traveler's household;
- Sex of the traveler;
- Age group of the traveler; and
- Functions of these variables such as number of automobiles divided by number of workers.

Trip context variables include:

- Trip purpose;

- Employment density at the traveler's workplace;
- Population density at the home location; and
- Dummy variable indicating whether the traveler's workplace is in the Central Business District (CBD).

The mode (alternative) related variables are the following:

- Total travel time;
- In Vehicle Travel time;
- Out of vehicle travel time;
- Walk time;
- Waiting time;
- Number of transfers;
- Transit headway; and
- Travel cost.

Interaction of mode and traveler or trip related variables:

- Travel cost divided by household income;
- Travel time or cost interacted with sex or age group of traveler; and
- Out-of-vehicle time divided by total trip distance.

The list above, includes almost all of the data that can be required, to make an experimental design for an SP exercise. However, not all of these, can be used in one single study. So, it is the responsibility of the researcher to choose what to include, relative to the study to be conducted. The following criteria concerning the definition of the attributes are set out in the work done by Sanko (2001):

- Attributes' values may be changed through proactive policy decisions;
- Attributes must appear believable;
- Attributes should be relevant to the traveler's experience;
- The values attached to the attributes should ensure that competitive trade-off decisions are presented;
- The values attached to the attributes should present trade-offs that cover the range of valuations held by each respondent.

After identifying attributes, the next task is to assign appropriate levels to these attributes. Levels are all possible values that an attribute can have. These should be chosen well but not beyond what the respondent is aware of. Hensher (1994) argues that the researcher should be strongly attentive to what levels of attributes to choose. He added that for the existing alternatives, the researcher should consider a range of levels which has values currently faced by the individual, because respondents will choose based on what they know rather than anything else. When new modes of transport are to be introduced in the system, the hypothetical levels require to be made believable and deliverable (Hensher, 1994). The number of levels to assign to each attribute will be decided by the overall complexity of the design. This process involves taking into account the interactions of the attributes' levels generated, as well as the manner in which they are exposed to a respondent (whether in blocks or entirely).

Drawing from a study by Boomer (2000), the guidelines for developing the values of levels include the following points:

- Define the marketplace;
- Identify all relevant substitutes;
- Ensure attributes are independent;
- For levels, use precise, concrete statements, with metrics if possible;
- Levels within each attribute should be mutually exclusive and collectively exhaustive;
- Levels should contain ranges sufficiently extreme to cover the shelf life of the research;
- Try to balance the number of levels across attributes; and
- For quantitative levels, use realistic points.

After getting alternatives, attributes of alternatives and levels of attributes, the step that follows is the statistical design of the SP experiment. The statistical design is where much effort is put in order to make a successful design. The end product of a statistical design is the choice games set from which respondents have to choose.

2.5.7 SP experiment statistical design

The statistical design of the SP experiment has an objective of creating the choice games (SP scenarios) between the alternatives. As stated previously, different game choices may be made; however, in this work only pairwise scenarios are reviewed and treated. The statistical design starts by combining the attributes and their levels. Based on the research by Sanko (2001), setting and combining attributes and attributes' levels in the process is the so called "SP statistical design". There are two statistical designs mostly used. These are elaborated on in Sanko (2001) as full factorial design and fractional factorial design. The advantage of using factorial designs is that all combinations of the attributes' levels can be considered. The next three sections discuss these designs in details.

2.5.7.1 Full factorial design

Full factorial is the design type that uses every possible combination of the attributes' levels in the sets. As said previously, the core element of the Stated Preference is the statistical design (See highlighted in the Figure 2-17), to make hypothetical situations of alternative choices available to the respondent. Sanko (2001) suggests that an experimental design must be orthogonal so as to ensure that attributes are independent, over the course of the process. In this way, the common problem of RP data, that is "Multi-Collinearity" is avoided. Orthogonality means that attributes must not have trade-offs in terms of the interpretation by people. In other words they must appear totally different. For example, if travel time is considered as an attribute, it shouldn't be an option to choose travel distance as another attribute. This is because of a trade-off between these attributes that great travel distance trip incurs great travel time. So, while in the choice process, the decision maker would be confused by this trade-off and would unwillingly base his decision on only one of the two.

Fundamentally, statistical design demonstrates nothing but a matrix of numbers whereby the rows represent the choice situations and the columns the attributes' levels combinations (Rose & Bliemer, 2008). The number of choice scenarios to be completed by a respondent in the full factorial design is determined by the following equation 2-1 as applied in the study by Fowkes (1998).

$$No.of\ combinations; C = L^N \tag{2-1}$$

Where:

C	Number of combinations
L	Number of levels
N	Number of attributes.

The above concept is strongly emphasised by Kroes and Sheldon (1988) who argue that the total number of combinations to be generated into an exercise is a function of both the number of attributes which they call factors of an alternative and the number of factors' levels used. For example, in a binary choice study, based on testing the preference of transport users where two alternatives (private driving and public transport) were set in the choices; if four attributes, say (Comfort, Waiting Time, In Vehicle Travel Time and Travel Cost) are considered with each of the three levels, the total number of combinations would be 81.

$$C = 3^4 = 81 \tag{2-2}$$

Sanko (2001), considers an experimental design developed in order to test the preferences of people between three attributes of a public transport operation (fare, travel time, and service frequency). In this case, each attribute has two levels to simplify the demonstration. This means that there are 8 choice games developed. Refer to the following Table 2-5.

Table 2-5: Full factorial design for three attributes each having two levels (Sanko, 2001).

	COMBINATION NUMBER	POSSIBLE ATTRIBUTES		
		Fare	**Travel Time**	**Service Frequency**
CHOICE SCENARIO	1	High	Slow	Infrequent
	2	High	Slow	Frequent
	3	High	Fast	Infrequent
	4	High	Fast	Frequent
	5	Low	Slow	Infrequent
	6	Low	Slow	Frequent
	7	Low	Fast	Infrequent
	8	Low	Fast	Frequent

When every possible combination is presented, the resulted process is termed as “full factorial design”. However, the full factorial design is accused of generating errors arising from the fatigue from many scenarios presented, and also the trivial combinations that confuse the respondent. Full factorial design is criticised by different authors like Kroes and Sheldon (1988), who suggest that respondents can only assess a fairly limited number of combinations at once. The proposed values were typically 9 to 16 combinations (Kroes and Sheldon, 1988). Besides, they say that a design that brings in all possible combinations of all levels for all attributes would only be used if very limited number of attributes and their levels are within the range given above.

On the other hand, in case a full factorial design generates too many scenarios, basically more than 16, the second type of design “fractional factorial design” can be used. In this way, the problems inherited from the full factorial design can be prevented by considering only a selection of possible combinations to the respondent. Fractional factorial design is supported as a more efficient design than the full factorial design (Kocur, Hyman & Aunet, 1981).

2.5.7.2 Fractional factorial design

As said earlier, fractional factorial design is supported by the fact that not all the interactions should be presented to the respondent, but significant interactions of the researcher’s interest (Louviere, Hensher & Swait, 2000). The great interest of the use of factorial design is that the number of choice games generated can be considerably reduced, therefore, reducing the fatigue and confusion related errors that could be brought in by full factorial design.

In the following demonstration, in Table 2-6, by Kroes and Sheldon (1988), a full factorial design made from three attributes each with 2 levels generated 8 choice combinations. Then a full factorial design was reduced into a fractional factorial design that is made of 4 combinations. Actually 8 combinations are not too many (not more than 16), but the following was done only with a purpose of demonstrating how to make a fractional factorial design from a full one.

Table 2-6: Example of process from full to fractional factorial design (Kroes & Sheldon, 1988)

	COMBINATION NUMBER	**ATTRIBUTE 1**	**ATTRIBUTE 2**	**ATTRIBUTE3**
	FULL FACTORIAL DESIGN			
	1	1	1	1
	2	1	1	2
	3	1	2	1
	4	1	2	2
CHOICE SCENARIO	5	2	1	1
	6	2	1	2
	7	2	2	1
	8	2	2	2
	FRACTIONAL FACTORIAL DESIGN			
	1	1	1	1
	2	1	2	2
	3	2	1	2
	4	2	2	1

When combinations generated by the fractional factorial design are still too large, the process can consider breaking down the set of combination into small sub sets called blocks with separate exercises. This is called “block design” where the small sub sets are to be presented to different respondents and one questionnaire would be answered by more than one respondent. This has been detailed in Sanko (2011), but he also added that in the transportation field, individual analysis has a lesser value as compared to the universal level analysis. That is why block design has less use in transportation related studies.

The SP statistical design achieves a set of the choice games to be presented to the respondent. This set is a matrix and needs to be transformed into an enjoyable questionnaire for the respondent to understand it. See the following section for details of how to come from statistical design profiles (combinations) to an understandable questionnaire.

2.5.8 From statistical design combinations to the understandable questionnaire

The list of combinations of attributes' levels resulted from designs, are meaningless when presented to the respondents. They, therefore, require to be transformed into meaningful questionnaires. Hensher (1994) says that the final stage of Stated Preference design is the selection and format of implementation. He added that these must be decided by the criterion of being comprehensible to the respondent. Particularly to the new mode or new product at the market, the respondent requires a clear clarification of it. A non-comprehensible questionnaire means a poor design and results in biasing the responses, so, this should be avoided whenever possible. Presentation of choices to respondents differs from researcher to researcher; the following three paragraphs explain different ways of presentations commonly found in researchers.

Some presentations use cards on which questions are written, and each card corresponds to one question that a decision maker responds to at a time. Therefore, the total number of cards in a set for one respondent corresponds to the total number of the questions generated by the factorial designs. Gunn *et al*. (1992) presented 14 sets with each consisting of 16 cards with time and cost levels varying with the trip distance. Each card has a different combination of travel time and cost for five modes (car, air, coach, rail and new high speed rail). The access/egress time and cost are added to calculate the total time and cost for each mode. After presented with four cards from one set sequentially, the respondent is asked to make a choice from the five travel modes.

The use of cards is also supported by Sanko (2001), who presented sets of cards on which respondents have to choose one of the two alternatives, (rail or auto). Different characteristics (attributes' levels) of each alternative are indicated as well. Refer to Figure 2-18, where users are presented with N choice games, and in game no.1 a particular respondent has said that he slightly prefers RAIL.

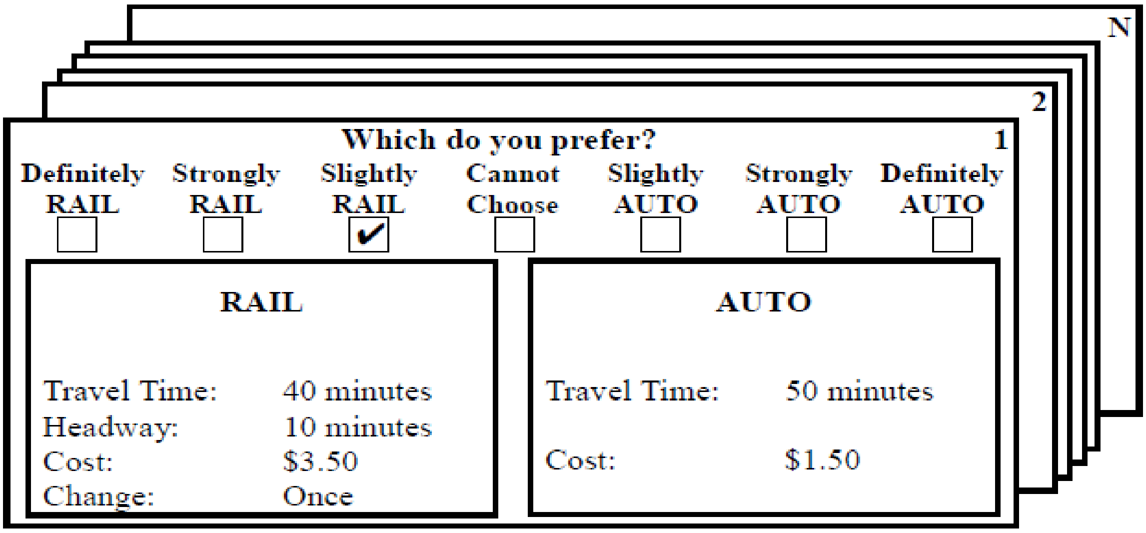


Figure 2-18: Stated Preference card with one choice scenario at a time (Sanko, 2001)

For explanation purposes, some researchers include photos or a portion of the photo of the new transport mode on the card. This makes it a better representation to the respondent, especially in a hypothetical situation. See Figure 2-19 below (this technique was presented by New Lines Programme in the Stated Preference Survey).

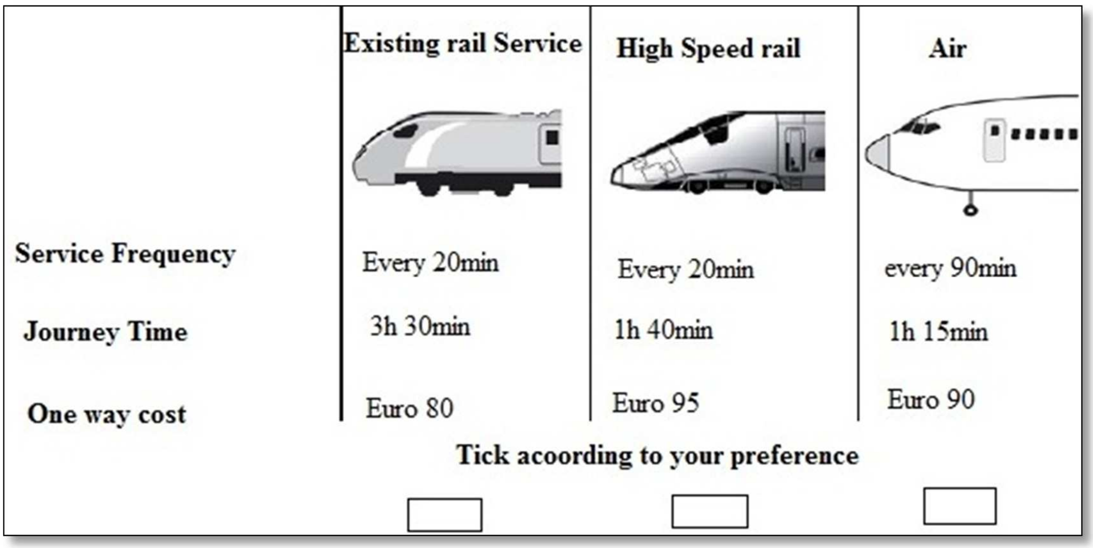
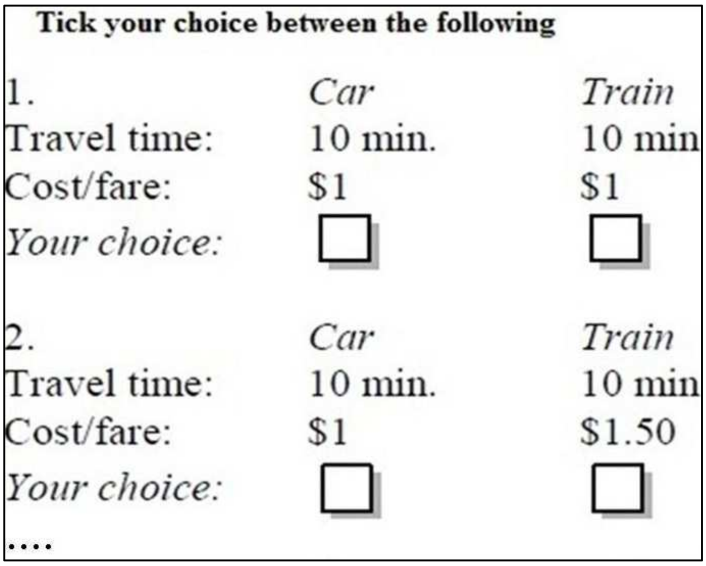


Figure 2-19: Representation of card with pictures

Other researchers prefer to put all the choice scenarios on the same sheet where the respondent sees it simultaneously. Looking at the work conducted by Rose and Bliemer (2008), one can see that different scenarios developed from a combination of alternatives (car and train) each with travel time and cost as attributes, were presented to facilitate a respondent to choosing the first scenario, but knowing the following one. Refer to Figure 2-20 below.


Tick your choice between the following

1.	*Car*	*Train*
Travel time:	10 min.	10 min
Cost/fare:	$1	$1
Your choice:	☐	☐
2.	*Car*	*Train*
Travel time:	10 min.	10 min
Cost/fare:	$1	$1.50
Your choice:	☐	☐
....		

Figure 2-20: Different choice scenarios on one sheet (Rose & Bliemer, 2008)

The choice decision procedure itself, is a different concern in the studies involving choice preferences. This is why discussion on decision making process was added to the content of this chapter, (see the whole section 2.5.9 ahead). When the choice is to be made between two alternatives, the set is called binary choice games. The game, which has more than 2 alternatives, is called a multinomial choice game. Sometimes the number of alternatives varies and the experiment is called a varying choice game and when it does not, the experiment is called a fixed choice game (Sanko, 2001). According to Toner *et al.* (1999). The fixed choice set designs are the most common type of SP application in the transportation research.

2.5.9 Respondent choice decision process

Individuals make different choices in the different cases they face. However, knowledge about people's choice behavior is still a myth. Literature suggests that the choice process starts by an individual who first uses the set of alternatives availed to him or her and then examines the related attributes to each alternative. From these two steps he/she uses the decision rule set by the analyst and then makes a decision of his/her choice among the available alternatives (Ben-Akiva & Lerman, 1985). Koppelman and Bhat (2006) discussed four factors that influence the choice decision process and these are:

- The decision maker ;
- The alternatives;
- The attributes of alternatives; and
- The decision rule.

Only the first and the last elements are discussed in this part, as the explanation for alternatives and attributes had been presented previously in this chapter.

2.5.9.1 The decision maker

The procedure of the decision making depends to a certain extent on the participation of the decision maker. In fact, a very big role of the process is played by the decision maker. A decision maker can be an individual, group or institution that is involved in the decision process. The type of the choice itself has an influence on the decision maker's ability to choose. According to Koppelman and Bhat (2006), a familiar observation is that while in the decision process, decision makers face different choice situations and can have different tastes. This means that their arguments on the attributes of alternatives are different. The explanation to this would include the socio-economic characteristics that differ with different respondents. For example, in travel mode choice modeling, transport users with different monthly earnings and with different residential locations will have different considerations on attributes like: travel time, travel cost and other attributes. It is the different socio-economic characteristics like income levels that are the basic reasons for these differences.

2.5.9.2 The decision rule

Drawing from the work done by Koppelman and Bhat (2006), an individual sets a decision rule. This is in other words, a mechanism with which he processes information received from alternatives and related attributes. This decision rule may include random choice, variety seeking, or other processes which are referred to as being irrational. Other decision makers may only use "follow the leader". This is a routine way of choosing where a decision maker just chooses according to his model or mentor. Although this is a routine way of choosing, it can also be a rational discrete choice. In this case, a decision maker who prefers to use habitual behaviour has to previously assess available alternatives and select what he prefers without any intervention. When follow the leader is adopted, the respondent is said to be rational if the leader shares the same value system. Rationality is built on two components: consistency and transitivity.

While consistency brings same choice sets in a repeated choice system in the same circumstances, transitivity brings a particular order of alternatives. In transitivity, if an alternative, say bus, is preferred over another, say, rail, and alternative rail is chosen over alternative air, then alternative bus is preferred over alternative air. Rational decision process information is detailed in Ben-Akiva and Lerman (1985).

In this research, focus has been placed on one of the decision rules detailed in Ben-Akiva & Lerman (1985). This decision process is the most used in the transport related research and is called “Random Utility Maximisation”. The RUM rule is constructed on two basic concepts. The following paragraphs provide a discussion of these two concepts:

- "The attribute vector characterising each alternative can be transformed into a scalar utility value for that alternative". This concept means that a compensatory decision process is to be developed. Decision makers make trade-offs among the attributes of alternatives in making their choice. Therefore, a person may prefer an expensive transport mode if the travel time reduction offered by that mode compensates for the increased cost.

- "The decision maker chooses an alternative that offers the highest utility magnitude". The use of RUM in this study is supported by its strong theoretical background, popularity in terms of use and amenability to statistical testing of the effects of variables on choice.

The following sections discuss the development of mode choice model, using the binary/multinomial logistic structure which in turn is based on utility maximisation concept and underlying principles.

2.6 MODE CHOICE MODEL DEVELOPMENT

2.6.1 Multinomial models

Multinomial logit models are the qualified models in terms of choice models adequate for the SP data analysis. The multinomial logit model, has a distinguished mathematical form that makes it possible to determine the probabilities of the alternative as a function of the systematic utility for all the alternatives (Kim & Council Southwest Washington Regional Transportation., 1997). The general mathematical structure of the probability of choosing an alternative "i", from a set of "J" alternatives is given by the equation 2-3 below:

$$\Pr\ (i) = \frac{Exp^{\ V_i}}{\sum_{J=1}^{j} Exp^{\ V_i}} \qquad 2\text{-}3$$

Where:

Pr (i) The probability of the respondent to choose an alternative "”" in a set of "J" alternatives

Vi The systematic component of the utility of alternative "i"

i Represents numerical value (i = 1, 2,.., J)

(Kim & Council Southwest Washington Regional Transportation., 1997)

Equation 2-3 has also been used by Koppelman and Bhat (2006), in the determination of the shares of alternatives available for a study they were conducting (see equations 2-4, 2-5, and 2-6 below). The alternatives that had been set in their case were Drive Alone (DA), Shared Ride (SR) and Transit (TR) transport modes:

$$\Pr(DA) = \frac{e^{v_{DA}}}{e^{V_{DA}} + e^{V_{SR}} + e^{V_{TR}}} \quad 2\text{-}4$$

$$\Pr(SR) = \frac{e^{v_{SR}}}{e^{V_{DA}} + e^{V_{SR}} + e^{V_{TR}}} \quad 2\text{-}5$$

$$\Pr(TR) = \frac{e^{v_{TR}}}{e^{V_{DA}} + e^{V_{SR}} + e^{V_{TR}}} \quad 2\text{-}6$$

Where:

Pr(DA), Pr(SR), and Pr(TR) Probabilities of Drive Alone, Shared Ride and Transit.

V_{DA}, V_{SR} and V_{TR} Systematic utilities of DA, SR and TR respectively.

McFadden (1974) and Thurstone (1927) had presented a utility of alternatives, as consisting of an observed (deterministic or systematic) component represented by V; and a random (disturbance) component denoted by ε. The deterministic portion V is a function of the attributes observed in the choice process for the alternatives; while the random error is associated with all factors beyond the analyst's control.The systematic portion of the utility function or simply systematic utility of alternative i, is determined using the rule of "Random Utility Maximisation". The theory of the RUM is that individuals assign a utility with each alternative, after which the alternative with the highest utility is selected. Kumar, Basu and Maitra (2004) say that Random Utility Maximisation theory gives a way to several models and theories of decision making.

The utility that individual "i" attributes to alternative "j" is given in the equation 2-7 below:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad 2\text{-}7$$

Where:

V_{ij} The measurable part of the utility value that an individual i assigns to alternative j.

ε_{ij} The random error part of the utility value.

The determination of the systematic utility, V is based on the parameters (coefficients) that determine a weight of influence of a given attribute in a utility function. These parameters are multiplied with the value of the attributes and the sum gives the systematic portion of the utility function. Refer to Equation 2-8 below:

$$V_{ij} = \alpha \ x \ Attribute_{(1)} + \beta \ x \ Attribute_{(2)} + ... + \lambda \ x \ Attribute_{(n)} \quad 2\text{-}8$$

The above equation had been applied by many researchers in the demand model and choices evaluation. This includes the work done by Kumar *et al.* (2004) that investigated "Modeling Generalised Cost of Travel for Rural Bus Users". They have considered a generalised utility function shown in the equation 2-9 below:

$$U = \alpha\ x\ (In\ vehicle\ Travel\ Time) + \beta\ x\ (Travel\ Cost) + \gamma\ x\ (Discomfort\ Level) + \varepsilon \qquad 2\text{-}9$$

Where:

In Vehicle Travel Time, Travel Cost, and Discomfort: Attributes (characteristics) of the utility

α, β, and γ: Parameters (coefficients) of attributes.

2.6.2 Binary models

The binary logistic regression model is a special case of a multinomial model, the difference is found in the fact that for binary models, two alternatives are considered at a time but for a multinomial model more than two alternatives are considered.

According to Hun, (2010) and Kurt, (2014), the expression of the determination of the probability values for binary models is given by:

$$Pr(i) = \frac{e^{V_i}}{1 + e^{V_i}}\ , \qquad 2\text{-}10$$

Where: V_i: Utility of the alternative i, for which the probability value is to be determined.

Pr(i): Probability to choose an alternative, i

2.6.1 Error Term

According to Koppelman and Bhat 92006), the random error term, ε is the portion of the utility unknown to the analyst. The analyst does not have any information about the error term. In order to take into account the total error which is the combination of errors from many different sources such as: imperfect information, measurement errors, omission of modal attributes, omission of the characteristics of the individual that influence his/her choice decision and/or errors in the utility function, a random variable is used. Different assumptions about the distribution of the random variables associated with the utility of each alternative result in different representations of the model used to describe and predict choice probabilities. Koppelman and Bhat (2006) continue by describing the mathematical form of a discrete choice model which is determined by the assumptions to be made regarding the error components of the utility function for each alternative.

The specific assumptions that lead to the Multinomial Logit Model are:

- The error components are extreme-value (or Gumbel) distributed,
- The error components are identically and independently distributed across alternatives, and
- The error components are identically and independently distributed across observations/individuals.

More details about the concepts of model specifications can be found in Ben-Akiva & Lerman (1985).

2.6.3 Relationship between systematic utility V_i and choice probability

The relationship between the magnitudes of the systematic component of the utility function and probabilities for an alternative, makes an S-shaped curve. The applications of the models of multinomial logistic analysis are always linked to the change of the V_i due to the change of values of its different attributes to the prediction of the model. It can be seen in Figure 2-21 below, that a linear increase in the value of V_i predicts an exponential increase of the choice probability of the alternative (Koppelman & Bhat, 2006).

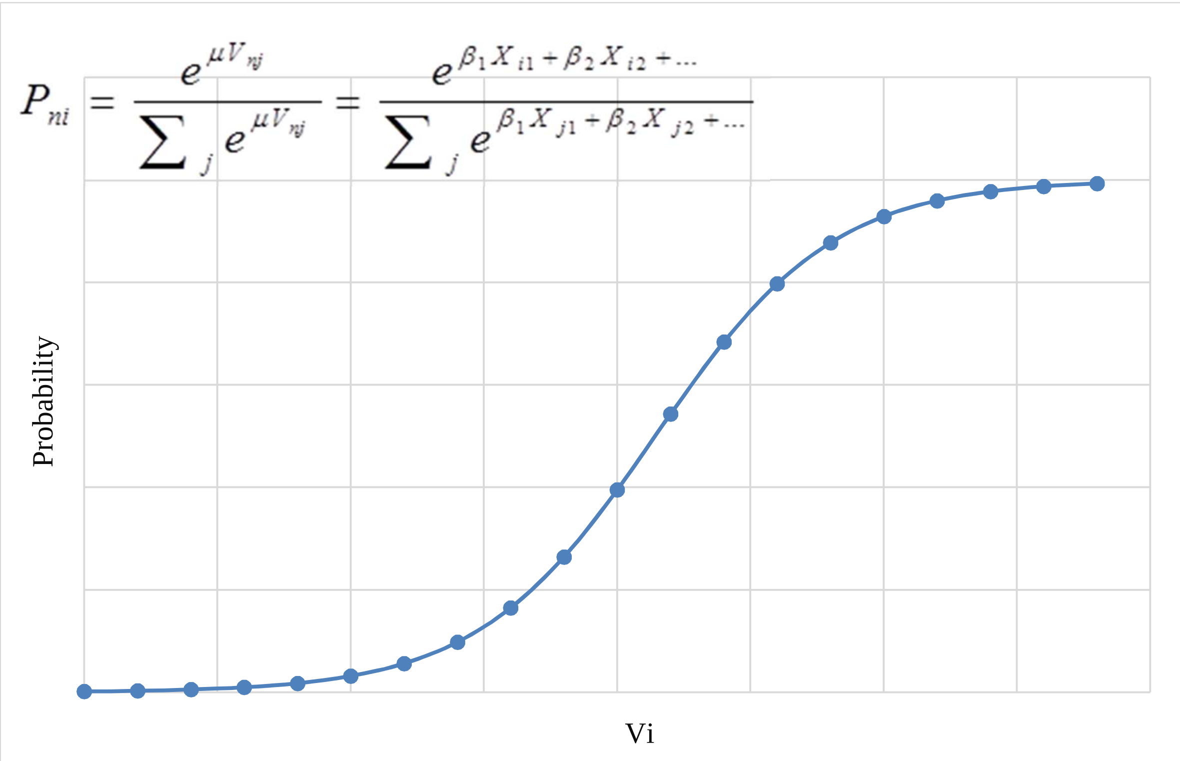


Figure 2-21: Relationship between Probability and Systematic utility (Koppelman & Bhat, 2006)

2.6.4 Determination of the values of parameters of attributes

Parameters (also called coefficients) of the attributes used to develop an MNL/BL model are determined using the data acquired from the SP surveys. Most of the researchers treat this data by using statistical computer programmes like SAS, STATA, SPSS and others. In these computer programs, choice preference data of binomial studies is entered as codes by 1 and 0, with 1 representing a chosen combination and 0 representing a rejected combination. The analyse tool found on the menu bar of the computer program is clicked on, then, the regression and binary logistics are chosen in the list of possible analysis techniques available. The interface of the program at this stage looks like Figure 2-22 below for an SPSS snapshot.

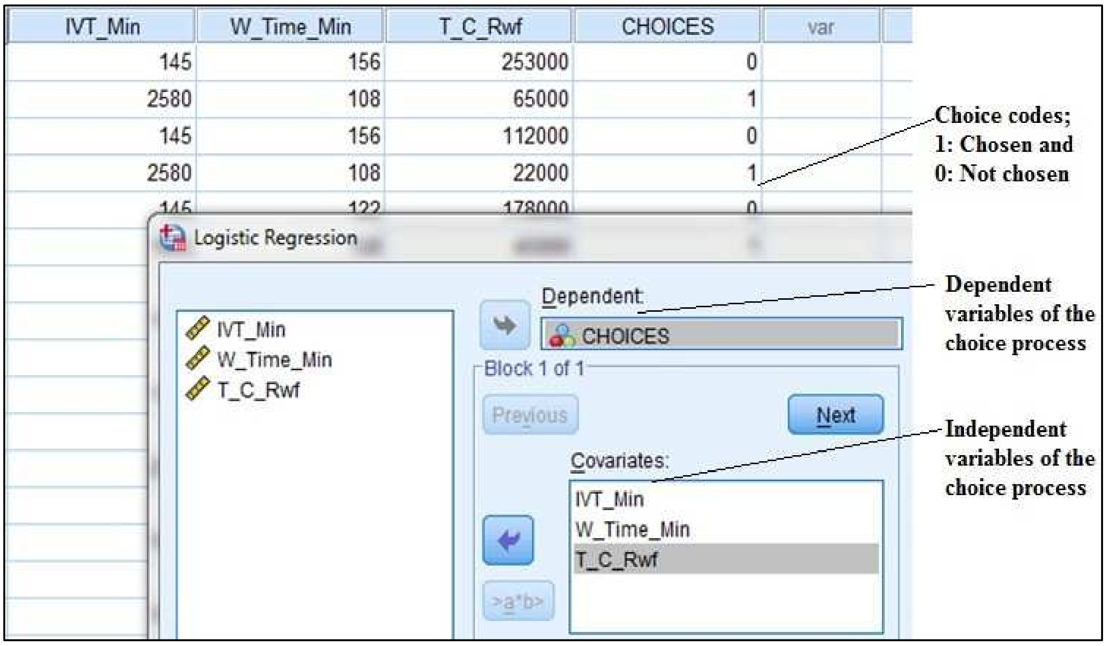


Figure 2-22: SPSS sheet, demonstrating dependent and independent (covariate) variables.

The independent variables demonstrated in Figure 2-22 are the characteristics of the mode which are called attributes of the transport mode alternatives in this research. The dependent variable is the choice. When all variables had been placed in the appropriate boxes, the user should click okay and wait for a few seconds for the program to analyse the data.

At this step, the programme displays a report of the analysis and among the other outputs, the model parameters' values associated to each attributes in the choice set combinations are shown together with their respective arithmetical signs. According to Burns and Burns (2008), the common statistical elements reported by these computer programmes are:

- The number of cases for which each alternative is available;
- Log-likelihood values at zero (equal probability model), Chi-Square;

- Nagerkerke's R-square and the corresponding Cox and Snell's R-square;
- The number of cases for which each alternative is chosen;
- The number of iterations required to obtain convergence;
- The attributes' parameters values and signs;
- The standard error assigned to the attributes determination;
- The Wald statistics and associated significance of the attributes in the model (P-values) (Burns & Burns, 2008).

2.7 MODEL REFINEMENT AND VALIDATION

In the process of modelling, one of the fundamental components, is to refine and validate the resultant models (Wegmann & Everett, 2008). This is so, because for the purposes of forecasting, it is believed that the parameters will remain constant over some time. Refinement and validation come in to increase the level of accuracy of the travel demand models in terms of prediction performance by variables. This process can be done by conducting an additional data collection to, by the end, cross check the similarity of the results. These techniques are most of the time associated with an additional cost which many modellers fear to provide. In the usual process and in this study particularly, the refinement and validation are done after the original development of the model has been done.

The intention of this section is to review some of the more accurate techniques of refinement and validation to be performed by the analyst for a travel demand model. In the Cambridge Systematics (2010) manual, a list of three fundamental types of refinement and validation checks for transport related modelling studies were reported. These are: aggregate validation, disaggregate validation, and statistical reasonableness checking of the model and its associated variables. Each of this is used in its context and may be inappropriate in a different context.

2.7.1 Aggregate validation

The aggregate validation is a process that is based on the general aggregated data of an area. It provides a general overview of model performance through regional travel characteristics such as average trip rates, average trip lengths, average mode shares, and regional vehicle kilometres travelled (VKT). This is due to the fact that travel models have traditionally been applied to aggregate data at the regional, country, district, or zonal level, because there was no data disaggregated to a household or individual level. But nowadays, as noted in emerging research, travel modelling procedures may include population synthesising techniques allowing travel models to be applied at the household or travellers level (Cambridge Systematics, 2010).

Since aggregate validation is very general and does not tackle a specific project or study particularities, the disaggregate validation was adopted. This method makes it possible to validate individual level models like the choice preference ones. In all these validation methods, the statistical refinement comes in to check the statistical reasonableness of the data and the sample used. In this study particularly the disaggregate validation has been applied, since the data used was disaggregated to an individual level (individual mode choice preference).

2.7.2 Statistical reasonableness checking

The statistical checking is a preliminary verification of the model specification. This technique is based on verifying the reasonableness of different statistical aspects of a particular study. In transportation planning, statistics is a tool of great potential, and this is even more powerful when it comes to modelling research projects. This is because, data used in the transport planning is statistically based and require to be statistically significant. Koppelman and Bhat (2006) say that a variety of informal statistical tests can be applied to an estimated model. They added that these tests are designed to assess the reasonableness of the implications of estimated parameters. The common checks used in the binary logistic regression analysis are based on the values of different statistical components that are reported by the computer programmes used.

From the information presented on the list above (Section 2.6.1), statistical checks are performed and a conclusion is made on the overall goodness of fit of the model and then individually, variables are checked to see how good they are in terms of the model's prediction performance. A variable that fulfils the requirements of the statistical test has a significant impact on the modal utilities and it should be retained in the model. In contrast, a variable that fails to meet the threshold values of statistical tests does not contribute significantly to the explanatory power of the model and can be considered for exclusion (Koppelman & Bhat, 2006).

2.7.3 Disaggregate validation

This method consists in providing different ways of looking at the fitness of a model into the observed data. This is to be done at the levels of household or individual for data disaggregation purposes. In the transport demand studies, this process involves the determination of the units of observations like household size, income or auto ownership levels. The predictions made from the models developed are, therefore, compared to the observed data on a different survey, in order to find out the systematic biases that might have occurred in the current study. Cambridge Systematics (2010) describes disaggregate checking as the use of disaggregate data to be compared with the money value of non-monetary variables engaged in the modelling process. The monetary value of one unit of a non-money based attribute is one of the important outcomes of the choice preference models. This technique is called ratio of parameters estimates. As Travel Cost (TC) is often among the explanatory variables of alternatives in choice competition, monetary value of non-monetary variables can be determined by using the ratio of parameters. This is what is known in different transport researches as transport demand elasticities.

2.7.4 Monetary value of the indirect cost attributes by ratio of parameters estimates

As presented by Kumar *et al.* (2004), the monetary value of the non-monetary attributes can be calculated from the utility function equation. They explain that a one unit change that is caused by one attribute like the "In-Vehicle Travel time" would be caused by changing that attribute by 1/α (referring to the equation 2-8 and 2-9 above. The ratio of the coefficient (parameter) of IVT time to the coefficient of TC indicates the value of IVT time in monetary terms as perceived by the respondents. This principle is known in literature as ratio of parameters estimates (Sanko, 2001) or transport demand elasticities (Koppelman & Bhat, 2006).

$$Monetary\ value\ of\ an\ attribute = \frac{Non\ monetary\ attribute's\ coefficient}{Monetary\ attribute's\ coefficient} \quad 2\text{-}10$$

The study by Kumar *et al*. (2004), demonstrated that In-Vehicle Travel time can be calculated using same principle:

$$\text{Monetary value of time} = \frac{\alpha}{\beta} \quad 2\text{-}11$$

Where,

α Coefficient of In-Vehicle Travel time

β Coefficient of Travel Cost

The transport demand elasticities determination principles have been also reported by Šenk and Biler (1900), to figure out the monetary value of time for a leisure trip. They say that the monetary value of Travel Time for the cases of trips executed on travels heading to leisure activities, is formulated as the maximum amount of money which people are Willing To Pay (WTP) to save one unit of their leisure time. This is done on the condition that all other trip related characteristics remain non-changed. Therefore, two hypothetical alternatives were considered with two attributes whereby:

Fuel related Costs X_{cost} [in CZK] and

Travel Time X_{time} [in hours]

With two alternatives i and j, the deterministic part of the utility equation looks like the one in the equation 2-12 below:

$$V_i = \beta_{costs} X_{costs} + \beta_{time} X_{time} \qquad 2\text{-}12$$

The resulted monetary value of the Travel Time Savings to trips heading to leisure $VTTS_{leisure}$ was obtained by substitution of estimated values of βcosts and βtime to the following expression.

$$VTT_{Leisure} = \frac{\beta_{time}}{\beta_{cost}} x\, 60 \text{ (CZK/h) (Šenk \& Biler, 1900)} \qquad 2\text{-}13$$

60 was multiplied in order to express the resulted value per hour because the study was conducted by using minutes as the travel time unit.

As said previously, the monetary value determined in the elasticities method is compared to the values got from a different survey, in order to check for the validity of the model. The model would be said valid, when all the monetary values of the non-monetary variables are in the range of 25%-50% of the hourly wage of the population. This range is considered as standard in different literatures (Šenk & Biler, 1900). In case the values reported are different from the range given above, the variable is to be excluded since its prediction in the model is inaccurate. Removing poor predictors in the model's equation, enhances the performance accuracy and hence the model is said to have been validated.

In conclusion, the literature suggests that an introduction of a new mode of transport should be looked at carefully in order to predict the preference of transport users toward its use. Most researchers believe that multinomial/binary models that use disaggregated data are the appropriate models type to be used for travel preference studies. The Stated Preference method is, on the other hand, the most powerful tool for the surveys of such studies. Then analysis would be efficient when done using computer programs to determine the model’s parameters for use in the multinomial/binary logit model's equation formulation. A model performs well after refinement and validation of its specifications. The methodological design presented in the next chapter of this report is based on the approaches presented in the above review of the literature in order to successfully achieve the objectives of this research.

Chapter 3 RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

The methodology of this research is developed based on the disaggregate transport planning approach by choice preference modelling process. This approach is able to make analyses of Stated Preference data and also gives a chance to all concerned elements of the logical decision making process to be involved. This chapter starts by discussing different techniques applied to collect relevant SP data and gives details of analysis using the SPSS. This part also demonstrates how the results of this computer program are used in the models' development, its refinement and validation. The last part concerns the explanation of the procedure of probability determination and the traffic demand volume quantification for each alternative.

3.2 DATA COLLECTION

In order to achieve the objectives of this study, different data sets had been collected. These include primary data and secondary data.

3.2.1 Primary data collection

Primary data collection is normally done when the researcher wants to use values that are directly taken at a site at a given time. These differ from the secondary data in the fact that, the latter is taken from the publications of other researchers and or bought from data selling houses or companies. In this study, primary data surveys make a very big part of data collection and it has engaged numerous factors for its success.

All the primary data was collected in three phases, whereby zero phase (also called preliminary phase), was undertaken to identify the potential attributes of alternatives. The first phase that was also called the pilot study, was comprised mainly of collection of the identified attributes' values, incomes of the population and Willingness To Pay values. The second phase, which was actually the major focus of this study, was based on the SP surveys. The reason of phasing the primary data collection is that, data needed in one phase was to be used in the next phase. In this regard, the preliminary surveys were conducted in order to find attributes to be used in the pilot survey where identified attributes' values were to be collected. In turn, the attributes' values were to be used in the design of Stated Preference experiment, which provides the questionnaires (choice games) to be used in the phase two of the primary data collection.

Other data has been collected regarding the incomes of the population and their Willingness To Pay; but these ones were particularly required for model refinement and validation purposes.

All of these data items have been collected among the transport users of the three routes identified as the best suitable field of survey in the actual study area (See Section 1.5 for scope of the study), based on the purpose of this work. The reasons for choosing these routes are found in Section 3.2.3 later in this report.

3.2.2 Secondary data collection

The role of secondary data in this study was crucial. The data collected here was to complement the primary data surveys for completion of the assignment. The intention was to assemble data regarding the past years' traffic demand, in order to be able to quantify the share of each mode involved. The attributes' values, related to the HLTA, were also found in the secondary data category since this mode was not yet operational. All data items taken from the literature review were considered to be part of the secondary data collection in this report.

3.2.3 Survey area coverage

The survey area coverage has also been presented in details in Section 1.5 of this report. The following sections are provided only to discuss the criteria of the identification of the three routes indicated in Section 1.5.

The following are the general criteria to choose the three routes of influence used in this study:

- The routes should be very influential in terms of heavy traffic demand, because HLTA is suitable in high demand of traffic, in order for it to enjoy economies of scale(successfully utilising its carrying capacity);
- High growth rates: Because of the fact that HLTA are in different categories in terms of carrying capacity, routes with high growth rates would benefit the most from the HLTA use;
- The routes should be of considerable distances. The reason of using long distance routes comes from the fact that the potential applications of HLTA make great impacts when the mode operates in long trips where it enjoys the economies of scale (successfully utilising the distance capacity).

Thus, the following sections provide details of choice of each specific route:

3.2.3.1 Short route

This is the route on which major road sections linking Kigali to other cities and districts of Rwanda are connected. It has, therefore, high traffic movement of passengers and freight. As can be seen from the map on Figure 1-1, Rusizi city is directly connected to Bukavu city (of the Democratic Republic of Congo). Although no formal transport operations are registered between the two cities, there are informal movements induced by people who travel between Kigali and Bukavu cities. These movements also add to the heavy traffic of the short route.

3.2.3.2 Long and Medium routes

These routes are composed of international roads, linking Rwanda to different ports and neighbouring cities of East Africa. As discussed in chapter one, international trade transport of Rwanda depends on two corridors i.e.: Northern corridor (The heaviest in East Africa), originating from Mombasa port, and the Central corridor originating from Dar-Es-Salaam port. Therefore, the very high growth rates and volumes on these routes from 2008 to 2013 are explained by the fact that all of the international traffic enters Rwanda through these routes connected to the Northern and Central Corridors.

The high traffic growth rates on these routes were also strengthened by the integration of Rwanda in the East African Community in June 2009. Since that time, Rwanda has been receiving a lot of traffic due to the trade agreement with other East African countries' members.

As reported by Rwanda Transport Development Agency, RTDA, 2014), heavy vehicles volume is generally high on all borders linking Rwanda and the East African Community countries. The following Table 3-1 has been compiled from the reports of traffic counts done by RTDA (2011) and RTDA (2014). It summarises the amount of demand available on the three routes considered. The growth rates presented on these three routes were reported by RTDA (2014) as the mean rates of increase of traffic from 2008 until 2013.

Table 3-1: Traffic demand volumes and growth rates of the used routes (RTDA, 2014)

TRAFFIC VOLUME									
Year	**Distance and route specification**	**Section name**	**Section number**	**Border /Node**	**Demand (ADT)**		**Demand (Yearly)**		**Annual Growth Rate (%)**
					Passenger (#)	Goods (Tons)	Passenger (#)	Goods (Tons)	
2010	Long: Kigali-Mombasa, Nairobi, Dar-Es-Salaam	Kigali-Kayonza-Rusumo	RN3	Rusumo	192	2574	70080	939510	
	Medium: Kigali-Kampala	Kigali-Gatuna	RN2	Gatuna	960	1441	568670	732190	
		Kigali-Kayonza-Kagitumba	RN5	Kagitumba	448	197			
		Kigali-Ruhengeri-Cyanika	RN8	Bunagana	150	368			
	Short: Kigali-Rusizi	Kigali-Butare-Cyangugu	RN6	Kitabi	210	425	76650	155125	
2013	Long: Kigali-Mombasa, Nairobi, Dar-Es-Salaam	Kigali-Kayonza-Rusumo	RN3	Rusumo	2254	4989	822710	1820985	143%
	Medium: Kigali-Kampala	Kigali-Gatuna	RN2	Gatuna	1798	7330	1800180	3590140	119%
		Kigali-Kayonza-Kagitumba	RN5	Kagitumba	1996	896			
		Kigali-Ruhengeri-Cyanika	RN8	Bunagana	1138	1610			
	Short: Kigali-Rusizi	Kigali-Butare-Cyangugu	RN6	Kitabi	1768	1486	645320	542390	203%

3.2.4 Preliminary study, zero phase primary data collection

The preliminary surveys have been conducted on the above mentioned routes to determine what attributes trip makers (from the population of the study area) consider in choosing a transport mode. This survey complies with identifying appropriate attributes to use in the design of the SP experiment in this study (see discussion of attributes setting in Section 3.3.2). During this survey, respondents were given a list of eight pre-identified attributes, such as:

1. Service Frequency;
2. Travel Cost;
3. Waiting Time;
4. Reliability;
5. Safety;
6. In Vehicle Travel time;
7. Security; and
8. Comfort.

Then, respondents were asked to choose which attributes they use to choose a given alternative. See APPENDIX A for details of a questionnaire used in this survey.

3.2.5 Pilot study, first phase primary data collection.

The first phase data collection had the purpose of revealing actual values of attributes of transport modes in Rwanda. The attributes that correspond to the object of this survey are those used in the choice preference data collection between different modes of transport on the above mentioned routes. The identification of the attributes used in this study is discussed later in this chapter. The following sections describe the attributes that were identified from the preliminary survey, i.e.

- **Travel Cost**

This is the out of pocket monetary cost experienced by passenger or for goods on a unit basis. The travel cost in this research is taken as a sum of the fare cost and other expenses made in order to execute the trip. These other costs are mostly related to airtime for communication, buying refreshments and accommodation in case of journeys that include transfers (in other literature, it is called out of pocket money). These costs vary depending on the respondents' socio-economic characteristics like income and life style. It also strongly depends on the trip length, number of terminals and the mode of transport due to the variability of transport modes' operating costs.

- **In Vehicle Travel time**

This is the amount of time taken by a passenger or goods from when the trip starts (the vehicle is started) from the origin until it stops at the destination. Normally, travelers assign different values that they use when they travel. The diversity of the IVT time values depends on the circumstances along the journey (police checks, weigh bridges, traffic jam, etc.) , the climatic condition when the trip is being executed, the current driver's behaviours and his driving abilities and again, most especially, the mode of transport concerned.

- **Waiting Time**

It is the time taken by passengers or goods to wait for the arrival of the vehicle and then to get seated or packed until the vehicle starts to move. This value changes according to the transport conditions of the area or terminal, from one traveler to another and, most especially, it is based on the type of alternative transport mode.

3.2.6 Questionnaire formulation for interviews

In this phase, the interview as a means of survey was applied to gather data about each particular mode of transport users. An alternative mode of transport used by a respondent was first identified together with a determined route and then the questioning session continued. A set of questions had been compiled and then printed on a paper. While compiling the questions, an effort was made to give different ranges of values to the respondents so that they could choose ranges that corresponding to their trip characteristics. Direct site interviews were preferred as a best method because respondents can easily remember their trip characteristics in terms of time and cost used. Other methods like CAPI (Computer Assisted Personnel Interview) and telephone interview were considered, but they were not judged suitable because respondents in such cases had to recall the experience on trips made some considerable time back. In addition, CAPI could not be feasible due to low ownership and expertise of personal computers in the targeted population of the study area. The following sections discuss different categories of questions that were composed in the questionnaires that were used.

3.2.6.1 Informative or descriptive questions

These questions include asking the information related to the transport users, transport operations and also the travels considered. The target here was to find information to be used in the design of Stated Preference experiment. Efforts were made to make the wording of such questions as simple as possible and also to use a language that is familiar to them during the explanation of the interview's instruction. All questions were limited to single questions for one concern, so as to prevent the bias in the responses. In wording the questions, efforts were made to avoid double barreled questions, proverbs and double negatives.

3.2.6.2 Questions to reveal the attributes' values

For the purpose of the Stated Preference design, values of variables to be included in the choice process require to be determined and are also considered for utility function formulation. The values of each attribute were collected from the transport users of each alternative mode of transport. In order to obtain accurate data on various attributes, separate questions were included in the questionnaire specifically for that purpose. Retrospective longitudinal design was employed, where the respondents were asked to provide information about the same attributes of In-Vehicle Travel time, Waiting Time and Travel Cost.

The possibility of using both open ended and pre-coded questions was investigated. In an open question, the respondent is given the freedom to decide the aspect, form, details and length of his answer. It is now the responsibility of the interviewer to record as much of it as he can. However, it is very difficult to code the open questions, which makes their analysis difficult and inaccurate. It was, therefore, decided not to use any open ended questions in the questionnaires. In the pre-coded questions, two types of coding were employed. The respondent was either provided with pre-coded questions with limited options or pre-coded questions with interviewer's code. For instance, in case of the cost of the travel, the respondent could pick the value corresponding to the *fare cost* and then the *other cost* associated to the trip in a range of preset (coded) values.

3.2.6.3 Transfer Price or Willingness To Pay data

The transfer price data is collected in order to determine the monetary values of the attributes. These data items are processed in the validation in order to cross-check the values obtained from the utility function's ratio of estimates results. As said previously, the purpose in this case is to evaluate the model's attributes performance in terms of prediction. The attributes considered here are: Waiting Time and In Vehicle Travel Time. Travel Cost being already expressed in terms of monetary values is not concerned. Transfer pricing in this case is thus, determining the money expensed on one hour waiting, or travelling in the vehicle for one hour. It is also referred in this study, as the Willingness To Pay (WTP) data.

3.2.6.4 Transfer price or Willingness To Pay questions

The transfer price questions have as their main purpose to determine how much the price of travel on an alternative has to increase before the transport mode user would shift (up to the point of indifference) to another alternative mode of transport. In other words, what is the maximum value he is willing to pay related to the attribute. The questions of the WTP were based on multiple ranges of cost where a respondent can increasingly choose up to his possible maximum before switching to another mode. For example, if 30 minutes are reduced to the waiting time, a respondent is asked to choose what would be the fare cost he is willing to pay. In this case, the assumption is made that the traveler or freight owner is able to know what he can add to place value on the time reduced in terms of waiting. The same question is asked for the IVT, where a respondent is given an increasing range of cost that he is willing to pay for a reduction of some amount of IVT.

3.2.7 Conducting interviews

All the categories of questions above were set and presented to respondents in a choice range. Respondents, therefore, had to tick according to their travelling experience. An effort was made to collect the values of the attributes based on the most recent data. This strategy required a respondent to give information based on his recent trip made or a trip he was going to make after the time of interview.

The ranges to be set on any given question were known first by the researcher based on the observation and experience gained while making preliminary interactions with the study area. Another element that has helped is that, the researcher is a native of Rwanda, and had experienced such trips numerously on the same routes. Different questions to gather all relevant information from the respondent were compiled. However, efforts were made to conduct the interviews for no more than 10 to 15 minutes for, so as not to induce fatigue problems and thus errors in the responses.

Normally in an interview, the respondent starts with less confidence in his/her responses, and consequently in the case of this research, two minutes were taken to explain about the interview and the intention of the research, in order to familiarise the interviewee with the exercise (See the starting statement on the questionnaire on APPENDIX B). After explaining the research's intention, variables (attributes) were explained so that a respondent would not answer according to his chaotic knowledge about variables, but based on the context of the research. Then simple questions started, such as: origin and destination, distance travelled and mode used, etc. At this stage, the interviewee and interviewer are on level fields, and the interviewee is ready to respond. Questions then proceed in a logical manner, moving from topic to topic and gradually towards more complex questions. Series of questionnaires used in this first phase are annexed to this report as APPENDIX B.

This pilot study survey was conducted in Nyabugogo (the main terminal in Kigali), Rusizi main terminal in Kamembe town, Kigali international airport, Kamembe international airport and on the borders of Rwanda with other East African countries (borders involved were: Rusumo, Gatuna, Kagitumba, and Cyanika) and freight related surveys from the businessmen in Rusizi and Kigali; especially in the free trade zone and the Gikondo industrial zone where goods congregate for tax clearance.

3.2.8 Sample size for pilot survey

As said previously, this survey was only for a preparation of the main survey of Stated Preference, thus a minimum sample size, required for the assumption about normal distribution, was used. This is in line with the rule of thumb that considers at least 30 interviews per market segment to produce statistically significant outcomes (de Dios Ortuzar & Willumsen, 1994). Responding to this rule, interviews were carried out on a 30 people sample of respondents that use the three routes considered and also per each mode. The total respondents, therefore, totalled 270. This number corresponds to: 30 Respondents x 3routes x 3existing modes considered (bus, air-passenger and truck). Every transport mode on the three routes had one surveyor and the 3 modes made a total of 3 surveyors on each route.

3.2.9 Main study, second phase data collection (Stated Preference surveys)

Stated Preference data collection is considered here as the main work, as it is the one that leads to the determination of traffic demand shares of modes. Therefore, a lot of work was done and a lot of effort was furnished at this stage in order to produce successful results. Stated Preference questions are not as direct as the previous ones of the Revealed Preference. They require pre-acquired information on the attributes and their levels (values). The design of choice questions referred here as “Choice Games’’ and their presentation in SP questionnaire engages conducting an experiment of the Stated Preference as discussed in Chapter 2. See also Section 3.3, about the methodological process of SP experiment design of this study.

3.3 STATED PREFERENCE EXPERIMENT DESIGN

Based on the advantages of SP surveys identified earlier, this technique was believed as the best suitable for modelling the influence of HLTA in the mode choice preferences in Rwanda.

The purpose of Stated Preference experimental design is to prepare a questionnaire to be used in the preferences data collection to accurately estimate the models with as little bias as possible. As discussed previously, there are different designs in Sanko (2001), used to develop a Stated Preference experiment. In this study, the full factorial design was developed but it has given a great range of observation to the respondents, therefore the solution for this was to adopt the fractional factorial design. Although the full factorial design gives full ranges of combination, it also induces fatigue problems to the respondent, which could affect the responses provided.

Six steps were used to successfully make an SP questionnaire and to conduct interviews. These steps are discussed in de Dios Ortuzar and Willumsen, (1994) to be accurate and they were followed in this study.

3.3.1 Step 1: Identification of alternative modes of transport

The identification of alternatives was made based on the pre-research works, where the researcher went to site to observe different modes used in the study area. The alternatives to look at, had to include both passengers and freight.

Two main modes of transport are available in Rwanda (as mentioned in the Chapter 2), especially on the three routes considered for this study. These are road transport and air transport. Hybrid Lighter Than Air was included in the modes of transport as it is the object of this study. Air-cargo operates in Rwanda but it has very low volumes and it is not competitive in freight transport. Therefore air-cargo was not considered in the analysis of this research. For the accuracy of data collection and model development, the two main modes available were disaggregated in the following:

i. Passenger Transport:

- Bus (Bu);
- Air-Passenger (AP);
- Hybrid Lighter Than Air (HLTA-Passenger).

ii. Freight Transport:

- Trucks (Tr);
- Hybrid Lighter Than Air Cargo (HLTA-Cargo).

3.3.2 Step 2: Identification of the attributes of the alternatives

Attributes of the alternatives are the variables that are preset to characterise the alternatives for use in the choice exercises. The attributes in the context of this research are all generic, which means they reflect all the alternatives from which choices are to be made. e.g.: For a combination of choices between bus and HLTA, the attributes used for bus are the ones used for HLTA. In other words, each attribute is presented for both the alternatives. Concerning the identification of the attribute, the criteria used are listed in Section 2.5.6.2.

These guidelines were used to pre-identify attributes that are believed influential in the transport users. So, this made a list of eight attributes, namely: Service Frequency, Travel Cost, Waiting Time, Reliability, Safety, In-Vehicle Travel time and comfort.

However, these attributes are many and all could not be used in this study. Consequently a method of factor listening, from Rasouli and Timmermans (2013) was applied in order to identify the most influential attributes. In order to succeed, a survey was conducted, whereby respondents were asked why they chose a particular alternative mode of transport and did not choose the other. Then respondents could choose from eight pre-identified attributes. According to this method, importance was assumed to be equal to frequency (number of times an attribute was chosen). Based on the choices of respondents, three attributes were identified, which are: Travel Cost (TC), In-Vehicle Travel time (IVT), and Waiting Time (WT) by order of decreasing frequency.

The identification of the attributes of the alternatives goes hand in hand with selection of the measurement unit for each attribute. In all of the cases, effort was made to express units of attributes in the familiar measuring units of the respondents in the population, for example, in the study area of this research, time was expressed in hours and minutes and days depending on the mode of transport and the route. Travel cost was expressed in United States Dollar for air transport mode; and Rwandan francs for bus. In case of truck, USD was used on long and medium routes but for short routes Rwf was used as it is the actual currency used.

For conversion purposes, one USD was taken equivalent to 700 Rwf, a conversion rate that was used after consulting the central bank of Rwanda and the foreign exchange bureau in March, 2014.

3.3.3 Step 3: Specification of number and magnitudes of the attributes' levels

The number and magnitudes of attributes' levels are of vital importance and play a major role in the design of SP experiments. Both of these two items were determined from the "questions to reveal the attributes values" discussed previously. These questions were set to specifically find different values of attributes of a particular mode of transport on different route categories. Based on the data from the pilot surveys, 3 levels were used for all attributes in this research: maximum level (the highest value of the attribute frequently answered by respondents), medium (the middle value of attribute frequently answered by respondents) and minimum (the smallest value frequently answered by respondents). From now onwards in this report, these levels shall be called Leve1, Level2 and Level3 in a decreasing order of their magnitude.

The approach of determining the number and magnitudes of the attributes levels for HLTA was different from other modes since this one is not yet operational at site. At the time of conducting this study, there were no updated values of cost rates published by HAV Ltd. By means of e-mail conversation in February 2014, data was requested by the researcher, but HAV Ltd responded that operating costs data was, until that time, commercially confidential.

The determination of the cost attribute value used in this research was taken from the cost estimates of Advanced Technologies Group Ltd of the UK and presented in Prentice *et al.* (2010). Refer to Table 2-3.

In that table, cost data is relevant for the year 2002, the year when ATG Ltd conducted the study. Therefore, the values to be used in this current study have to undergo a discounting process, in order to update the monetary values used. Discounting has thus been applied, to figure out the appropriate cost to be assigned to the Travel Cost attribute of HLTA in the year 2014, the base year of the research. To determine the cost in the year 2014, the following discounting expression was applied:

$$Cost_{2014} = (Cost_{2002}) x (1+r)^{t} \quad \text{3-1}$$

Where:

r Discount rate (%)

t Time in years between the study's base year, 2014 and the past year, 2002 in this case.

As per HMTreasury (2013), the recommended discount rate is 2.2% in Britain, where the manufacturers of HLTA and ATG Ltd are seated. So, the discounting rate used for updating the cost of transport of the HLTA was taken to be 2.2%.

Only the prices of transport of HLTA-Cargo were available. So, in order to determine the cost of HLTA-Passenger transport, an interpolation technique has been applied. In this technique, RwandAir-cargo transport costs on different routes were compared to cargo transport cost of HLTA and the ratio was applied to the passenger transport costs on the same route. Details of calculation are presented in the next chapter for analysis.

For the IVT, the speed of the HLTA was used, taken from a report by HAV Ltd (2014), where a value of 105 knots (which is equivalent to 105x1.85=194km/h), was used. Then the lengths of different routes were divided by this speed value to determine the levels of IVT for HLTA on different routes as per the following equation.

$$IVT(h) = \frac{Dis\tan ce}{Speed} \qquad 3\text{-}2$$

For the Waiting Time values of HLTA, an argument was that it operates like a helicopter (see the second chapter for details). The value used for both passenger and freight are discussed in the next chapter.

3.3.4 Step 4: Stated Preference statistical design

In the previous chapter of the literature, it was mentioned that the main part of the stated preference experimental design is based as a whole on the statistical design. This part concerns the construction of hypothetical choice scenarios to respondents, which is the main output of the SP statistical design.

In this work particularly, the set of alternative numbers does not change. In every situation a respondent has to choose between two alternatives available to him in the design. This is called "binary choice game". In order to create the binary choice games between different alternatives on different routes, attributes' levels and numbers have been combined as per Sanko (2001). So, the full factorial experiment design was determined by presenting every possible combination of attributes and their levels. Recall that, the number of combinations is the result of the number of levels raised to the power of the number of attributes. Therefore, for the case of this study, engaging three attributes and three levels, the total number of scenarios for a full factorial design was found equal to:

$$\textit{Total Scenarios (Full factorial design)} = L^N = 3^3 = 27 \textit{ choice scenarios} \quad \text{3-3}$$

The 27 choice scenarios resulted were judged to be many as compared to 9-16 combinations recommended by literature (Kroes & Sheldon, 1988). A solution that had been applied was to transform the design from a full to a fractional factorial one. This is suggested by many publications like Pearmain, Swanson, Kroes and Bradley (1991) and Sanko (2001).

Transforming a full factorial design into a fractional factorial design is based on the observation of all the combinations. Rejecting some of the profiles (combinations) is not done randomly; the combination to be rejected is the one that is obvious or redundant. These kinds of combinations are also called dominant profiles, which means that they dominate other combinations set with them in terms of choice. They are also referred to in research as trivial questions, which means one can know the result of the choice process before even the respondent answers.

For example, the scenario B can dominate any other scenarios, and the scenario A is dominated by any other scenarios. Therefore, in the multinomial choice game which includes scenario B, scenario B is always chosen. In the multinomial choice game which includes scenario A; scenario A is always rejected. In binary choice game, which includes scenario A, the opponent scenario to A is always chosen. Since they are trivial, efforts were made to reject such combinations in this study.

From 27 combinations of full factorial design of this research, a reduction was made to 16 combinations, which both include the main effects and also eliminate biases. Efforts were made to develop choice games for disaggregated situations based on the route categories and the modes of transport available for both passengers and freight transport.

3.3.5 Step 5: SP questionnaire formulation

It is a must to explain to respondents about the rules of the choice game. So, an effort was made to formulate an understandable questionnaire from combinations’ sets.This makes it possible to bring a respondent in a hypothetical mood as if the mode is already operating with such characteristics presented. Sivakumar *et al.* (2006) analysed the introduction of the new transit systems in developing countries and one of their findings is that the SP questionnaire worked well when the users are explained about the unfamiliar New Transit System.

The choices that had been presented to respondents in this study were binary sets, where transport modes of reference were combined with the rest of the modes in the same categories (either passengers or freight transport). For passenger transport, a bus was taken as a reference and respondents had to choose between bus and air-passenger in a different questionnaire and bus and HLTA-passenger on another. For freight transport, truck was taken as reference and respondents had to choose between truck and

HLTA-cargo. Each pair of combinations from two transport modes in the choice competition was transformed into 1 question; and, therefore, 16 questions resulted from each questionnaire.

3.3.6 Step 6: Conducting interview

Due to a big number of responses that was required for modelling (see Section 3.4.2, on sample size estimation), an optimum sample size was used for different routes, and different mode choice interactions. The total size of the sample came to 1212 respondents for all the surveys of the second phase data collection. In order to make it possible within a limited time of the research, a group of 9 junior engineers was trained to conduct the survey. Every surveyor had to interview approximately 134 respondents depending on the sample size of the route itself and modes engaged. To make sure that everything went right, the researcher had to make tours in the area where the exercises were taking place to see if there were no challenges encountered by the surveyor and to propose a solution in case there was a problem.

Respondents made their choices very well in sets of existing modes (bus and air-passenger) but for the case of hypothetical situations, (combinations engaging HLTA-passenger and HLTA-cargo), pictures and videos were played in order to explain more about the HLTA transport, to the respondents. The videos used include: "P-791 Hybrid Air Vehicle" by Bob Boyd, John Moorhead and Valorie Evans. The use of videos was optional depending on the respondent's agreement; sometimes a surveyor had to meet a trader in his office and start an interview, and when the respondent agreed, the videos could be watched before the choice exercise started. This required a surveyor to have a smart phone or a tablet to be able to play the videos. However videos were kept very short not to interrupt the interviewee's concentration. All choice games questionnaires of the second phase survey are annexed in APPENDIX E.

3.4 SAMPLING METHODS

Normally, in the sampling procedure two major factors apply, the first is based on the avoidance of the bias in the sample selection and then trying to achieve as maximum precision as possible (Moser & Kalton, 1979). Efforts were made, in this regard, to use appropriate methods for sampling processes in order to account for these two major factors.

3.4.1 Types of sampling

Many sampling strategies exist with the same objective as underlined above, but the main two types are explained below: cluster sampling and random sampling methods.

3.4.1.1 Cluster sampling

The process of sampling complete groups of units is called cluster sampling. If any sub-sampling within the cluster is chosen in the first stage, in order to proceed with the cluster sampling, this is termed multistage sampling. Since the number of traffic demand on each route considered for this study is very high, the cluster sampling was not considered appropriate for this research.

3.4.1.2 Random sampling

Random sampling methods consist of taking a sample composed of different elements called units. The unit should be taken in the general population and should be related in one way or another to the study. Taking this unit is independent and each unit to be taken has the same probability of being chosen and placed in the sample, with a sample being a collection of a number of different units. This independence in the choice of units made this method the most acceptable method with a relatively great probability of use compared to the other methods. Random sampling strategies are divided into the two following categories:

i. Simple random sampling

Simple random sampling consists of randomly identifying units to be engaged in the sample of the study. Units are chosen one by one until the desired sample size is achieved. The common problem here is that a greater percentage of the units in the sample may not well reflect the context of the study; and consequently, the very small percentage taken can be the only one that reflects the study context. In this way the accuracy of results would not be optimised. Another problem stemming from using this method is that a very large sample size might be required to ensure sufficient data for less representative or minority groups. Due to these two problems, this method was not chosen for use in this study. Relating it to the study background, rejecting this method is due to the fact that not all the population in Rwanda is concerned with the transport operation on the route Kigali to Nairobi, Mombasa and Dar-Es-Salaam; Kigali to Kampala and Kigali to Rusizi. It is very easy to find a lot of people who never operate the trips on these routes. Another point is that people do not use the same mode of transport. It is easy to find a traveller who has never used air-passenger the whole of his life, so, that one is not eligible for the survey. Therefore including these travellers in the sample units would reduce the accuracy of the data collected.

ii. Stratified random sampling

This category makes use of *a priori* information about the composition of different subgroups in the population to sample from. Subsequently, this information is used to create strata of homogenous characteristics from the population, after which the process continues like in the simple random sampling technique. This method ensures that accurate representation of each subgroup is met and eradicates all errors caused by simple random sampling. This technique was adopted in this study due to the above mentioned advantages. The strata here are compared to the routes engaged in the data collection in the sense that each route's units are homogeneous with the same characteristics. In order to do so, units from a route had the same probability to be chosen for use in the survey process, and therefore, three routes correspond to three strata used.

3.4.2 Sample size determination

The determination of the size of the sample requires a careful procedure. A small sample would result in the inaccurate representation of the population but an overestimated sample size would also waste resources and incur a lot of costs. Bari (1999) argues that a large sample does not necessarily guarantee the accuracy of the results. He said that although, for a given design, an increase in sample size will tend to increase the precision of the results, it will not guarantee to eliminate or reduce any bias in the selection process. In this line, therefore, a lot of effort was made to prevent all biases and to optimise the number of samples to be collected, taking into account the budget available for the study.

All the sampling processes within a stratum (route category) were done at random. This means that everyone who executes trips on any route category was eligible for survey on that stratum. Again, everyone who carries his goods via any of the three routes was eligible for the survey on the relative route. This would enable the choice preferences collected to reflect all individuals of the population in the study area concerned with the study.

Different methods were proposed by researchers to come up with an optimum size of the sample for a better representation of the population. The publication of Robert and Daryle (1970) presented the following model formula:

$$S = X^2 NP(1-P)/d^2(N-1) + X^2 P(1-P) \qquad \text{3-4}$$

Where:

S Required sample size.

X^2 The table value of Chi-square for 1 degree of freedom at the desired confidence level.

N The population size.

P Population proportion (assumed to be 0.5 since it provide a maximum sample size).

d The degree of accuracy expressed as a proportion (0.05) (Robert & Daryle, 1970).

Since this method brings some complications like the table of values for chi-square which was not readily available, the optimum sample size in this research was estimated using the method proposed by Moser and Kalton (1979). The equation 3-5 below demonstrates the concept of this method.

$$S.E.(p_{SRS}) = \sqrt{\frac{p(1-p)}{n}} \qquad 3\text{-}5$$

Where:

$S.E_{(p,\ srs)}$	Standard Error of a proportion, P based on simple random sampling (srs)
P	Proportion of population having attributes.
n	Sample size (Moser & Kalton, 1979)

This expression can be rearranged when it comes to stratified random sampling in the following way:

$$S.E.(p_{props}) = \sqrt{\frac{\sum n_i p_i (1-p_i)}{n^2}} \qquad 3\text{-}6$$

Where:

S.E (P_{prop})	Standard Error of a proportion of population, p in a proportionate stratified sample
n_i	Sample size in i^{th} stratum
p_i	Proportion of the sample in i^{th} stratum possessing the attribute
n	Total sample size

3.4.2.1 Sample sizes of strata (routes)

The sample sizes of routes used in this study were determined using Equation 3-6 above. The process has considered the population size determined from the total traffic on the three routes previously described. In order to know the number of trip makers involved on the routes per year, separate questions were asked in the pilot survey about the number of trips executed by travelers on a given route. So, the number of passengers counted divided by the number of trips that a passenger execute per year, gives the total number of travelers that generate such traffic demand on the route. The same process was followed to determine the number of the freight owners on different route, where an amount of freight carried per person per year was determined from the pilot study. Details about the calculation can be found in Table 3-2.

As can be seen from the Table 3-1 and Table 3-2, the intercity route (Kigali to Rusizi) is the one having low traffic both for passengers and freight, as compared to the other routes. Therefore, in order to collect a significant size of the sample that meets statistical requirements of this less representative route, efforts were made to satisfy Equation 3-6 with a standard error of 3 to 4 percent for stratified random samplings (Note that Standard Error of 5% is the optimum recommended in literature, and the lesser the SE, the greater the Sample size and the better the accuracy). Table 3-2 and Table 3-3 below demonstrate the determination of the sample size on each route based on its portion within the total population of the three routes using Equation 3-6.

The process of minimum sample size determination for discrete models has to be treated with a proper approach because normally these models are developed using very big samples; a characteristic that is known as "asymptotic property" in model building studies. This means that the number of observations, N to base on, should tend to infinity. In the model building, this is achieved by one or both of the following two techniques: either by increasing the number of interviewees as much as possible, or increasing the number of combinations while in the design of the SP experiment. In this study both techniques were applied.

As suggested by Kroes and Sheldon (1988), most SP designs involve 9 to 16 combinations for fatigue avoidance purposes. So, with a sample of 107 travellers found as the minimum sample size in all the routes in this study (see Table 3-3 below), there were at least 1712 responses, (i.e.: 107x16) from the respondents. This value is the minimum possible number of responses used. Some of the strata have got their samples even very high, like passenger transport sample size on the long route and the medium route with 153 and 155 respondents each. These produced, 2448 and 2480 responses respectively. The sample sizes used in this study are well within the range proposed by Bradley and Kroes (1990), Pearmain *et al.* (1991) and Swanson, Pearmain and Loughead, (1992) who all argue that 75-100 interviews per segment would be appropriate for an efficient SP exercise but they also add that a larger sample size than the presented values would be even better.

Table 3-2: Proportions of strata (Routes)

		PASSENGER TRANSPORT				FREIGHT TRANSPORT			
Year	**Stratum**	**Passengers (#)**	**Number of trips/year**	**Travellers**	**Proportion /Stratum**	**Goods (tonnes)/year**	**Tonnage per person/year**	**Carriage owners (#)**	**Proportion /Stratum**
2013	Long: Kigali-Mombasa, Nairobi, Dar-Es-Salaam	822710	5	164542	0.42	1820985	150	12140	0.22
	Medium: Kigali-Kampala	1800180	10	180018	0.46	3580285	100	35803	0.65
	Short: Kigali-Rusizi	645320	15	43021	0.11	542390	75	7232	0.13
Total				387581	1	Total		55175	1

Table 3-3: Sample size of each stratum (Route)

	PASSENGER TRANSPORT			FREIGHT TRANSPORT		
Stratum	**Proportion/Stratum**	**S.E**	**Sample size (n)**	**Proportion /Stratum**	**S.E**	**Sample size (n)**
Long: Kigali-Mombasa, Nairobi, Dar-Es-Salaam	0.42	4	153	0.22	4	107
Medium: Kigali-Kampala	0.46	4	155	0.65	4	142
Short: Kigali-Rusizi	0.11	3	110	0.13	3	127

3.4.2.3 Sample size determination

The sample sizes determined in the Table 3-2 and Table 3-3 are applicable to each modes' interaction on each route. Thus, the total sample size is equal to the sum of sample sizes of interactions on different routes. Table 3-4 gives a process of determination of the overall size of the sample used for the SP survey in this study.

Table 3-4: Total Sample size calculation

INTERACTIONS	LONG ROUTE	MEDIUM ROUTE	SHORT ROUTE	TOTAL (RESPONDENTS)
Passenger transport	153	155	110	418
Freight transport	107	142	127	376

3.5 MODELS DEVELOPMENT

The targeted models here are a type of binary logistic regression. In the binary choice method, two modes of transport had been set in choice competition at a time, and transport users had to choose from a combination of alternative modes that is suitable to their preferences. The model building stage here is based on the data collected in Rwanda, in order to analyse the alternative use of the Hybrid Lighter Than Air in this country. The BLR model developed, uses basic specifications of attributes which include: IVT time, WT, and TC as the explanatory variables of the model. In the choice process used, when all other variables are kept constant, a faster mode of travel is more likely to be chosen than a slower mode and a less expensive mode is more likely to be chosen than a costlier one. A transport mode whereby a user has to wait long to start the trip is less chosen.

3.5.1 Model's parameters determination

The model's parameters are the coefficients associated to the variables of the utility equation of the model. The magnitude of these coefficients depends on different factors, with the main factor being transport mode attributes' values and types of modes engaged in the choice games. For example, if bus is interacted with HLTA-passenger the parameters resulted from analysis are different as compared to when bus is combined with air-passenger. Depending on the variables' prediction, the effects of their parameters result in the increase or decrease in the utility of the model. In this current study, all the parameters are cost based, which means that their increase results in the increase of a disutility or reduction in the utility magnitude. Therefore, the parameters resulting from the analysis should show a negative sign.

Different techniques are available to determine the model's parameters, but the fast and reliable way is to use statistically based computer programmes. It is in this regard that SPSS version 21 has been used throughout the analysis of the data. Stata S/E 11.1 program has also been used, to verify the analysis of SPSS and to confirm the results of the analysis. SPSS is better than STATA because it is easy to use and makes it possible to determine some statistical aspects not available in STATA, for example Pseudo R-square for the goodness of fit measure. However, the work done by the two is the same.

The computer programme analyses the choice data, based on an iterative maximum likelihood procedure. The program starts with arbitrary values of the regression coefficients and constructs an initial model for predicting the observed data. The observed data refers to data entered in the programme. It consists of levels of attributes' values, their combinations, which are considered in the model building as independent variables, and then choice data, which is considered as dependent variables. Choice is considered as dependent on other variables because a change in the value of any variable (attributes' values) affects the choice decision of the combination by a decision maker. Then, the models evaluate errors in such prediction and change the regression coefficients so as to make the likelihood of the observed data greater under the new model. This procedure is repeated until the model converges, meaning until the difference between the newest model and the previous model trivial.

Concerning the running of the software, the analyst opens the SPSS programme where it is installed on an appropriate computer, uploads an excel sheet where the choice preference data has been entered together with their combinations. The choice data is entered in codes by 0 representing a no chosen alternative and 1 representing a chosen alternative, a process that is called "coding the data" in the modelling studies. Coding data by 0 and 1 is done because the software analysis of binary regression understands such kind of binary information. At this stage the software opens in the data view. For the analysis to continue, the program interface should be changed from data view to variable view. Analysis in the menu bar of the software should then be clicked, followed by Regression, then Binary logistics for the analysis to start. Now, a dialogue box opens, after which the choice variable is entered into the dependent variable's box and other variables (IVT, WT, and TC) are also entered into the covariates (independent) box. The dialog box should now look like Figure 2-22. When this is accurately done, the operator clicks Ok. SPSS processes the information and it takes less than a minute to report the results of the analysis.

From the variable in the equation table that is among the results reported, all the values of the parameter estimates, their respective signs and the corresponding residual term of the model are presented. Also, statistical characteristics of each attribute as presented in chapter 2, are reported. Another interesting element reported is the model summary table which gives a strong statistical parameter, called “goodness of fit”, represented by Nagerkerke’s R-square. A series of tables that have resulted from SPSS analysis of this study are annexed to this report in APPENDIX F.

Given the values of coefficients/parameters from the SPSS analysis results, the model’s utility equations have been formulated, based on the fundamental mathematical structure of the binomial logistic regression models.

3.5.2 Models’ utility expressions formulation

The models to be built in this study, were based on the utility maximisation theory, where a respondent was believed to choose a combination that maximises his utility. From this theory a utility function is developed for each alternative and includes the three identified attributes. Note that for disaggregation purposes, a utility function has been developed for different categories of routes. The bus mode was considered as reference mode for passenger transport and truck was considered as reference for goods transport. The following modes’ labels have been used in the subsequent discussion and equations:

Bu	Bus
AP	Air-Passenger
Tr	Truck
HLTA-P	Hybrid Lighter Than Air Passenger
HLTA-C	Hybrid Lighter Than Air Cargo

Both deterministic and residual portions of the utility are expressed in the following expressions for the above modes:

$$U_{AP} = \alpha_{AP} xIVT_{AP} + \beta_{AP} xWT_{AP} + TC_{AP} x\gamma_{AP} + \xi_{AP} \quad 3\text{-}7$$

$$U_{HLTA-P} = \alpha_{HLTA-P} xIVT_{HLTA-P} + \beta_{HLTA-P} xWT_{HLTA-P} + TC_{HLTA-P} x\gamma_{HLTA-P} + \xi_{HLTA-P} \quad 3\text{-}8$$

$$U_{HLTA-C} = \alpha_{HLTA-C} xIVT_{HLTA-C} + \beta_{HLTA-C} xWT_{HLTA-C} + TC_{HLTA-C} x\gamma_{HLTA-C} + \xi_{HLTA-C} \quad 3\text{-}9$$

Where:

U_i	Model’s utility function of alternative i
α_i	Model’s parameter related to IVT of alternative i
β_i	Model’s parameter related to WT of Alternative i

γ_i Model's parameter related to TC of Alternative i

ξ_i Residual term of the model's utility function of alternative i

According to the above expressions the total utility magnitude of a mode of transport is equal to the sum of the product of its attributes (IVT, WT and TC) to their respective parameters (α_i, β_i and γ_i respectively); then add the error term ξ_i .

Note that bus and truck were taken as references for other modes in the binary process and therefore in the utility formulation, only equations of other modes than references are to be presented.

3.6 REFINEMENT AND VALIDATION OF THE RESULTED MODELS

Different ways of refinement and validating a model have been discussed in the second chapter of this report. The validation process of models in this study used one type called disaggregation validation. This is qualified for models engaging disaggregated data, like choice preferences in the case of this research. Refinement was done by statistical screening by comparing the statistical values of the SPSS results to the actual values that statistical aspects should look like in the standards.

After this, demand elasticities were determined using the ratio of parameters estimates for validation. Then the resulted values of elasticities of the two non-monetary attributes were compared to the observed hourly monetary value of time attributes. These values used in comparison had been determined before, in the pilot study. The pilot surveys have revealed hourly wages of the passengers and then the transfer price cost of one container per hour for WT and that of IVT time, in case of freight transport.

The statistical refinement and the comparison of the model's monetary value of time attributes process led to a conclusion of removing the Waiting Time attribute from the model's explanatory variables. This was done as suggested by different literatures Koppelman and Bhat (2006) and Šenk and Biler (1900). The rejection of the Waiting Time attribute from the explanatory variables is supported by the fact that the statistical items associated to this attribute (WT) are not significant compared to the standards; and also the money value from ratio of parameters estimate technique was by far different from the results of the pilot surveys (both for passenger's hourly income and hourly cargo holding cost per container of freight).

The removal of one variable from the explanatory variables, brought back the model building process to the stage of starting the model building. This is due to the fact that the analysis by SPSS depends on the one hand on the number of variables set for the process.

New and validated models have been built, and were found a little bit different from the previous ones in terms of parameters' values. The statistical parameters and ratio of parameters estimate revealed good results of the remaining variables of the validated models. So, in the utility expressions of the validated models only two variables appear, which are IVT and TC. These variables are then the real predictors of the model's utility equations to be used for the probability determination for different alternative modes in the binary choice sets on different routes.

3.7 PROBABILITIES OF TRANSPORT MODES

The models' utility functions' magnitudes, calculated in the previous stage, finally make it possible to determine mathematically the probabilities of each mode of transport with respect to the reference mode in the interaction. As discussed in the second chapter, determination of choice probabilities of each alternative is done based on the systematic portion of the utility function of the alternative. This is in fact due to the fact that considering the error term of the utility functions for both modes, probability equation can change nothing to the determined probabilities, since the error term is the same for both modes in the binary logistic sets. So, from the models' utility functions' magnitudes, the probabilities are determined by using Equation 2-10 by Schmidheiny, (2014) and Hun, (2010).

In the binary sets, the probability determined by this equation reflects a mode other than the reference, then the probability of the reference mode is calculated by subtracting that value from one, as per binomial distribution principle. Table 3-5, shows the expressions of calculation of probabilities used in this study.

Table 3-5: Expressions of calculation of probabilities of transport modes

INTERACTION	PROBABILITY EXPRESSION
Bus and Air-P	Pr(Air-P)= $\frac{e^{V_{AP}}}{1+e^{V_{AP}}}$ and Pr (Bus) = $1-\frac{e^{V_{AP}}}{1+e^{V_{AP}}}$ (3-10)
Bus and HLTA-P	Pr(HLTA-P) = $\frac{e^{V_{HLTA-P}}}{1+e^{V_{HLTA-P}}}$ and Pr (Bus) = $1-\frac{e^{V_{HLTA-P}}}{1+e^{V_{HLTA-P}}}$ (3-11)
Truck and HLTA-C	Pr(HLTA-C)= $\frac{e^{V_{HLTA-C}}}{1+e^{V_{HLTA-C}}}$ and Pr (Tr)= $1-\frac{e^{V_{HLTA-C}}}{1+e^{V_{HLTA-C}}}$ (3-12)

In the passenger transport, three modes of transport were used on each route, air-passenger had been combined with bus and then HLTA-passenger was combined with bus (bus being reference mode as suggested). Therefore bus had had different probability values in its different interactions with other modes in the binary sets. To handle this issue, probability values for different modes have been normalised for a given route for passenger transport. In order to do so, a ratios analysis technique was used by assuming the transitivity between the modes. Then, the probability values of all modes were combined to come up with final probability values on a given route.

3.8 DETERMINATION OF TRAFFIC DEMAND OF MODES

Different traffic demand volume data acquired from RTDA (2011) and RTDA (2014) were used to quantify each transport mode's traffic demand share on the different routes. This in fact, has led to the achievement of the sole objective of this research. The calculation of the amount of traffic demand assigned to each mode of transport in this study has been done by multiplying the total demand available on a given route to the probability value of each mode by the following equations:

- $Traffic\ demand\ of\ bus = \Pr(Bus) x total\ traffic\ demand$ (3-13)
- $Traffic\ demand\ of\ air\text{-}p = \Pr(AP)\ x\ total\ traffic\ demand$ (3-14)
- $Traffic\ demand\ of truck = \Pr(Truck)\ x total\ traffic\ demand$ (3-15)
- $Traffic\ demand\ of\ HLTA = \Pr(HLTA)\ x total\ traffic\ demand$ (3-16)

This chapter discussed different methods and techniques that have been applied in this study. Different steps followed for SP experiment design were presented and data collection technique was envisaged. The final parts were concerned with a discussion of how the models have been built and how probabilities were determined and finally the process of the quantification of traffic demand of different modes.

The fourth chapter that follows, applies different principles that were developed in the previous chapter. It introduces the data used and the analysis by showing different stages followed to achieve the quantification of the demand of different modes, which is the actual objective of the current study.

Chapter 4 DATA ANALYSIS, MODEL DEVELOPMENT, REFINEMENT AND VALIDATION

4.1 INTRODUCTION

In order to achieve the objectives set for this study, analysis of data was crucial. Different studies had been done previously in various areas to model the preference of transport users on the new modes of transport. However, none of these studies have yet tackled the preference of people towards the use of HLTA, particularly in Rwanda. This new mode of transport is gaining market share these days, due to its potential characteristic of reduced economic and environmental cost. This current study makes use of the state-of-the-art tools and expressions to analyse the data, that was collected from several sources in order to model the traffic demand shares of different modes engaged in the study area of influence Rwanda, and to see if there is an amount of traffic that can be assigned to a new mode of HLTA to motivate its development.

In this chapter, the analysis of the choice data collected was done using SPSS, and the resulting parameters' values were used to build specific models between different modes and also to analyse the significance of the model by statistical refinement. The last stage was validation, where indirect cost attributes' monetary values were compared to their money values from income and Willingness To Pay analysis.

4.2 PRESENTATION OF ATTRIBUTES' LEVELS

Data gathered in different regions of the study area, represented values of the attributes considered and preferences of people on different modes as set to them in pairs of binary sets. In addition, incomes of the respondents were also collected for use in the validation process of the passenger transport models and transfer price data was collected and used to determine the monetary values of the non-monetary attributes (IVT and WT for the freight transport validation. The case of HLTA attributes' values was different, because it was not yet operational as per the time of compiling this report. HLTA attributes levels were determined by secondary data from different publications.

4.2.1 Values of attributes' levels of existing modes

Attributes' levels magnitudes have been determined from the results of data collection in the first phase mentioned in chapter 3. The values collected from the site surveys reflect only the alternatives already in use in the transport system in Rwanda, i.e. bus, air-passenger and truck. For all the functional alternative modes, interviews were used to collect the attributes data. Effort has hence been made to determine three values that repetitively were more dominant than others in the responses. With this method, respondents were not surprised at having such a value on the corresponding attribute in the phase of choice preference surveys because they were already familiar with it. These values of an attribute mostly dominant in the responses of people are called levels. In order to keep orthogonality, the effort was made to leave equal space between levels. For example, on a short route, bus passengers have to wait between 10 and 16 minutes as from the surveys, therefore the levels in this case were 10, 13 and 16 and equal space between them is 3.

The units specified in responses were varied, depending on two factors; in the questionnaires the units had been expressed in practical values that the trip makers are familiar with, and another factor is that for the calculation purposes units require to be set in harmony. Therefore, the units presented in the questionnaires were practical at the study area and the units presented in tables (APPENDIX C) correspond to the units used in calculation for units' harmonisation purposes. For example, in the questionnaire USD (United States Dollar Units) was used for Travel Cost ranges of the air-passenger mode. But this was converted into Rwf (Rwandan francs) for harmonisation with units of Travel Cost attribute of bus. This was done before analysis procedures and it makes it possible to make binary logistic regression with bus (whose units of TC were expressed in Rwf, in the questionnaires). Another point here is that on different routes units could change, for instance in the intercity route (short route), the freight carriage is paid per tonne while on the long and medium distance routes, the freight carriage is paid per container. All these parameters were therefore taken into account before commencing the binary logistic regression analysis with SPSS. A series of tables demonstrating different levels of different alternatives on different routes used in this study, are annexed under APPENDIX C.

4.2.1.1 Magnitudes of attributes' levels of Hybrid Lighter Than Air

i. In Vehicle Travel time

On the long route, which is composed of different destinations with different distances, the IVT time of HLTA was determined by dividing the distances to each destination by the speed of the HLTA, which is 194km/h.

The flight distance between Kigali and Dar-Es-Salaam is 1157km. Therefore, the IVT of HLTA is 1157/194=6hours.

The distance between Kigali and Mombasa is 1093km. With a speed of HLTA 194 km/h (HAV Ltd, 2014), the IVT is =1093/194 =5.6hours.

The flight distance between Kigali and Nairobi is 755km. So, the IVT of HLTA at this destination is 755/194=4hours.

ii. Travel Cost of HLTA

The data used in this research was taken from the publication by Advanced Technology Group Ltd in 2002. The cost value used in this research corresponds to 200 metric tonnes range of carriage. This range is the one that matches with the commercial long range and outside cargo/freight delivery (referring to Table 2-1: Capabilities and main uses of Hybrid Air Vehicles). The 200 metric tonnes had had a per tonne-km cost equal to $0.2 in the year 2002 (referring to Table 2-3: Freight rates of HLTA in the second chapter). In order to update this cost value for the 2014 base year, a discounting technique was applied and this value has become $0.3 per tonne-km. This was done using the following discounting expression:

$$C_{2014} = 0.2x(1+0.022)^{12} = \$0.3/tonne\text{-}km \qquad \text{4-1}$$

- **HLTA-Cargo Travel Cost levels**

The levels of cargo TC per container by HLTA-C are calculated by multiplying $0.3/tonne-km to the distances involved and the total tonnage carried by one container. According to the respondents, the average weight carried by a 40ft container is 27tonnes. This value was approved by PADECO Co. (2011) in the "Study for the Harmonisation of Vehicle Overload Control in the East African Community", in which Rwanda is a member.

The flight distance between Kigali and Dar-Es-Salaam is 1157km. With $0.3 per tonne-km for a 40feet container carrying 27 tonnes, therefore, TC=0.3 x 1157 x 27=$9372=6560000Rwf/container.

The flight distance between Kigali and Mombasa is 1093km. With $0.3 per tonne-km for a 40feet container carrying 27 tonnes, TC=0.3 x 1093 x 27=$8853=6197000Rwf /Container.

The Flight Distance between Kigali and Nairobi is 755km. With $0.3 per tonne-km for a 40feet container carrying 27 tonnes, TC=0.3 x 755 x 27=$6115.5 =4280000Rwf/Container.

- **HLTA-Passenger Travel Cost**

As there were no direct data of passenger travel cost of HLTA-P, the values used for HLTA-passenger cost were interpolated from the Air-Cargo transport cost for three destinations on the long distance route.

- The cost of Air Cargo transport to Mombasa from Kigali is 1765$/tonne (RwandAir, 2014). With a flight distance of 1093 km, the per tonne-km cost is 1.6$. The cost of a passenger from Mombasa to Kigali is 499$ (Kenya Airways, 2014). By interpolation, the cost of HLTA-Passenger to Mombasa is 93.5$. And in terms of Rwandan Francs=93.5x700=65000Rwf

- The cost of cargo transport to Nairobi from Kigali is 1200$/tonne (RwandAir, 2014), corresponding to a flight distance of 755km and, therefore, to a per tonne-km cost of 1.6 $. The cost of a passenger from Nairobi to Kigali is 381$ (Kenya Airways, 2014). By interpolation, the cost of HLTA-passenger to the same place is equal to 71.5$ and in terms of Rwandan francs=71.5x700=50000Rwf.

- The cost of cargo transport to Dar-Es-Salaam from Kigali is $2015/tonne (RwandAir, 2014), corresponding to a flight distance of 1157km, and therefore to a per tonne-km cost of $1.7. The cost of a passenger from Dar-Es-Salaam to Kigali is $447 (Ethiopian Airways, 2014). By interpolation, the cost of an HLTA Passenger to the same place is 79$ and in terms of Rwf=79x700=55300Rwf.

iii. Waiting Time of HLTA

The transport operation of the HLTA is the same as the helicopter transport operation, with a difference in the energy used, where one uses totally aerodynamic forces and another uses a combination of aerodynamic and buoyancy forces. Hence, the value of WT of a HLTA Passenger is very small and very unpredictable. Therefore, for this research an assumption was made to take the value of WT for passenger transport of HLTA as zero. See APPENDIX C for different levels of HLTA-Passenger and HLTA-Cargo.

4.3 COMBINATION OF ATTRIBUTES' LEVELS

At this stage, the attributes' levels are combined to create a full factorial design and thereafter a fractional factorial design to make an SP questionnaire. Attributes' combining is a process whereby the first level of the first attribute is maintained while changing the values of the levels of the other attributes. Table 4-1 and Table 4-2, demonstrate a typical combination process for bus transport and air-passenger transport on all distances. In the process of determining combinations for the bus, the IVT value of 2580 min has been kept constant nine times (see nine same values on the first column of Table 4-1) while changing the next two attributes' levels. This process was reproduced for the two other levels of IVT attribute (1680 and 1080 min).

Each attribute has to appear nine times and the total full factorial design results in 27 attribute combinations. Tables of combination of attributes of other alternatives and corresponding distances are presented in APPENDIX D annexed to this report.

Table 4-1: Attributes' levels combination of bus transport mode.

BUS ATTRIBUTES' LEVELS COMBINATION								
LONG DISTANCE			MEDIUM DISTANCE			SHORT DISTANCE		
IVT (min)	W.T (Min)	T.C (Rwf/P)	IVT (Min)	W.T (Min)	T.C (Rwf/P)	IVT (Min)	W.T (Min)	T.C (Rwf/P)
2280	90	68000	720	40	18500	360	16	8400
2280	90	45000	720	40	15000	360	16	7200
2280	90	22000	720	40	11500	360	16	6000
2280	54	68000	720	25	18500	360	13	8400
2280	54	45000	720	25	15000	360	13	7200
2280	54	22000	720	25	11500	360	13	6000
2280	18	68000	720	10	18500	360	10	8400
2280	18	45000	720	10	15000	360	10	7200
2280	18	22000	720	10	11500	360	10	6000
1680	90	68000	600	40	18500	300	16	8400
1680	90	45000	600	40	15000	300	16	7200
1680	90	22000	600	40	11500	300	16	6000
1680	54	68000	600	25	18500	300	13	8400
1680	54	45000	600	25	15000	300	13	7200
1680	54	22000	600	25	11500	300	13	6000
1680	18	68000	600	10	18500	300	10	8400
1680	18	45000	600	10	15000	300	10	7200
1680	18	22000	600	10	11500	300	10	6000
1080	90	68000	480	40	18500	240	16	8400
1080	90	45000	480	40	15000	240	16	7200
1080	90	22000	480	40	11500	240	16	6000
1080	54	68000	480	25	18500	240	13	8400
1080	54	45000	480	25	15000	240	13	7200
1080	54	22000	480	25	11500	240	13	6000
1080	18	68000	480	10	18500	240	10	8400
1080	18	45000	480	10	15000	240	10	7200
1080	18	22000	480	10	11500	240	10	6000

Table 4-2: Attributes' levels combination of air-passenger transport mode.

AIR PASSENGER ATTRIBUTES' LEVELS COMBINATION								
LONG DISTANCE			MEDIUM DISTANCE			SHORT DISTANCE		
IVT (min)	W.T (Min)	T.C (Rwf/P)	IVT (Min)	W.T (Min)	T.C (Rwf/P)	IVT (Min)	W.T (Min)	T.C (Rwf/P)
128	160	244000	58	144	161000	44	150	102000
128	160	178000	58	144	140000	44	150	79000
128	160	112000	58	144	119000	44	150	56000
128	122	244000	58	122	161000	44	120	102000
128	122	178000	58	122	140000	44	120	79000
128	122	112000	58	122	119000	44	120	56000
128	84	244000	58	90	161000	44	90	102000
128	84	178000	58	90	140000	44	90	79000
128	84	112000	58	90	119000	44	90	56000
99	160	244000	48	144	161000	37	150	102000
99	160	178000	48	144	140000	37	150	79000
99	160	112000	48	144	119000	37	150	56000
99	122	244000	48	122	161000	37	120	102000
99	122	178000	48	122	140000	37	120	79000
99	122	112000	48	122	119000	37	120	56000
99	84	244000	48	90	161000	37	90	102000
99	84	178000	48	90	140000	37	90	79000
99	84	112000	48	90	119000	37	90	56000
70	160	244000	38	144	161000	30	150	102000
70	160	178000	38	144	140000	30	150	79000
70	160	112000	38	144	119000	30	150	56000
70	122	244000	38	122	161000	30	120	102000
70	122	178000	38	122	140000	30	120	79000
70	122	112000	38	122	119000	30	120	56000
70	84	244000	38	90	161000	30	90	102000
70	84	178000	38	90	140000	30	90	79000
70	84	112000	38	90	119000	30	90	56000

4.4 CHOICE GAMES DEVELOPMENT

Developing choice games for a binary system, means putting together combinations from an alternative with combinations from another alternative. By doing so, trivial combinations have been simultaneously rejected and from 27 combinations, 16 combinations were retained, and the full factorial design was hence converted into a fractional factorial design. In order to ensure orthogonality, the effort was made to make the same number of appearances of attributes. In order to elaborate on the game choice creation, Table 4-1 for bus attributes' levels combinations and Table 4-2 for air-passenger attributes' levels combinations were used to make the choice games. The resulted in Table 4-3 presents the 16 choice games with biased combinations removed. Tables of development of choice games of other alternatives and corresponding distances in binary sets are presented in questionnaires of SP in APPENDIX E.

Table 4-3 Development of choice games for air-passenger versus bus on long distance

CHOICE GAMES				
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	128	84	112000	
BUS	2280	90	22000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	128	122	112000	
BUS	2280	90	22000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	128	122	178000	
BUS	1680	90	45000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	128	84	244000	
BUS	1080	90	45000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	128	84	112000	
BUS	1080	18	22000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	99	160	178000	
BUS	2280	90	22000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	99	122	244000	
BUS	1680	54	45000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	99	122	112000	
BUS	1080	90	45000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	99	84	178000	
BUS	2280	18	22000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	99	84	112000	
BUS	1680	18	68000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	70	160	244000	
BUS	2280	54	45000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	70	160	112000	
BUS	1680	54	68000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	70	122	178000	
BUS	1080	54	68000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	70	84	244000	
BUS	2280	90	45000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	70	84	244000	
BUS	1080	18	22000	
ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	128	122	112000	
Bus	1680	90	22000	

4.5 CHOICE PREFERENCES DATA ANALYSIS BY SPSS

The data acquired from respondents' preferences on different choice sets between combinations were analysed by SPSS version 21 in terms of the regression and Binary logistical process. As discussed earlier in this report, this program provides many statistical parameters and models aspects, but the reported tables (see annexed in APPENDIX F) present the main elements used in this study. This series of tables annexed, are according to the binomial sets of modes on different distance categories mentioned in the third chapter.

Table 4-4 and Table 4-5 were taken from the series annexed; they demonstrate typical contents of the model summary and variables in the equation tables used in this research. The contents of these tables have been applied in the model's utility equation formulations (model building), and in the model's refinement and validation processes in this chapter.

Table 4-4: Model summary results of interaction of Truck and HLTA-Cargo on short route

MODEL SUMMARY			
Step	-2 Log likelihood	Cox & Snell R Square	Nagerkerke's R Square
1	2968.351[a]	0.34	0.554

The values of the elements reported in the above table are used in the refinement of the models.

Table 4-5: Variable in the equation results of interaction of Truck and HLTA-Cargo on short route

VARIABLES IN THE EQUATION							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	IVT_Min	-0.0007644	0	4.945	1	0.026	0.999
	W_Time_Min	-0.0008955	0.001	1.421	1	0.233	0.999
	TC_Rwf	0.0000167	0.0007644	59.369	1	0	1
	Constant	2.75	0.448	37.746	1	0	15.645

This Table 4-5, shows the main elements used in the analysis of this study. The B-values (including the constant, error term) presented, are the parameters' values to be used in the formulation of the models' equations. Exp (B) or Exponential (B) was used in the application chapter of this study, to predict the effect of change of V_i (or change in variables) on the choice probabilities. Then, the remaining elements, i.e.: S.E (Standard Error), Wald, df (degree of freedom), Sig. (Significance) have been used in the refinement of the models.

Negative values of parameters correctly suggest that higher TC and higher IVT, have higher negative impacts on utility magnitude. This is as shown by Šenk and Biler (1900).

4.6 MODELS' UTILITY FUNCTIONS FORMULATION

The models' utility functions expressions have been formulated using the parameters (B-values) as reported by the SPSS analysis. These parameters change according to the modes set in the binary choices as can be seen in the tables of APPENDIX F. The famous equations in literatures for choice preference demand modelling by Kim and Council Southwest Washington Regional Transportation (1997); Koppelman and Bhat (2006) and Kumar *et al.* (2004) have been discussed in the 2nd and 3rd chapters of this report and they were directly applied in this chapter to come up with the utility functions and then utility magnitudes for different alternatives as set into choice games.

These equations were formulated in such a way that "the value of the model's utility magnitude is equal to the sum of the products of the coefficient (parameters from computer programmes) of the value of the corresponding attribute and the residual term (also determined by statistical software)". Table 4-6 below, provides a list of the models' utility expressions. (See, Equations 4-2 to 4-10) as predicted.

Table 4-6: Models' utility equations.

MODES	ROUTE	UTILITY EQUATION	
Passenger Transport			
HLTA-P	Long	U= -0.00169IVT-0.0072052WT- 0.00003TC + 3.39	(4-2)
	Medium	U= -0.0037336VT-0.0476159WT- 0.0000471TC + 4.361	(4-3)
	Short	U= -0.0006028VT-0.0084804WT- 0.000006 TC+2.614	(4-4)
Air-P	Long	U= -0.0069IVT-0.001055WT-0.000045TC + 4.141	(4-5)
	Medium	U= -0.0025578 IVT-0.012276WT - 0.0000141 TC + 2.714	(4-6)
	Short	U= -0.022925 VT-0.004461WT - 0.00013 TC+ 9.361	(4-7)
Freight Transport			
HLTA-C	Long	U= -0.016271IVT-0.021211WT- 0.000001TC + 1.55	(4-8)
	Medium	U= -0.0266273 IVT-0.088296WT- 4.34×10^{-7} TC+ 6.031	(4-9)
	Short	U= -0.0008955 IVT-0.0007644WT- 0.0000167 TC+2.75	(4-10)

4.7 MODELS REFINEMENT AND VALIDATION

The re-evaluation of the utility function for the Multinomial logit model is essential, to validate the results of the parameters and to ensure the prediction's performance of the variables. In the context of this research, refinement and validation refer to critically assess the ability of the developed models to perform the intended purposes. In order to succeed in this process, a combination of statistical analysis, testing, judgment and intuition is applied. The judgement and intuition of the developer result from the theory, the anecdotal approvals, the logical analysis and the experience accumulated throughout the modelling process by the developer. In whole or in part, the experience had been accumulated through the academic courses learnt, advice from other modellers and experts in the field of transport planning, and then enhanced by review of the published papers in different conferences, modelling videos, presentations, academic documentation and other documents related to the same objective of transport demand modelling.

4.7.1 Statistical discussion

The resulted binary logistic regression mode choice models are estimated by making use of SPSS version 21.The information of how to use this computer based program, and different specifications associated with it, are available on the internet and in the series of manuals and examples in tutorials found in their help menu. The results from the analysis by SPSS are much linked to statistical processes in a sense that components of models were based on the variables' values and the statistical elements associated with the analysis. Therefore, it was found appropriate to make a statistical checkup, in order to give preliminary approval of the models. This builds a confidence in the use of the models in whichever concept that would be applied afterwards. It is in this regard that, statistical aspects of the modelling process done in this study was treated and interpreted, based on the comparison to standard values.

In this study, the goodness-of-fit measure was used to first see how good the model fits in the prediction performances. This has been done on each individual model and the comparison was done on each variable (attribute) individually.

4.7.1.1 Goodness of fit measure

Goodness of fit measure is a good indicator that provides an indication of how well the model fits in terms of prediction. In the SPSS tool, the overall goodness of fit is represented by a parameter called Nagerkerke's R-square and Cox Snell's R-square. These two statistical parameters were previously introduced from a table of "model Summary''. The value of Nagerkerke's R square is the most reported of the R-squared estimates. For statistically fit models, Nagerkerke's R square should be greater than Cox Snell's R square and it should always be greater than a value of 50%; the higher, the better.

Looking at the series of tables reported in APPENDIX F, in the model summary, it can be seen that the pseudo R square (Nagerkerke's R square) values are all greater than 0.5 or 50% and it is higher than the Cox and Snell's R-square in all interactions. This indicates a good prediction of the predictors (Attributes) to the models, i.e.: The variables involved taken together, explain more than 50% of the fitness in the model utility magnitude. However, there are 4 out of 9 models for different binary sets, which have their pseudo R-square values less than 60%, which implies that the prediction is not very strong. But the remaining 5 models have got their pseudo R-square greater than 60% which indicates a strong prediction.

The best model in terms of the goodness of fit, was found to be the model of Bus and Air passenger on the long distance with Nagerkerke's R square equal to 0.722 or 72.2%. Based on this test, a conclusion can be drawn that, taken together, the effect of the variables in the models, fit well.

4.7.1.2 Sign test

One of the most basic checkups for the results in the binary logistic regression models is to examine the signs of the estimated parameters based on theory, intuition and judgment regarding the expected impact of the corresponding variable. Checking the sign means, observing if the model's variables have a positive or negative effect on the alternative's utility magnitudes.

In the above developed models, all the variables are cost related. This means that their increase brings in a disutility to be suffered by the transport user of the mode. Hence, all the parameters associated with the variables in the utility equation should have negative signs. The negative sign also indicates that, the cost that people are willing to pay not to suffer such a disutility. The parameters estimated assigned to the attributes in all the models' equations resulted in this study have a negative sign as expected, refer to Table 4-6 and APPENDIX F. This means that the utility magnitude will always decrease due to the increase of any of the attributes used.

The sign test is more understood when taken together with the magnitude of the coefficient that it is assigned to. For example, in almost all the cases considered in this research, the magnitudes of the coefficients of the WT are greater than those of IVT, which means that a negative sign will have a very great effect on the utility magnitude due to WT than due to IVT.

The air-passenger, has normally little IVT which means that the effect of the negative parameter is low as compared to slow transport modes of Bus and Truck. However, their WT is relatively great and the product of their WT and great negative parameter associated, influences the reduction of the utility.

In this line also, the expansive modes in terms of total TC result in a reduced utility and again air-passenger loses scores in the binary competitions.

The effect of reduced utility of a mode, was very much realized in the probability it gained vis-à-vis another mode in interaction. This is because, probability reduces exponentially with a linear reduction in a utility.

The reduction in the probability implies an automatic reduction of the traffic demand volume to be assigned to a given mode.

4.7.1.3 Significance of the attributes (P-values) and Wald statistics

These are statistical elements reported in variables in the equation table. The Wald statistic and its associated P-values provide an index of the significance of each variable (predictor). The Wald statistic has got a chi-square distribution in its meaning. In order to assess it, the analyst has to look at the significance value associated (P-value). A value of significance (P-value) equal to 0.05 or 5% is used for comparison purposes. If a particular variable has a P-value greater than 0.05, the variable is said to have no significance in the model's utility equation. Looking at the snapshots of the SPSS analysis report of this study (APPENDIX F), it can be seen that IVT and TC are all significant to their models; this is so, because all P-values are less than 0.05. In the case of WT, most of the predictions are not significant, except only two cases on the long distance, for Bus and HLTA-P and truck and HLTA-C where values of 0.000 were reported.

The reason for the less significance of the WT in the sample of respondents in some of the models, can be explained in the context of the big difference that exists between the WT and IVT. For example, for Bus transport on the short route, people would rather consider the 6 hours of IVT than thinking of 13 min of WT. This is even more pronounced for the long route. Therefore, people would use IVT and TC only while the choice process, and thus the analysis, shows that WT is not significant.

For the case of models engaging HLTA-passenger, the WT was also found insignificant on 2 of the 3 cases. This might be due to an assumption that had been made previously to use zero values of WT for HLTA-P.

Literature suggests that it is better to drop independent variables from the model when, in analysis, their effect is not significant by Wald statistic, i.e. if their P-values are greater than 0.05.

4.7.2 Validation by monetary value of time comparisons

Demand models are checked for the proportion of the coefficients, and these are compared to the known values in the publications or other reliable sources of data, or also to the values taken at site on a different data survey. In this test the modeler wants to know whether the ratio between the parameters of the correct sign is in a reasonable interval of 25%-50% of the hourly wage of the population as discussed in Section 2.7.4. The ratio between travel time coefficient and that of the cost gives an estimated travel time monetary value. In the case of this research, monetary values of travel time reflect the IVT and WT monetary values. The monetary values of these two temporal attributes are compared to hourly income of the sample collected from the wages of the interviewed people in the pilot survey and the values of WTP for the case of the freight transport. The ratios of the estimated IVT and WT to the TC parameters are calculated in section 4.7.2.1 below.

The income comparison makes sense when it is applied to the travel of a passenger but it is not related to freight IVT and WT money values. That is why it was necessary to collect the willingness to pay values for the case of cargo transport so as to know the cost of cargo holding cost. This has helped to have a basis of comparison of IVT and WT money values for one container per hour and the cost that a person is willing to pay for his container not to suffer one hour WT or one hour IVT. In this chapter monetary values of IVT and WT were determined for all distance categories and for all modes of transport engaged in the choice process.

4.7.2.1 IVT and WT money values by ratio of parameters estimates

The following series of equations (see Equations 4-10 to 4-27) from Table 4-7, Table 4-8 and Table **4-9**, have yielded the money values of the non-monetary attributes, i.e. IVT and WT. The values are determined by taking the ratio of the non-monetary value coefficient to the monetary value coefficient. This was done on different routes and then separated to different modes set in the choice scenarios.

Note that, in some expressions, a value of 60 is included in order to convert the value of money from per minute (used as familiar to respondents in the survey) to per hour.

Note also that, due to the fact that in the interaction of truck and HLTA-cargo on the short route, the unit familiar to respondent was tonne instead of container. Therefore, their model included a value of 27, which is there to convert a per tonne value to a per container one.

Table 4-7: Calculation of monetary values of non-monetary attributes on long route

ROUTE	INTERACTIONS	MONEY VALUE OF VARIABLES
Long	Bus vs Air-P	$IVT = \frac{(-0.0069)}{(-0.000045)} x60 = 9200 Rwf/h$ (4-11)
		$WT = \frac{(-0.001055)}{(-0.000045)} x60 = 1407 Rwf/h$ (4-12)
	Bus vs HLTA-P	$IVT = \frac{(0.00169)}{(0.00003)} X\,60 = 3380\,Rwf/h$ (4-13)
		$WT = \frac{(0.0072052)}{(0.00003)} X\,60 = 14410\,Rwf/h$ (4-14)
	Truck vs HLTA-C	$IVT = \frac{(0.016271)}{(0.000001)} = 16272\,Rwf/Container/h$ (4-15)
		$WT = \frac{(0.021211)}{(0.000001)} = 21211\,Rwf/Container/h$ (4-16)

Table 4-8: Calculation of monetary values of non-monetary attributes on medium route

ROUTE	INTERACTIONS	MONEY VALUE OF VARIABLES
Medium	Bus vs Air-P	$IVT = \frac{(0.0025578)}{(0.0000141)} X\,60 = 10581\,Rwf/h$ (4-17)
		$WT = \frac{(0.012276)}{(0.0000141)} X\,60 = 52238\,Rwf/h$ (4-18)
	Bus vs HLTA-P	$IVT = \frac{(0.0037336)}{(0.0000471)} X\,60 = 4756\,Rwf/h$ (4-19)
		$WT = \frac{(0.0476159)}{(0.0000471)} X\,60 = 60657\,Rwf/h$ (4-20)
	Truck vs HLTA-C	$IVT = \frac{(0.0266273)}{(4.34x10^{-7})} = 61353\,Rwf/Container/h$ (4-21)
		$WT = \frac{(0.088296)}{(4.34x10^{-7})} = 203447\,Rwf/Container/h$ (4-22)

Table 4-9: Calculation of monetary values of non-monetary attributes on short route

ROUTE	INTERACTIONS	MONEY VALUE OF VARIABLES	
Short	Bus vs Air-P	$IVT = \frac{(0.022925)}{(0.00013)} X\ 60 = 10884\ Rwf/h$	(4-23)
		$WT = \frac{(0.004461)}{(0.00013)} X\ 60 = 2059\ Rwf/h$	(4-24)
	Bus vs HLTA-P	$IVT = \frac{(0.0006028)}{(0.00006)} X\ 60 = 6028\ Rwf/h$	(4-25)
		$WT = \frac{(-0.0084804)}{(-0.00006)} X\ 60 = 8480\ Rwf/h$	(4-26)
	Truck vs HLTA-C	$IVT = \frac{(-0.0008955)}{(-0.0000167)} x60x27 = 86868 Rwf/Container/h$	(4-27)
		$WT = \frac{(-0.0007644)}{(-0.0000167)} x60x27 = 74151 Rwf/Container/h$	(4-28)

4.7.3 Monetary value of time attributes by income

The income of people gives a general indication of their value of time. However, the income of the respondent is not a good indicator of travel time values for his freight. In this line, income was used for comparison of the passenger transport's IVT and WT money value only. Equation 4-28 below gives an average value of income of passengers that use two different modes in a binary set. This was preferred because it had to be compared to values from the ratios of estimates method, which in turn reflect both modes at a time i.e. bus and air-passenger and then, bus and HLTA-passenger. The average income is determined statistically by the following equation:

$$Average\_Income = \frac{\sum Mid\text{-}Pont\ x\ \ Frequency}{\sum Frequency} (Rwf\ /\ Month) \quad 4\text{-}29$$

Where:

- Mid-Point: The middle value of the respondent's choice range, e.g.: If the respondent has chosen a range of income between 1,000,000-2,000,000Rwf/month, the midpoint is taken to be 1,500,000Rwf.
- Frequency: This is the total number of respondents that have chosen a given range, e.g.: The total number of those who have chosen 1,000,000-2,000,000Rfw range.

The hourly wage was thus determined based on the monthly wage. Hourly wage is equal to monthly wage divided by 20 days of work/month (excluding weekends, holidays and leave) and 9 hours of work per day (excluding breaks and sleeping hours from 24 hours of a day).

These values were taken from the Rwanda labour law provided in the "Official Gazette of the Republic of Rwanda" published in 2009. This law states in its chapter II: "EMPLOYMENT DURATION, article 49: legal duration of work that, "In all enterprises, the legal employment's duration is forty five (45) hours per week. However, due to the specific nature of the work the weekly working hours shall be based upon the agreement between the two parties".

4.7.4 IVT and WT monetary value of freight by WTP technique

The willingness to pay study was conducted in the population, in order to assess what value it assigns to one hour of IVT and WT, for either a container or a tonne of carriage depending on the route. However, everything was brought on the basis of cargo holding cost per hour per container in order to be able to compare to the ratios of estimate. Hypothetical transfer price questions were asked to the respondent with some amount of time that is reduced to IVT and WT and then a respondent could state what he would be willing to pay in such a situation. Now, the differences between the willingness of respondents to pay for a reduction of a fixed amount of IVT and WT to the actual travel cost of the trip were calculated so as to find a value that each respondent assigns to 1hour IVT and WT for a container or tonne of freight. The analysis of data acquired from surveys includes the use of spreadsheets for processing of mathematical arithmetic operations, which leads to an average monetary value of 1h IVT and 1h WT.

For example, freight owners were asked to give their fare of WTP cost, subject to a reduction of 15 hours of the IVT for a medium distance truck out of an actual IVT of 44 hours. And in a different question they were asked to provide their fare willingness to pay cost, subject to a reduction of 10 hours on a WT out of 21 hours actual WT per one container. A particular respondent stated that he would be willing to pay up to 1575000Rwf/container (a mid-value of a range of 2001-2500$, converted in Rwf) if 15 hours are reduced out of 44 hours of IVT. Knowing the actual cost of a container transport by truck on a medium distance (1,150,000Rwf/container), the WTP per 1 hour IVT of this particular respondent would be:

$$WTP\_IVT = \frac{1{,}575{,}000 - 1{,}150{,}000}{15} = 28{,}333\,Rwf/Container - hour \qquad 4\text{-}30$$

The same respondent indicated that he would be willing to pay 1925000 Rwf/container (mid of a range of 2501-3001$), if 10 hours are reduced out of the 21 hours of WT. So, the value of 1 hour WT of a container was calculated by the following equation:

$$WTP\_WT = \frac{1{,}925{,}000 - 1{,}150{,}000}{10} = 77500\,Rwf/Container - hour \qquad (4\text{-}31)$$

The values of the hourly wage resulted from ratios of parameters estimates, income surveys for passenger and WTP surveys for freight are reported in Table 4-10 below. As it can be seen from that table, the monetary values of IVT are well within the expected range of the income of the respondents by a range of 25%-50% comparison. This indicates how good the IVT is perceived by the travelers on whom the research was conducted and can significantly predict the model's utility.

This is not the case with the WT variable. In this case, monetary values of WT do not make sense, since the ratios of parameters estimates are unrealistically much higher than the incomes and willingness to pay results, and also fluctuates a lot. This demonstrates how poor the WT variable predicts the utility of the models and thus the choice probability.

From the statistical discussion, it was also found that the WT variable has not been a good predictor of the models developed. Therefore, based on these findings of refinement and calibration, waiting time was judged to be rejected from the explanatory variables of the model. Refer to the Table 4-10 below, where R.P means Ratio of Parameter.

Table 4-10: Comparison of Ratio of parameters and average Income and Willingness To Pay.

BINARY PAIRS	**ROUTE**	**IVT BY R.P (Rwf/h)**	**WT BY R.P (Rwf/h)**	**INCOME (Rwf/h)**	
PASSENGER TRANSPORT					
Bus vs HLTA-P	Long	3380	14410	3596	
	Medium	4756	60657	7906	
	Short	6028	8480	3165	
BUS vs Air-P	Long	9200	1407	14793	
	Medium	10581	52238	11937	
	Short	10884	2059	13159	
FREIGHT TRANSPORT				**WTP**	
				IVT(Rwf/ Container-h)	**WT(Rwf/ Container-h)**
TRUCK vs HLTA-C	Long	16272	37860	21211	13800
	Medium	61353	203447	51728	39802
	Short	86869	74151	83925	48357

Rejecting the WT time from the explanatory variables, has implied going back to the analysis by SPSS, to see the interaction of IVT and TC alone. The same process has been followed as before and the parameters were determined, only parameters of the IVT and TC are reported together with other statistical elements by SPSS. The following section presents the formulation of systematic utility functions made out of two attributes, IVT and TC for validated models.

4.8 VALIDATED MODELS' EQUATIONS AND BINARY PROBABILITIES

The equations 4-31 to 4-35 reported here below have been developed using only two variables, as Waiting Time was removed in the stage of validation.

Note that only the deterministic portion of the utility function is used to determine the utility magnitude of a mode. This was done respecting the argument of Koppelman and Bhat (2006), who say that, the determination of probability values is based on the systematic utility.

$$V_{AP} = \alpha_{AP} xIVT_{AP} + \gamma_{AP} xTC_{AP} \quad \text{4-32}$$

$$V_{HLTA-P} = \alpha_{HLTA-P} xIVT_{HLTA-P} + \gamma_{HLTA-P} xTC_{HLTA-P} \quad \text{4-33}$$

$$V_{HLTA-C} = \alpha_{HLTA-C} xIVT_{HLTA-C} + \gamma_{HLTA-C} xTC_{HLTA-C} \quad \text{4-34}$$

From the model's systematic utility equations, the systematic utility magnitudes of modes of transport have been calculated using their attributes' values and the corresponding parameters, as in the following Table 4-11, Table 4-12 and table 4-13. Then in the same table binary probabilities were directly determined.

Table 4-11: Utility magnitude and probabilities of modes on long distance route

INTERACTION	UTILITY AND PROBABILITY
Bus Vs Air-P	V_{AP}=4.1+ (-0.003 x99) + (-0.000046x 178000)=-4
	Pr (AP) = $\frac{e^{-4}}{1+e^{-4}}$ =0.02 and Pr (Bus) =1-0.2=0.08
Bus and HLTA-P	V_{HLTA_P}= 3.9+(-0.00295x 336) + (-0.000034x55300) = 1.4
	Pr (HLTA-P) = $\frac{e^{1.4}}{1+e^{-1.4}}$ =0.8 and Pr (HLTA) =1-0.8 =0.2
Truck and HLTA-C	V_{HLTA-C}=1+(-0.003x5.6) + (-0.00000x6191000) =0.9
	Pr (HLTA-C) = $\frac{e^{0.9}}{1+e^{0.9}}$ =0.21 and Pr (Truck) =1-0.71 =0.29

Table 4-12: Utility magnitude and probabilities of modes on medium distance route

INTERACTION	UTILITY AND PROBABILITY
Bus Vs Air-P	V_{AP}=2.7+(-0.0025578x48)+(-0.0000241x140000)= -0.8
	Pr (AP) = $\frac{e^{-0.8}}{1+e^{-0.8}}$ =0.31 and Pr (Bus) =1-0.31=0.69
Bus and HLTA-P	V_{HLTA_P}=4.4+(-0.0047336 x 108) + (-0.0000471x 36000) = 2.2
	Pr (HLTA-P) = $\frac{e^{2.2}}{1+e^{2.2}}$ =0.9 and Pr (Bus) = 1-0.9=0.1
Truck and HLTA-C	V_{HLTA-C}=4.71+(-0.08826 x 2) + (-0.000002x 2150000) = 0.23
	Pr (HLTA-C) = $\frac{e^{0.23}}{1+e^{0.23}}$ =0.56, and Pr (Truck) = 1-0.56=0.44

Table 4-13: Utility magnitude and probabilities of modes on short distance route

INTERACTION	UTILITY AND PROBABILITY
Bus Vs Air-P	V_{AP}=9.4-0.022331 x 37 -0.00013x79000 = -1.7
	Pr (AP) = $\frac{e^{-1.7}}{1+e^{-1.7}}$ =0.15, and Pr (Bus) = 1-0.15=0.85
Bus and HLTA-P	V_{HLTA_P}= 2+(-0.007447x72) + (-0.000023x24000) = 0.5
	Pr (HLTA-P) = $\frac{e^{0.5}}{1+e^{0.5}}$ =0.62 and Pr (Bus) = 1-0.62=0.38
Truck and HLTA-C	V_{HLTA-C}= 5+(-0.006113x50) + (-0.000063x55000) = 1.2
	Pr (Tr) = $\frac{e^{1.2}}{1+e^{1.2}}$ =0.77, and Pr (HLTA-C) = 0.23

Table 4-11, Table 4-12 and Table 4-13 above, contain equations 4-36 to 4-62 that were developed after removing WT in explanatory variables. This is why the parameters of attributes used differ from the parameters of attributes of the equations 4-2 to 4-10 of the table 4-6, since these were developed before the removal of WT. When the computer program analyses the weighted effect of three variables the results reported are different from when it analyses two variables.

4.9 FINAL PROBABILITIES BY RATIOS ANALYSIS TECHNIQUE

The final probabilities are now determined, by the ratio analysis principle. This process is applied when one of the alternatives has got different values of probability in different combinations. In this research Bus was taken as a reference to make different choice scenarios for the passenger transport alternatives, where it was combined with Air-passenger and then after with HLTA-Passenger. In these two combinations Bus has got different probability values (Equations 4-56 and 4-59). So in order to harmonise its probability with the probabilities of other modes, the Ratio analysis technique was applied (See Table 4-14, Table 4-15 and Table 4-16). For the freight transport modelling nothing could change to the probability values determined above since there are only two alternatives where each has got one fixed probability value at each route.

Table 4-14: Arrangement of probabilities from binary sets to the final values on long distance

MODES	BINARY PROBABILITIES	COEFFICIENT RATIO	SHARES	FINAL PROBABILITIES (%)
Passenger Transport Modes				
Bus	0.98	1	0.98x1=0.98	$\frac{0.98}{4.92}$x100=19.9
Air-P	0.02	1	0.02x1=0.02	$\frac{0.02}{4.92}$x100=0.4
Bus	0.2	$\frac{0.98}{0.2}$	$\frac{0.98}{0.2}$x0.2=0.98	$\frac{0.98}{4.92}$x100=19.9
HLTA-P	0.8	$\frac{0.98}{0.2}$	$\frac{0.98}{0.2}$x0.8=3.92	$\frac{0.8}{4.92}$x100=79.7
Totals			4.92	100%
Freight Transport Modes				
HLTA-C	0.71	1	0.71	0.71x 100=71
Truck	0.29	1	0.29	0.29x 100=29
Totals			1	100

Table 4-15: Arrangement of probabilities from binary sets to the final values on medium distance.

MODES	BINARY PROBABILITIES	COEFFICIENT RATIO	SHARES	FINAL PROBABILITIES (%)
Passenger Transport Modes				
Bus	0.69	1	0.69x1=0.69	$\frac{0.69}{7.21}$x100=9.6
Air-P	0.31	1	0.31x1=0.31	$\frac{0.31}{7.21}$x100=4.3
Bus	0.10	$\frac{0.69}{0.1}$	$\frac{0.69}{0.1}$x0.1=0.69	$\frac{0.69}{7.21}$x100=9.6

HLTA-P	0.90	$\frac{0.69}{0.1}$	$\frac{0.69}{0.1}$x0.9=6.21	$\frac{6.21}{7.21}$x100=86.1
Totals			7.21	100%
Freight Transport Modes				
HLTA-C	0.56	1	0.56	0.56x100=56
Truck	0.44	1	0.44	0.44x100=44
Totals			1	100

Table 4-16: Arrangement of probabilities from binary sets to the final values on short distance

MODES	**BINARY PROBABILITIES**	**COEFFICIENT RATIO**	**SHARES**	**FINAL PROBABILITIES (%)**
Passenger Transport Modes				
Bus	0.85	1	0.85x1=0.85	$\frac{0.85}{2.38}$ x100=35.7
Air-P	0.15	1	0.15x1=0.15	$\frac{0.15}{3.2}$x100=6.3
Bus	0.38	$\frac{0.85}{0.38}$	$\frac{0.85}{0.38}$ x0.38=0.85	$\frac{0.85}{2.38}$ x100=35.7
HLTA-P	0.62	$\frac{0.85}{0.38}$	$\frac{0.85}{0.38}$ x0.62=1.38	$\frac{1.38}{2.38}$ x100=58
Totals			2.38	100%
Freight Transport Modes				
HLTA-C	0.77	1	0.77	0.77x100=77
Truck	0.23	1	0.23	0.23x100=23

Tables 4-14, 4-15 and 4-16, demonstrate the arrangement of probabilities from binary values to final probability values of modes. In order to explain more about what was done in these tables, an explanation is given here below. This discussion reflects the harmonisation of probabilities by ratio analysis technique on the short route (reference made to table 4-16 above) where:

Bus and Air-P interaction resulted in probabilities of Pr(Bu)=0.85 and Pr(Air-P)=0.15 4-35

Bus and HLTA-P interaction resulted in probabilities of Pr(Bu)=0.38 Pr(HLTA-P)=0.62. 4-36

Multiply the probability values of equation 4-64 by a constant ratio: $\frac{0.85}{0.38}$ (which is the ratio of values of bus in the two different interactions), the following values of shares of each modes results:

Bus and Air-P interaction resulted in probabilities of Pr(Bu)=0.85 and Pr(Air-P)=0.15. 4-37

Bus and HLTA-P with Pr(Bu)=0.38 x $\frac{0.85}{0.38}$ = 0.85 and Pr(HLTA-P)=0.62 x $\frac{0.85}{0.38}$ =1.39 4-38

(Note that when an equal amount of a constant like ($\frac{0.85}{0.38}$above) is multiplied to both values of probabilities, it changes nothing to their proportions).

At this stage the shares of modes are: Pr(Bu) = 0.85, Pr(Air-P)=0.15 and Pr(HLTA-P)=1.39 and the sum of probabilities = 0.85 + 0.15 + 1.38 = 2.38.

The final probability of each mode on this short route as in Table 4-16 is therefore the ratio of its share over the total sum of the probabilities; Pr(Bus)= $\frac{0.85}{2.38}x100 = 35.7$, Pr(Air-P)= $\frac{0.15}{2.38}x100 = 6.3\%$ and HLTA-P=$\frac{1.38}{2.38}x100 = 58\%$.

The harmonisation of Bus probabilities on other routes, i.e.: long and medium routes, has followed the same process as that explained above for the short route.

After getting the final probability values, the next task was to determine the share of transport demand of different modes. The following sections demonstrate this process.

4.10 QUANTIFICATION OF TRAFFIC DEMAND OF MODES

The knowledge about the preferences of people, makes it possible to determine probabilities of different modes and thereafter the amount of traffic reserved for each mode. This was done by simply multiplying the mode's choice preference probability by the total demand on a given route.

The available data of traffic demand on different routes was presented in the previous chapter and the values reflect the 2010 and 2013 years. Therefore, these values require to be updated to the 2014 year in order to accurately present the shares of each mode on different routes for the 2014 year (the year of the study).

4.10.1 Traffic demand projection for the year 2014

The total traffic movements are taken from different reports and publications. This work has made use of traffic count report by RTDA (2014) as demonstrated in the Table 3-1 in the third chapter of this report. In order to calculate the amount of traffic on different routes identified for analysis in this work, the 2013 traffic volumes were used and projected in 2014 using an equivalent growth rate on each route. Table 4-17 below demonstrates this process.

Table 4-17: Traffic demand volumes projection for 2014 volumes

APPLICATION OF GROWTH RATES ON DIFFERENT ROUTES FOR 2014 TRANSPORT DEMAND PROJECTION						
2014	**Distance and route**	**Traffic volume (2013)**		**Growth Rate**	**Traffic Volume (2014)**	
		Passenger (#)	Goods (Tons)		Passenger (#)	Goods (Tons)
	Long: Kigali-Mombasa, Nairobi, Dar-Es-Salaam	822710	1820985	143%	1999185	4424994
	Medium: Kigali-Kampala	1800180	3580285	119%	3942394	7840824
	Short: Kigali-Rusizi	645320	542390	203%	1955320	1643442

4.10.2 Traffic demand for alternative modes in 2014

As said previously, the probability of each mode is multiplied by the available amount of traffic on routes and therefore the demand reserved for each alternative is found. Table 4-18 below exhibits the sharing process.

Table 4-18: Traffic demand shares of alternative modes in 2014

MODE	ROUTE	PROBABILITY (%)	CARRIAGE	DEMAND (2014)	SHARES
HLTA-P	Long	79.7	Passenger (#)	1999185	1593351
	Medium	86.1		4374437	3766391
	Short	58		1568128	909514
BUS	Long	19.9		1999185	397838
	Medium	9.6		4374437	419946
	Short	35.7		1568128	559822
AIR-P	Long	0.4		1999185	7997
	Medium	4.3		4374437	188101
	Short	6.3		1568128	98792
TRUCK	Long	29	Goods (Tons)	4424994	1283248
	Medium	44		8700093	3828041
	Short	23		3810550	876427
HLTA-C	Long	71		4424994	3141745
	Medium	56		8700093	4872052
	Short	77		3810550	2934124

This fourth chapter was entirely composed of a presentation of data and the analysis process. Different data with regards to levels of attributes was presented together with its use in the main work of developing the models, refinement and validation of the models and thereafter a determination of probability and the quantification of the available traffic demand of each mode.

The following chapter five, is intended to present the results found in the fourth chapter and then gives an interpretation of these results.

Chapter 5 ESULTS PRESENTATION AND INTERPRETATION

5.1 INTRODUCTION

The object of this work was the formulation of the models for determination of transport demand shares of alternative transport modes. This has been done using the data collected in Rwanda, where, three potential routes have been considered. Among the modes considered, HLTA took part hypothetically, because it was not yet operating in the study area. Thus, the overall intention was to determine whether this mode could have room to operate in Rwanda, in terms of preferences of the transport users. The intention of this chapter is to present the results achieved and to provide interpretation of different findings, as well as to discuss the effects of the factors involved.

5.2 CHOICE PREFERENCE MODELS

The models developed in the course of this study (see Equation 5-1 to Equation 5-9 in Table 5-1 below) are of the type of binary choice preference models because they have been built using data of choice interaction between two modes at a time. Explanatory variables of the models, on the deterministic part of the equation, are respectively: IVT and TC, and their parameters keep changing depending on the characteristics of alternatives that had been set in the choice interactions. The error term, also changes accordingly. The negative signs associated with the values of the parameters of attributes of time and cost in the equations of Table 5-1 below means that all the explanatory variables are cost based. The following equations are presented according to route categories used.

Table 5-1: Choice preference models

ROUTE	INTERACTIONS	MODEL'S EQUATION	
Long	Air-P	U= -0.003IVT-0.000046TC + 4.1	(5-1)
	HLTA-P	U= -0.00295IVT- 0.000034TC + 3.9	(5-2)
	HLTA-C	U= -0.023908IVT - 0.000001TC + 2.3	(5-3)
Medium	Air-P	U= -0.0025578 IVT - 0.0000241TC + 2.714	(5-4)
	HLTA-P	U= -0.0047336 IVT-0.0000471TC + 4.361	(5-5)
	HLTA-C	U= -0.08826IVT -0.000002TC+ 4.71	(5-6)
Short	Air-P	U= -0.022331 x IVT - 0.00013TC+ 9.361	(5-7)
	HLTA-P	U= -0.007447VT - 0.000023TC+2	(5-8)
	HLTA-C	U= -0.006113IVT- 0.000063TC+5	(5-9)

5.4 ANNUAL TRAFFIC DEMAND VOLUMES OF MODES IN 2014

Results of total traffic demand suggest that HLTA-passenger comes first with predicted annual volume of 6269256 passengers equivalent to 79%, followed by Bus which is expected to carry 1377606 passengers equivalent to 17% and the last is Air-Passenger, which is expected to carry 294890 passenger equivalent to 4%. The same thing was found for the freight transport where HLTA-C is first with 10947921 tonnes per year equivalent to 65% and Truck 5987716 tonnes per year equivalent to 35%. (Refer to the Table 5-2, Figure 5-1 and Figure 5-2 below).

Table 5-2: Predicted annual traffic volumes of different modes for 2014.

Mode	Route	2014 Traffic	Total	% Share
Passenger (#)				
HLTA-P	Long	1593351	6269256	79
	Medium	3766391		
	Short	909514		
Bus	Long	397838	1377606	17
	Medium	419946		
	Short	559822		
AIR-P	Long	7997	294890	4
	Medium	188101		
	Short	98792		
Freight (Tons)				
HLTA-C	Long	3141745	10947921	65
	Medium	4872052		
	Short	2934124		
TRUCK	Long	1283248	5987716	35
	Medium	3828041		
	Short	876427		

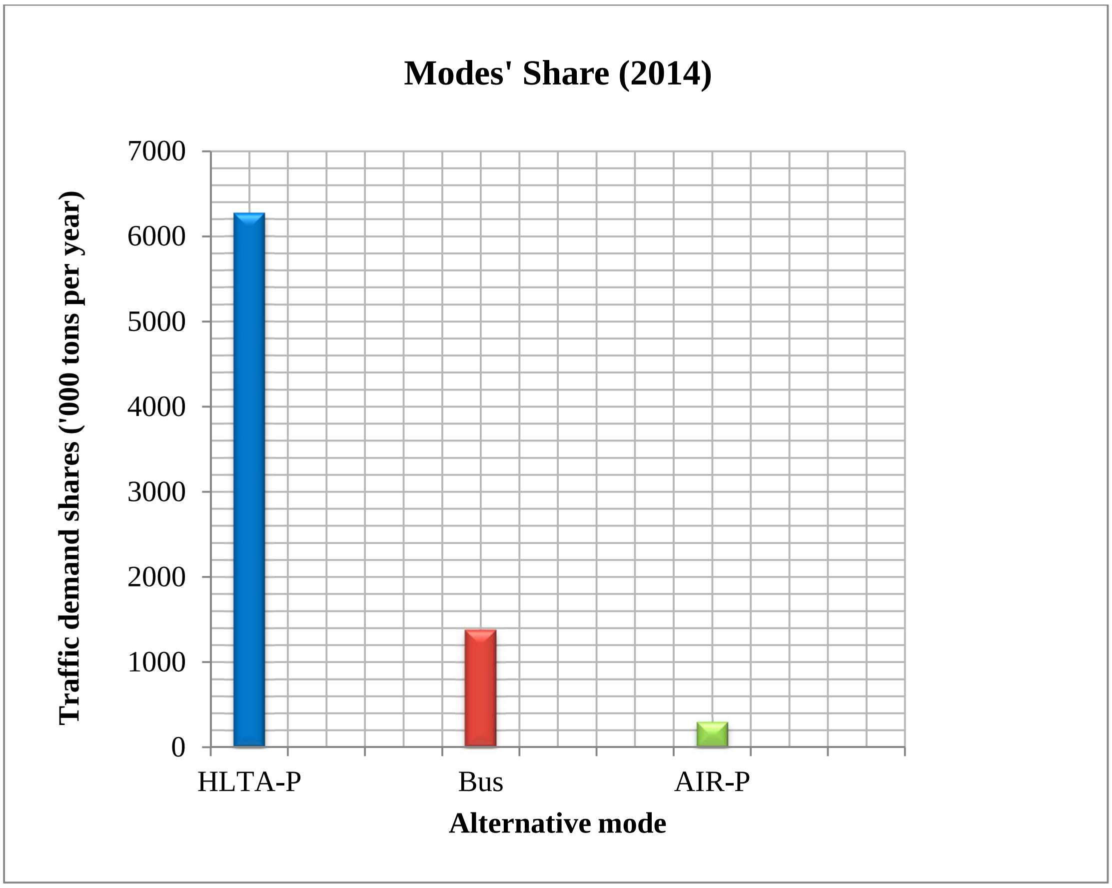


Figure 5-1: Comparison of passenger transport modes' shares in 2014

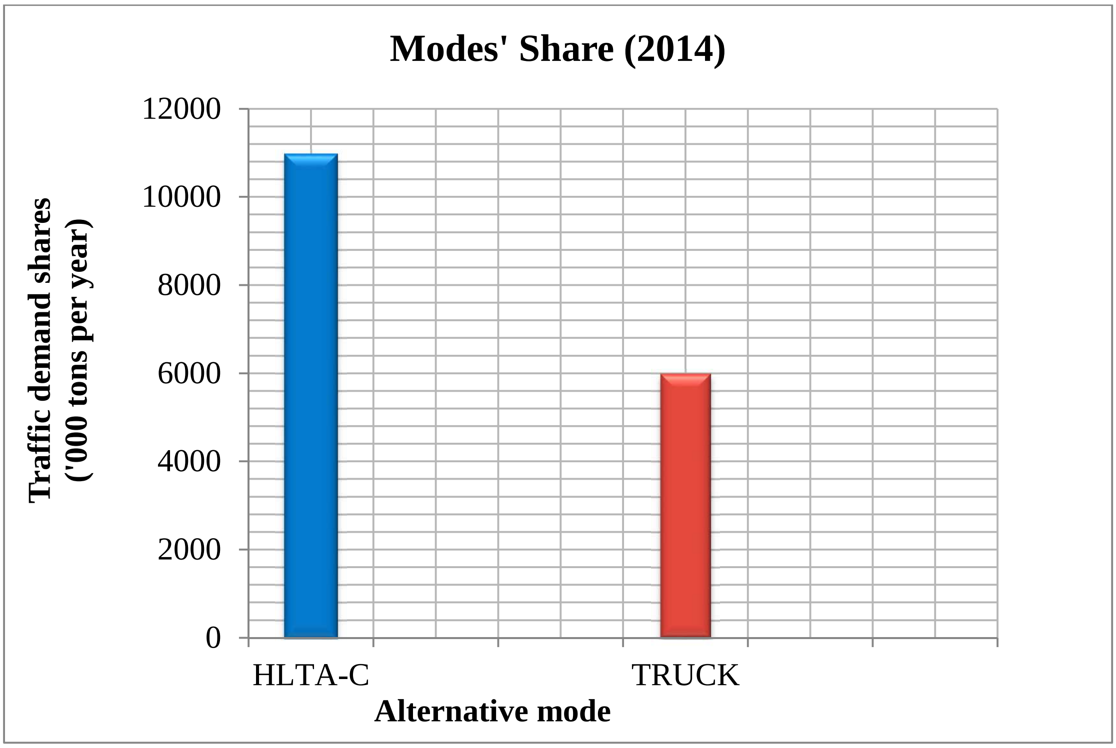


Figure 5-2: Comparison of freight modes' shares in 2014

The great tendency of people to choose HLTA in both passenger and freight travel modes is obvious, based on the values assigned to its attributes. Looking back on chapter four, in the values of attributes of different modes, HLTA-passenger has got small values (which are its inherited advantages over other transport modes, as discussed in the Chapter 2).

When compared with bus (which is the mode of reference for passenger transport), HLTA-P values for IVT are much less than the values for bus. For example HLTA-P, has a mean value of 336 minutes on the long distance against 1680 minutes of bus. When looking at the TC values, on the same long route, HLTA-P users would pay 55300 Rwf equivalent to (79$) against 45000 Rwf equivalent to 64$ for bus; this cost difference was not enough to compensate the very high difference in the IVT, thus a high choice probability from respondents. The TC of air-passenger is by far greater than that of rival modes and this is why the smaller IVT than other modes did not convince the choice decision makers.

For the case of freight transport operation, the same phenomenon applies; the difference of IVT values is even higher between HLTA-C and truck. The value of 5.6 hours of IVT for HLTA-cargo against 144 hours for Truck on a long distance was used. Even though the TC of HLTA-C (6,197,000Rwf/Container) is greater than the TC of Truck (4,550,000Rwf/container), transport users still believe that the difference in TC was not big enough to compensate for the time lost on the road.

5.5 TRAFFIC DEMAND VOLUMES OF DIFFERENT ROUTES

As can be seen from Figure 5-3 and Figure 5-4, for passengers and goods transport, heavy traffic is realised on the route of Kigali-Kampala. This can be explained in terms of many borders linking Rwanda and Uganda (most evident in Figure 1-1 showing the map of Rwanda and its borders). In addition to many sections of this medium route, there is also a significant part of traffic deviation that goes to the Northern corridor. This deviation is made by some of the articulated trucks from Mombasa port carrying two containers for two different destinations. i.e.: Kampala and Kigali. Therefore, the truck is in that case imposed to leave from Mombasa and pass through Kampala instead of passing through Dar-Es-Salaam and continues to Kigali.

In terms of traffic generation, the huge amount of passenger traffic on this medium route, is due to the historical background of the two countries that it connects (issues related to exile). A lot of people in Rwanda have got their families in Uganda and in other cases some people live in Uganda but have their families in Rwanda. This creates a lot of movement between the two countries due to socio-economic activities (which are known in transportation studies as the major factors that cause traffic generation of an area).

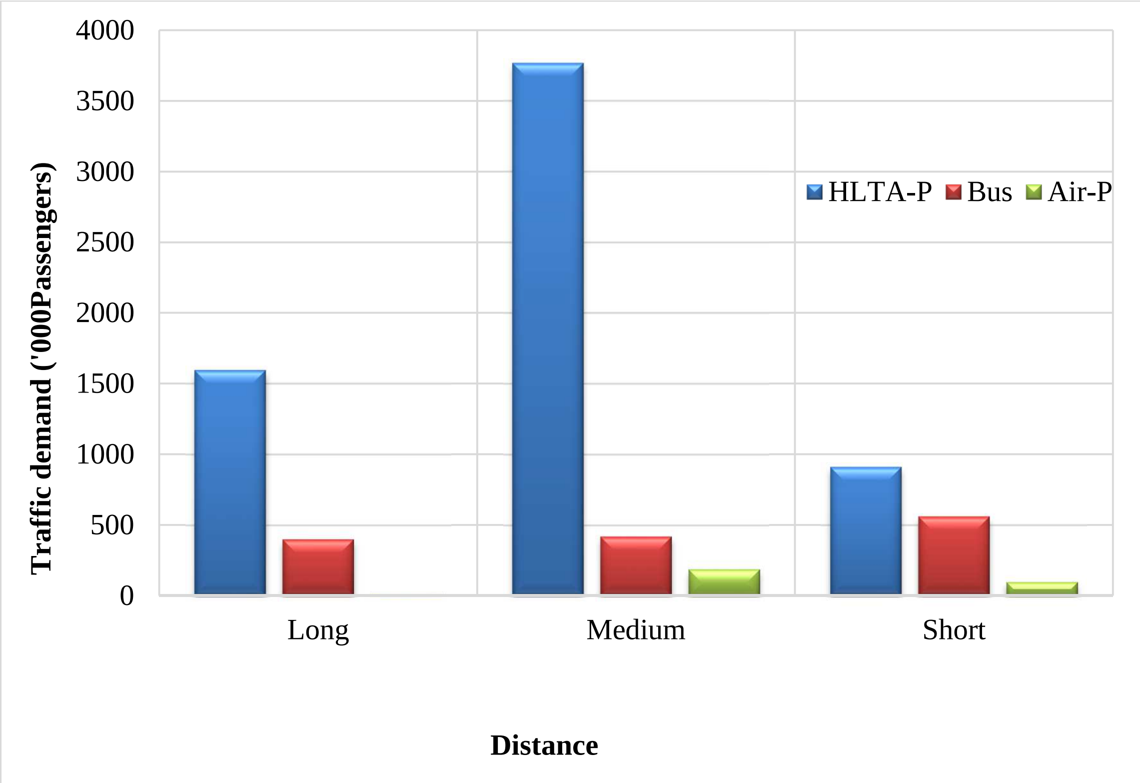


Figure 5-3: Comparison of passengers traffic demand for different routes

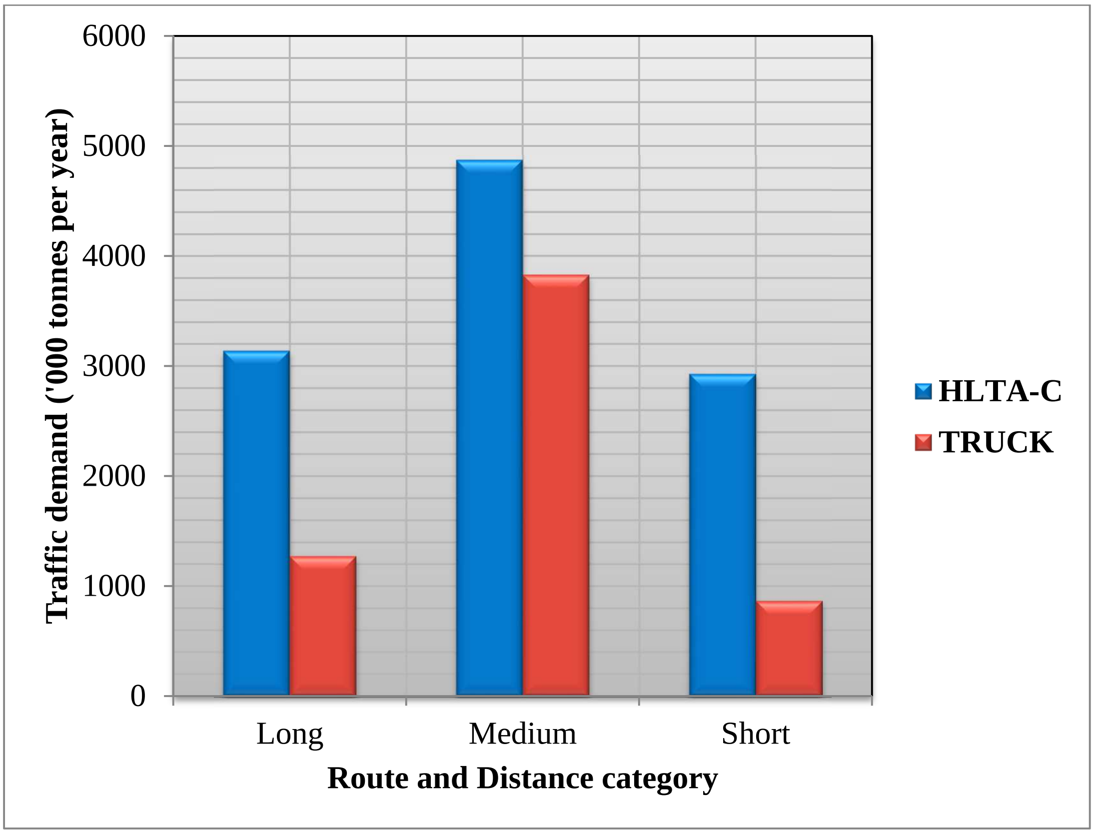


Figure 5-4: Comparison of freight traffic demand for different routes

5.7 MONEY VALUE OF TIME ATTRIBUTES

One of the most interesting outcomes from preference models, is the monetary value of non-monetary attributes (like travel time). This is possible when one of the explanatory variables is a direct money related attribute (direct cost attribute, like travel cost). In the context of this study elasticity gives the increase in the transport cost with respect to the increase in one unit of IVT time. Generally, respondents have understood the IVT time attribute and their choices have been used to predict the money value of IVT time successfully. Table 5-3 below, shows the money values of IVT time of different models that resulted in this research. The monetary value of IVT time attribute in that table, was calculated by a ratio of the parameter of the IVT time over that of TC.

Table 5-3: In Vehicle Travel Time money values for validated models.

Mode	ROUTE	UTILITY EQUATION	IVT VALUE
PASSENGER TRANSPORT			
HLTA-P	Long	U= -0.00295IVT- 0.000034TC + 3.9	5206
	Medium	U= -0.0047336IVT-0.0000471 TC + 4.361	6030
	Short	U= -0.007447IVT - 0.000023TC+2	19426
Air-P	Long	U= -0.003IVT-0.000046TC + 4.1	4043
	Medium	U= -0.0025578IVT - 0.0000241 TC + 2.714	6368
	Short	U= -0.022331IVT - 0.00013 TC+ 9.361	10307
FREIGHT TRANSPORT			**(Rwf/Container-h)**
HLTA-C	Long	U= -0.023908IVT - 0.000001TC + 2.3	23908
	Medium	U= -0.08826IVT -0.000002 TC+ 4.71	44130
	Short	U= -0.005113IVT- 0.000063 TC+5	157191

5.7.1 Effect of distance on the money value of In Vehicle Travel Time

The value assigned to time by travelers differs according to the distance and time. A general principle in transportation studies is that when a traveler has to make a long distance journey, he/she assigns little value to 1 hour Travel Time compared to when he/she makes a short journey. Figure 5-5, and Figure 5-6 explain the relationship between the money value of IVT time of a passenger and the distance made. The two cases of modes' interactions (bus and HLTA-P and bus and Air-P) demonstrated on the figures below, show that at the short distance route, the value of IVT is high and it decreases with an increase of the distance as expected. This is the same as suggested by the results of Todd (2013) that the travel demand graphics demonstrate the effect of the travel quantity consumed and the price. He added that, the higher the price, the less the quantity of the travel consumed.

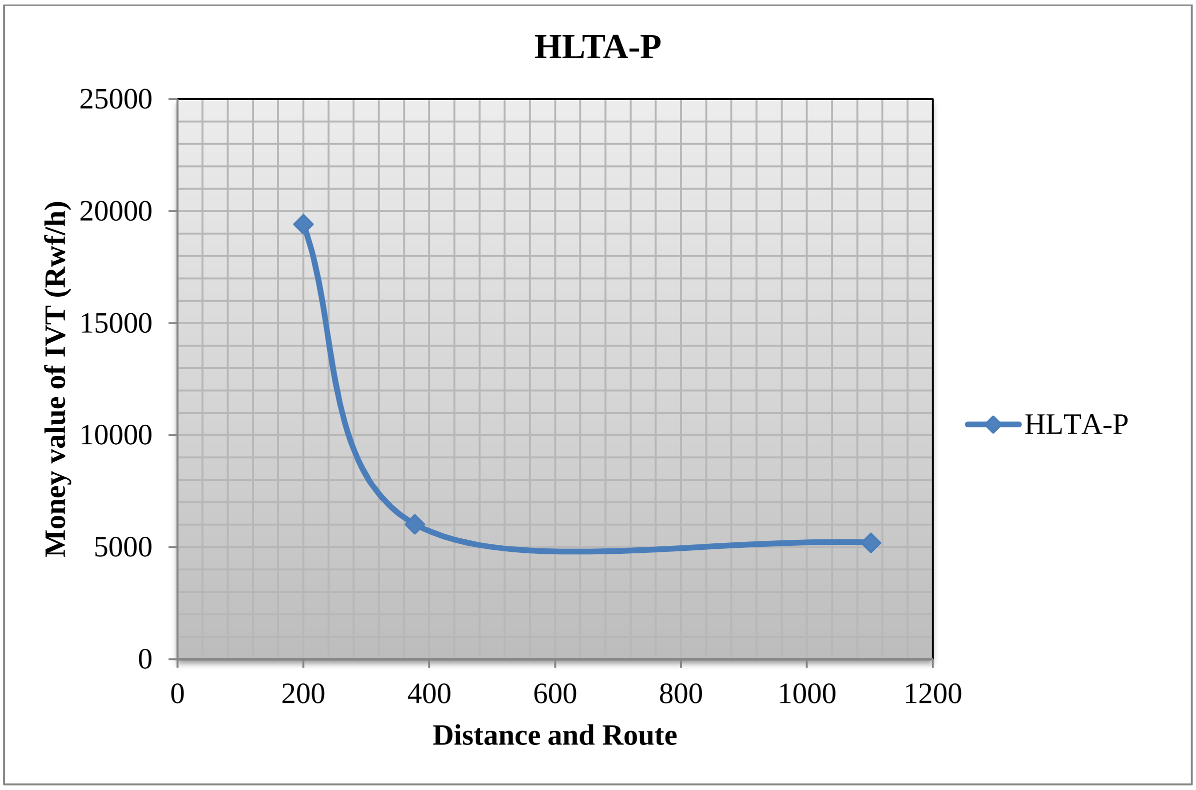


Figure 5-5: Effect of distance on monetary value of IVT time for Bus and HLTA-P

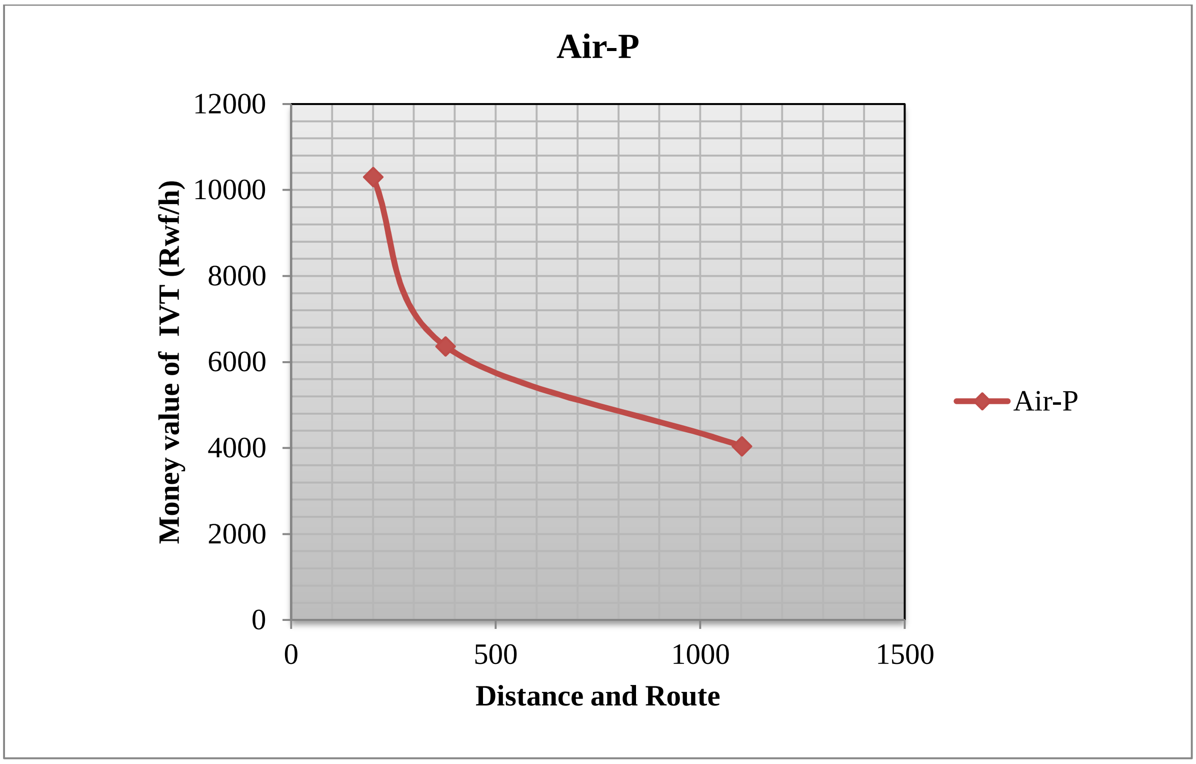


Figure 5-6: Effect of distance on monetary value of IVT time for Bus and Air-P

The relationship between cargo holding cost found as money value of 1 hour IVT for a container and the distance, has no difference, the trend is the same, i.e., whenever goods have to travel long distances, the owners assign little IVT time hourly cargo holding money value as compared to when they have to make short distances. Figure 5-7 below shows such a trend of decrease in the money value of time with distance. The longer the distance, the less the value of cargo holding cost.

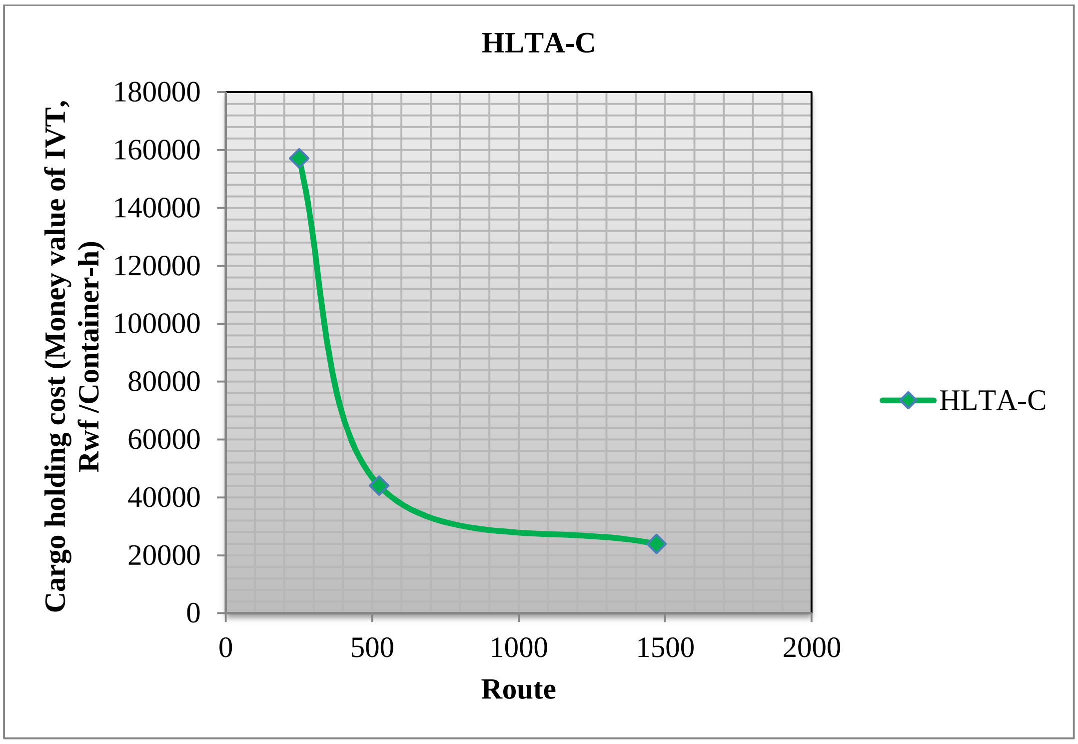


Figure 5-7: Effect of distance on cargo holding cost as money value of IVT time

Chapter 6 APPLICATION OF TRANSPORT DEMAND AND RESULTANT MODELS

6.1 INTRODUCTION

Transport demand models find their applications in the traffic management and other studies that intend to formulate transport policies. Regarding this particular study, results yielded have direct applications of determination of modes' transport demand volume shares and the project of developing HLTA in Rwanda. These include the economic viability and environmental benefit studies. Apart from these direct applications, the resulted models can also be used to predict the utility magnitudes and the related probabilities of the modes in future or in the changed circumstances.

6.2 DIRECT APPLICATIONS

6.2.1 Determination of transport modes' demand volumes

The probabilities to use both HLTA-passenger and HLTA-cargo were determined in comparison to the reference modes available in Rwanda. These results can be used, to determine the traffic demand for different modes on envisaged routes. This is simply done by multiplying the total demand on a route and the probability of a given mode. This application can be done in the same way as it has been applied in Section 4.10.2 of this report.

6.2.1.1 Economic viability

Transport demand volumes are basic data items, used to conduct economic evaluation of transport related projects. Particularly to this study, HLTA use in Rwanda has to undergo economic evaluation, to see if it is an economically viable project. In order to do so, the following two alternatives should be set and they all require the extensive use of the HLTA demand data:

i. Alternative 0: Without HLTA or Null hypothesis

With this alternative, economic evaluation would be done by taking only the existing alternative modes. The total economic cost is then calculated as a sum of economic cost using existing modes without HLTA. The intervention of the results of this study here is in the use of traffic demand shares of each mode (excluding HLTA), which in turn will be used to determine the total cost per transport mode.

ii. Alternative 1. With HLTA

With this alternative, the total costs would be calculated taking into account the involvement of HLTA as if it is an existing mode. Then the total transport cost on all the routes is determined.

The economic evaluation would then be done by different techniques such as:

- **NPV: Net Present Value**

This would be determined by subtracting the total cost of alternative 1 from the total cost found in the alternative 0, i.e.: Cost of Alternative 0 – Cost of Alternative 1. A positive value will indicate the benefit and approval of the project. But a negative sign value will indicate a loss and rejection of a project.

- **B/C: Benefit over Cost ratio**

The benefit accruing from the use of HLTA has to be divided by the cost, and a ratio should be more than 1 for approval of the project, otherwise the project is to be rejected because it is not in that case economically justified.

- **IRR: Internal Rate of Return**

This technique is based on determination of the rate at which, the total cost of using HLTA is equal to the total benefits of using HLTA. The IRR is then compared to the discount rate of the country reported by the central bank or the World Bank or other public financial institution. For the approval of the project, IRR determined when using HLTA data, should be greater than the discount rate of the country.

6.2.1.2 Environmental benefit analysis

Environmental pollution studies can be done comparing two cases where the total emissions will be calculated for the existing modes without the use of HLTA, and total emissions will be determined when all alternatives are used together with HLTA. Then a conclusion can be made whether or not HLTA project will reduce the environmental emissions or not. The intervention of the results of this current study in the environmental benefit analysis would be the use of transport demand volumes to assign to each mode when HLTA is used and when not used.

6.3 INDIRECT APPLICATIONS

6.3.1 Prediction of attributes (variables) on the models' utility

The effect of a variable to the model's utility magnitude is evaluated using the value of its parameter. The values of the parameters are reported under the "variables in the equation table" in the SPSS report. They are in the column B and are called B-values in different literatures. The regression coefficient B (parameter), predicts the amount of change occurred to the dependent variable (choice utility in the case of this study), when an independent variable (attribute) changes by a single unit.

In order to elaborate on this application, the next sections discuss typical examples on the medium route, where variables' predictions have been assessed separately on the binary model's equation of

Bus and HLTA-Passenger. In these sections the effects of IVT and TC on the model's utility are demonstrated.

6.3.1.1 Effect of IVT on utility

The increase of the IVT time has a negative effect on the magnitude of the utility of the model. When the TC attribute is kept constant, the utility magnitude continues to decrease when the IVT time increases. This is due to the fact that transport users do not want to suffer high IVT, therefore, they consider it as a disutility.

Consider the systematic portion, V of Equation 5-5, (V=4.4-0.0047336 IVT-0.0000471TC); which reflects a model of HLTA-passengers on a medium route. As it can be seen in Figure 6-1 below, each single unit increases in IVT time, (i.e. 1minute increase) corresponds to a reduction of 0.0047336 on the utility. This is the same value as the parameter of IVT time in the equation 5-5. In other words, the disutility suffered by the traveler in case he/she spends 1 minute in the vehicle, is equal to 0.0047336. So, as expected, the more the IVT time, the less the utility of the transport mode.

Figure 6-1 below also shows a point of the current magnitude of the systematic utility of the HLTA (2.2), which corresponds to the current 108 minutes HLTA-P.

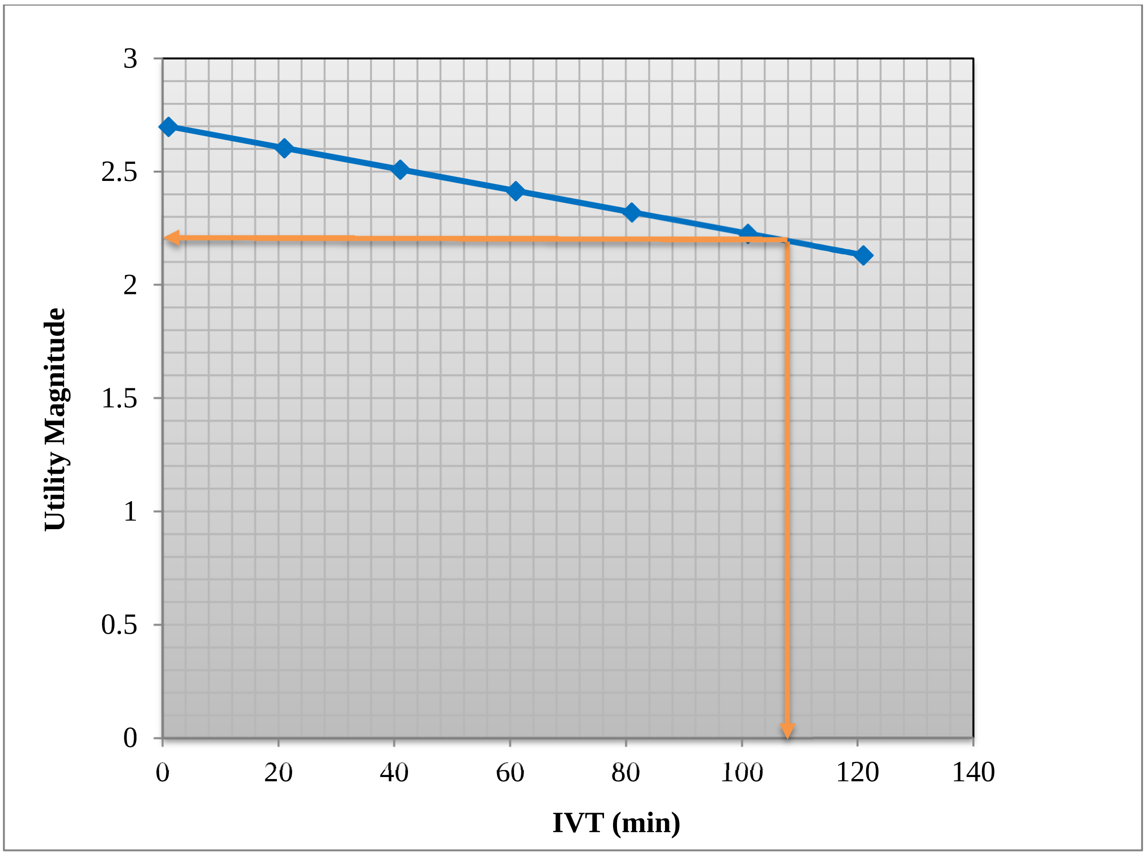


Figure 6-1: Relationship between increase of IVT and model's utility.

6.3.1.2 Effect of TC on utility

The TC effect on the model's utility magnitude is the same in nature with that of IVT. The increase of one unit of travel cost has a negative impact on the utility. This means that the magnitude of the utility goes on reducing when the cost of travel is increased by 1Rwf.

Consider the systematic portion, V of Equation 5-5, (V=4.4-0.0047336 IVT-0.0000471TC), which reflects a model resulting from the interaction of Bus and HLTA-passenger on a medium route. An increase of 1 Rwf francs in this case causes a reduction of 0.0000471, which is very little when compared to the effect of increasing 1 minute of IVT. The difference is ascribed to the fact that 1Rwf has very little value when compared to 1 minute of Travel Time. So to show how well the trend of the utility decreases, an increase of 5000Rwf of Travel Cost was used in Figure 6-2 below.

Figure 6-2 below also indicates a point on the graph corresponding to the utility magnitude of the HLTA equivalent to 2.2, corresponding to Travel Cost of 36000Rwf.

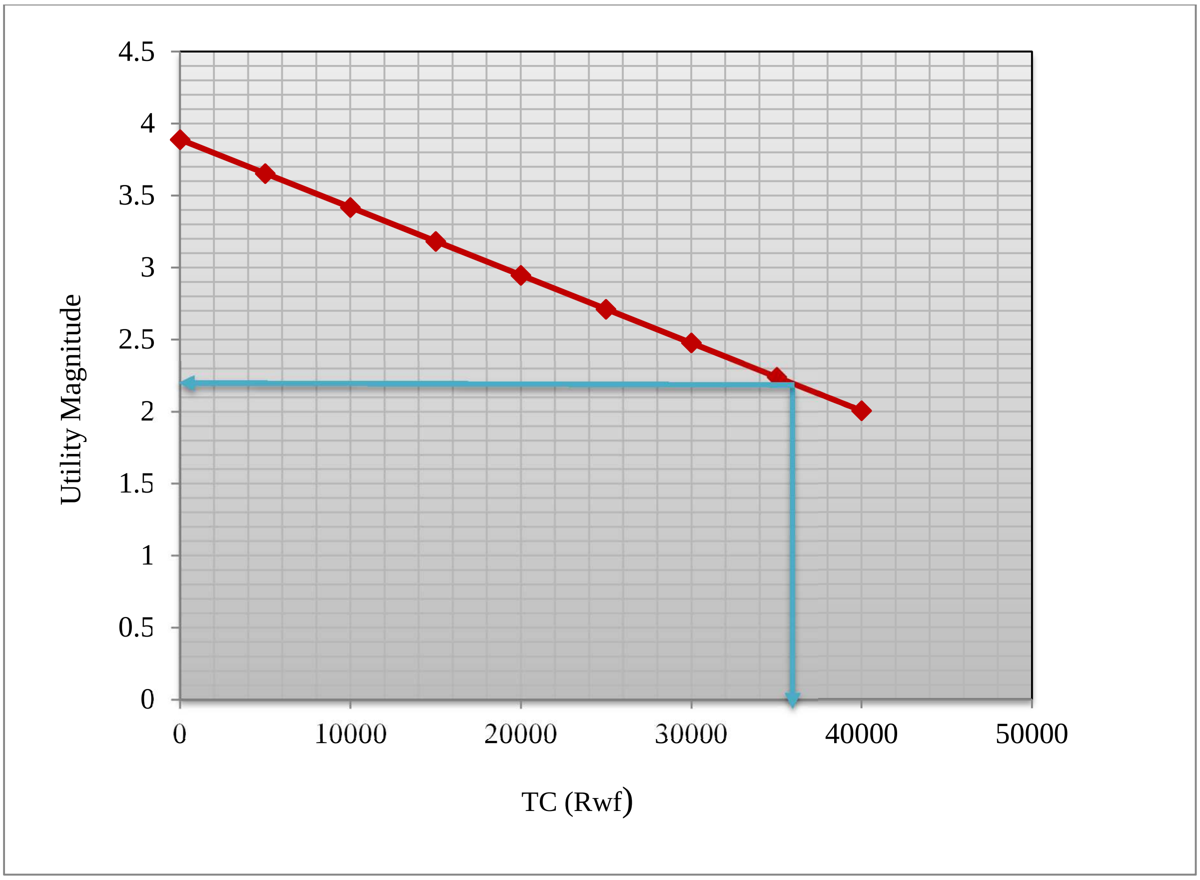


Figure 6-2: Relationship between increase of TC and model's utility

6.3.2 Prediction of probabilities of transport modes in future

The traffic shares of different modes can be determined using the resulted models' equations of this study. As it was done previously, this study has achieved the results that have been able to determine the probabilities of the modes and also the modes' shares in terms of traffic demand volumes. This was done using fixed values of the variables (actual IVT time and actual Travel Cost). But, values of variables are not constant, they can change any time due to different reasons, such as: inflation of money in the study area, fuel cost increase, in case of Travel Cost. Traffic jams and regional policies (traffic restriction in the future, e.g.: speed limits, enforcement of night/day driving for trucks, etc.) would influence IVT time. The binomial models resulted in this study have been designed in such a way that they can predict the changes that can occur in variables in the future. The next sections explain the applications of changes of variables on the choice probabilities and hence to the traffic demand volumes.

The statistical element of Exp (B) which appears in the variable in the equation table reported by SPSS is the one that applies here. It represents the extent to which raising the corresponding variables' measure by one unit influences the probability values of the mode by Exp (B). This is mathematically justified because the probabilities of Binary logistic models are determined by exponential functions. The sections below discuss this application using typical examples separately for IVT and TC variables.

6.3.2.1 Effect of change of IVT on probabilities

At this time, the model's equation of HLTA-Cargo and Truck on a medium distance should be considered (V= -0.08826IVT -0.000002TC). The corresponding probability values of HLTA-C and Truck had been determined previously to be 0.56 and 0.44 respectively. The parameter of IVT in that equation is -0.08826, which means that raising the IVT of HLTA-C by 1 hour (because the unit is in hour) corresponds to a change in choice probability of that mode by Exp (-0.0882)/1 + Exp($V_{HLTA\text{-}C}$). Thus, the gradual increase of IVT does incur an exponential change of probability as can be seen from Figure 6-3 below. This figure shows a change that occurs to the probability value that goes on decreasing exponentially due to a gradual increase of IVT.

The probability change is very sensitive to the early increase of IVT and is even more so, when it approaches the current value 0.56. Then, greater increases of IVT start to make the probability constant, and then its value asymptotically approaches a null value to 60 hours IVT (see the shape of the curve). This means that when the IVT of HLTA-C becomes 60 hours on a medium distance freight owners will shift and choose to use Truck.

In Figure 6-3 below, the current probability of HLTA-C, i.e. 0.56 is shown corresponding exactly with an IVT of 2 hours as used in the probability determination.

This application of IVT change was developed assuming that the Travel Cost of the HLTA is kept constant and all the characteristics of Truck are also kept constant.

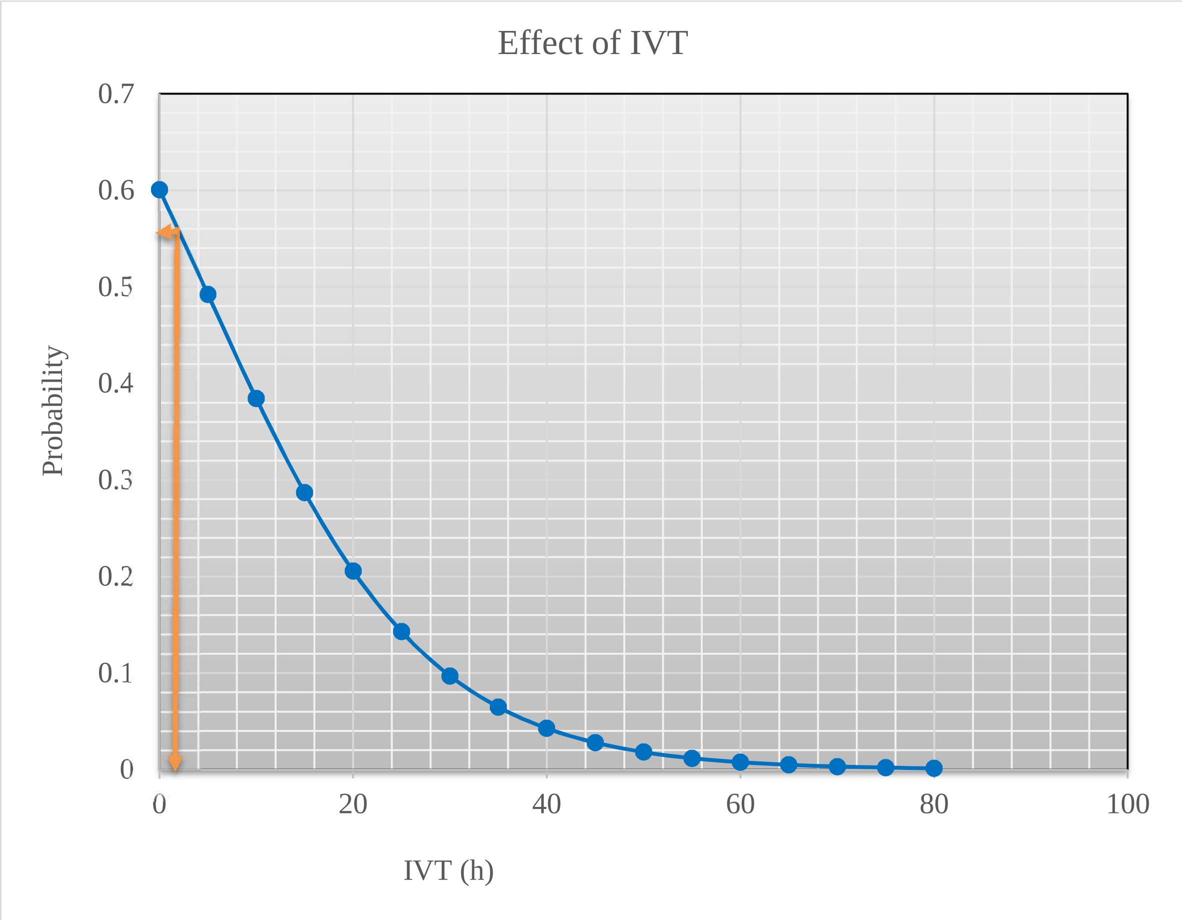


Figure 6-3: Prediction of IVT on the choice probability

6.3.2.2 Effect of change of TC on probabilities

If the same example as above is considered, the model's equation of HLTA-cargo and truck on a medium distance, the parameter of TC in that equation is -0.000002, which means that raising the IVT of any of these two modes, (i.e., HLTA-C and Truck) by 1Rwf corresponds to a change in choice probability of that mode by Exp (-0.000002)/1+ Exp ($V_{HLTA\text{-}c}$). An exponential increase in the probability can be seen in Figure 6-4 below, where the Travel Cost was increased gradually by retaining constant the IVT and all the characteristics of the HLTA-C. The choice probability becomes very sensitive to early increase of TC, and it becomes constant and ends up to be nullified at a cost of approximately 4,200,000Rwf/container, which means that at that cost transport users will consider shifting from Truck to HLTA-C.

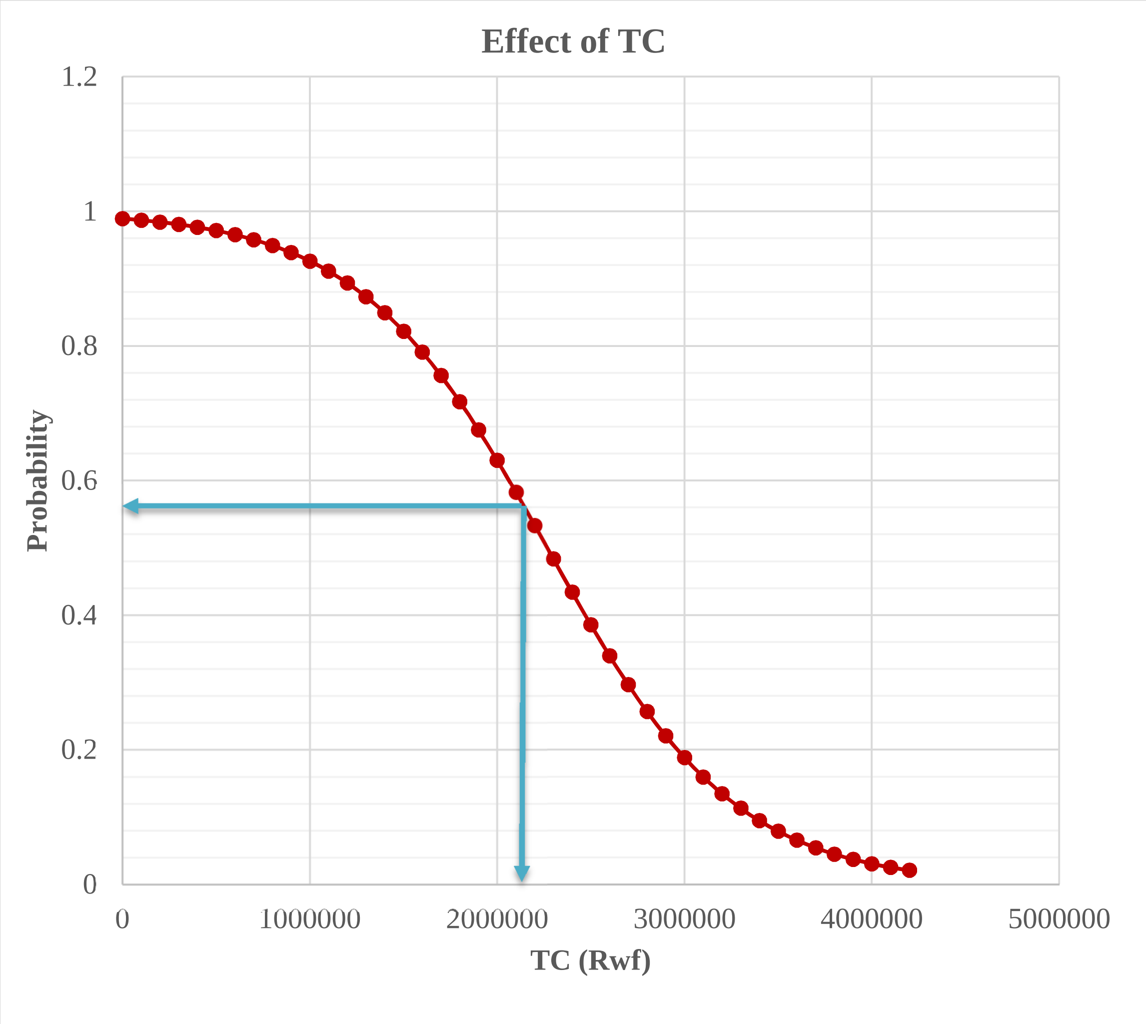


Figure 6-4: Prediction of TC on the choice probability.

It can be seen from Figure 6-3 and Figure 6-4 above that the probability of an alternative choice increases monotonically when the systematic utility increases and vice versa. This same choice probability also decreases with increases in the systematic utility of other alternatives in binary choice combinations. In addition to this, the above two figures conform to the important properties of the MNL which are:

- The Sigmoid curve (S-shape);
- The fact that the alternative's choice probability depends on the difference or change in the systematic utility (which obviously changes due to the change in variables), (Koppelman & Bhat, 2006).

Train (1993) argues that the sigmoid curve has got a point at which an increase in the related alternative's utility has the greatest impact on its choice probability. This point is at the maximum slope on the curve and it is when the related utility is equivalent to the combined utility of other alternatives in a choice set, *i.e.*, equivalent to the effect of utility of another alternative in case of binary choice. When this is verified, an increase or decrease in the utility of one alternative can induce a large increase or decrease in choice probability of the alternative being chosen.

Chapter 7 CONCLUSION AND RECOMMENDATIONS

7.1 INTRODUCTION

The objective of this study was to examine the preference of transport users towards different modes of transport engaged, through the transport demand volumes quantification. The main reason of doing this, was to know whether there is enough demand that can motivate the development of HLTA in Rwanda. The results of the analysis of SPSS data using SPSS, made it possible to develop modes choice models, and thereafter to determine the amount of transport demand volumes. From the results of this study, the following conclusions and recommendations can be derived.

7.2 CONCLUSION

The main conclusions of this research are presented here below:

7.2.1 Stated Preference in choice modelling

It was observed in this study that Stated Preference methods are very positively influential in gathering data related to preference studies. It could be very difficult to use any other method available, say Revealed Preference due to the hypothetical mode of HLTA that had to be included in the transport modes. By using the SP method, it was found that full factorial design generated 27 combinations, which were many as compared to the standard number in the literature. Therefore, it was deemed necessary to reduce the value to 16 combinations by adopting a fractional factorial design.

During data collection, HLTA had to be explained more than other modes, since it was not operational at the time of conducting this study, i.e. in the year 2014. Therefore, explanations were required, and this was done using pictures and videos.

7.2.2 SPSS in SP choice data analysis

SPSS version 21, is a strong statistical tool. It saves time of analysis and improves the process when it comes to refinement and validation of the models. The reported results of this programme contain a lot of information that can be used to develop other relevant researches.

7.2.3 Variables on model’s prediction

During the refinement and validation, the Waiting Time variable was found not to be an appropriate predictor of the models and judged to be rejected from explanatory variables. This, on one hand is due to a small magnitude that this variable has as compared to the IVT time (like in case of Bus and Truck) and on the other hand, it was due to a neglected value that WT of HLTA had and which was taken to be 0 min.

After refinement and validation, variables demonstrated a trustworthy relationship to the models that they built.

7.2.4 Models' refinement and validation

Refinement and validation are very useful techniques that all studies that involve modelling should undergo. If this step is omitted in the modelling, there is a chance of keeping insignificant variables in the models and hence inaccuracy in terms of the overall model's prediction.

7.2.5 Monetary value of In Vehicle Travel time

The monetary values of IVT time were evaluated for different models and were found reasonable as compared to the standard of 25%-50% found in the literature. In all the cases considered, the IVT money value was found to be greater for short route and kept reducing with the increase of the route's distance. This justifies the effect of distance on the money value of non-monetary attributes.

7.2.6 Results of preference probability and transport demand of transport modes

Travel Time and Travel Cost are disutility variables, and a mode with less magnitude of such variables would result in higher preference than others. HLTA had had a less combination effect of values of IVT and TC than all other modes, thus high preferences. Thus Hybrid Lighter Than Air transport was the most preferred of all other modes in the choice comparison. HLTA had had high probability values; (79.7%, 86.1%, and 58% for HLTA-passenger, on long, medium and short route respectively), followed by bus (19.9%, 9.6% and 35.7%) and lastly air-passenger (0.4%, 4.3%, and 6.3%). For the freight transport (71%, 56% and 77% for HLTA-cargo on long, medium and short route respectively) against truck with (29%, 44% and 23%).

Finally, a transport mode that has strong preferences in the transport users would also result in higher traffic demand volume, since the latter is directly proportional to the former. With strong preferences, HLTA comes first again with a high quantified traffic demand. On the three routes considered, HLTA-passenger is expected to carry 6269256 passenger per year in totality, against the second mode, bus with a yearly volume of 1377606 passengers and air-passenger 294890 passengers per year. The freight transport shares resulted in HLTA-cargo getting a yearly demand of 10947921 tonnes against truck with a total demand of 5987716 tonnes.

Thus, the following recommendations were derived from the results of this study:

7.3 RECOMMENDATIONS

The recommendations presented here below, concern different professionals related to this study in one way or another:

1. The HLTA has strong preferences in the transport users in Rwanda, based on the results of the data from users of the routes of Kigali to Mombasa, Dar-Es-Salaam, Nairobi, Kampala and Rusizi. Therefore,

   - Further research should conduct an analysis of the economic viability of the use of HLTA in Rwanda to see if it is an option that is economically viable as well.
   - Environmental benefit analysis should be carried out on the HLTA operations, to find if HLTA can help in the reduction of pollution accruing from transport operations in Rwanda.
   - Moreover, studies should be undertaken on relatively short length trips by HLTA, as it is believed to enable point to point movements. e.g.: trips to or from: shops, works, leisure, school, etc.

2. While conducting interviews in the studies engaging SP surveys, the researcher should have supporting visual information when some of the alternatives are to be introduced in the environment.

3. Further research is recommended to consider the nature and value of the freight transported and relate it to preferences of HLTA, for example transport of perishable goods and oil.

4. International consideration should be given to HLTA as a preferred alternative in transport related operations and developing countries, most especially those that are landlocked, should think of appraising the use of HLTA in their transport activities.

5. HAV Ltd and other companies that manufacture HLTA vehicles are recommended to emphasise the production of heavy lift transport vehicles, because they show considerable preferences in transport users.

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APPENDICES

APPENDIX A: PRELIMINARY SURVEY QUESTIONNAIRE

CHOICE OF INFLUENTIAL ATTRIBUTES

Date.../.../2014

Dear Respondent, My name is.......

This survey is intended to capture information and suggestions approximately the transport industry in Rwanda. It was designed for academic purposes only and has nothing to do with business; therefore filling it, is voluntarily. It is a pleasure for us having you taking part of this interesting work. May God bless you.

Your privacy and secrecy will be secured by the researcher.

1. **What is your origin and Destination?**

- Kigali-Rusizi ☐
- Rusizi-Kigali ☐
- Kigali-Kampala ☐
- Kampala-Kigali ☐
- Kigali-Dar-Es-Salaam ☐
- Dar-Es-Salaam-Kigali ☐
- Kigali-Mombasa ☐
- Mombasa-Kigali ☐
- Kigali-Nairobi ☐
- Nairobi-Kigali ☐

2. Indicate by (V), the important attributes that you use to choose the mode of transport on such a trip.

- Service Frequency ☐
- Travel Cost ☐
- Waiting Time ☐
- Reliability ☐

- Safety ☐
- In Vehicle Travel time ☐
- Security ☐
- Comfort ☐
- Other………………………………..

APPENDIX B: FIRST PHASE SURVEY QUESTIONNAIRES

B-1: LONG DISTANCE SURVEY, AIR-PASSENGER   Date.../.../2014

Dear Respondent, My name is.....

This survey intends to capture information and suggestions approximately the transport industry in Rwanda. It was designed for academic purposes only and has nothing to do with business; therefore filling it, is voluntarily. This research is conducted in order to develop a transport demand model for HLTA and see the preference of transport users approximately this new mode as compared to the existing ones. It is a pleasure for us having you taking part of this interesting work. May God bless you.

Your privacy and secrecy will be secured by the researcher.

Description of Terms:

Waiting time: Waiting time is the time you spend waiting for Air Vehicle to take off and start your trip.

In Vehicle time: In Vehicle time is the time you use from when you get in the Air Vehicle up to leaving it.

Travel Cost: All the monetary cost expensed to accomplish the trip: (out of pocket money, Fare, Refreshments...)

Tick according to your opinion.

1. **What is your origin and Destination?**
   - Kigali-Dar-Es-Salaam ☐
   - Dar-Es-Salaam-Kigali ☐
   - Kigali-Mombasa ☐
   - Mombasa-Kigali ☐
   - Kigali-Nairobi ☐
   - Nairobi-Kigali ☐
2. **What is your trip purpose?**
   - Business/Work ☐

- Commuting ☐
- Leisure ☐
- Schooling ☐
- Other............................

3. What is your travel time for one trip (IVT)

- Between 30-1h ☐
- Between 1-1:30h ☐
- Between 1:30-2h ☐
- Between 2-2h30h ☐
- Between 2h30-3h ☐

4. How much time do you wait to start the trip (checking time...)?

- Between 30-1h ☐
- Between 1-1:30h ☐
- Between 1:30-2h ☐
- Between 2-2h30h ☐
- Between 2h30-3h ☐
- Between 3-3h30 ☐

5. What is the average fare cost of your trip (Single ride)?

- 100-150$ ☐
- 151-200$ ☐
- 200-250$ ☐
- 251-300$ ☐

- 301-350$ ☐
- 351-400$ ☐

6. Suppose that you are currently using another mode of transport that can reduce 30min on your trip IVT. How much fare cost would you be willing to pay to reach your destination?

- 100-150$ ☐
- 151-200$ ☐
- 200-250$ ☐
- 251-300$ ☐
- 301-350$ ☐
- 351-400$ ☐
- 401-450$ ☐

7. Suppose that you are currently using another mode of transport that can reduce 1h on your trip waiting Time. How much fare cost would you be willing to pay to reach your destination?

- 100-150$ ☐
- 151-200$ ☐
- 200-250$ ☐
- 251-300$ ☐
- 301-350$ ☐
- 351-400$ ☐
- 401-450$ ☐

8. How much is the other cost incurred in your trip?

- 1-10$ ☐

- 11-20$ ☐
- 21-30$ ☐
- 31-40$ ☐
- 41-50$ ☐
- Other....................

8. How many times do you execute such a trip per year?

- Between 1-2 ☐
- Between 2-4 ☐
- Between 5-7 ☐
- Between 8-10 ☐
- Between 11-13 ☐
- Between 14-16 ☐
- Between 16-18 ☐
- Between 18-20 ☐
- Other……………………….

10. How much is your monthly income?

- Less than 500,000Rwf ☐
- 500,001Rwf – 1,000,000Rwf ☐
- 1,000,001Rwf – 2,000,000Rwf ☐
- 2,000,001Rwf – 3,000,000Rwf ☐
- 3,000,000Rwf – 4,000,000Rwf ☐
- 4,000,001Rwf – 5,000,000Rwf ☐
- 5,000,001Rwf – 10,000,000Rwf ☐

- 10,000,001Rwf -50,000,000Rwf ☐
- More than 50,000,000 Rwf ☐

B-2: LONG DISTANCE SURVEY, BUS **Date.../.../2014**

Dear Respondent, My name is.....

This survey intends to capture information and suggestions approximately the transport industry in Rwanda. It was designed for academic purposes only and has nothing to do with business; therefore filling it, is voluntarily. This research is conducted in order to develop a transport demand model for HLTA and see the preference of transport users approximately this new mode as compared to the existing ones. It is a pleasure for us having you taking part of this interesting work. May God bless you.

Your privacy and secrecy will be secured by the researcher.

Description of Terms:

Waiting time: Waiting time is the time you spend by waiting for Bus for you trip to start.

In Vehicle time: In Vehicle time is the time you use from when you get in the Vehicle up to leaving it.

Travel Cost: All the monetary cost expensed to accomplish the trip: (out of pocket money)

Tick according to your opinion.

1. **What is your origin and Destination?**
    - Kigali-Dar-Es-Salaam ☐
    - Dar-Es-Salaam-Kigali ☐
    - Kigali-Mombasa ☐
    - Mombasa-Kigali ☐
    - Kigali-Nairobi ☐
    - Nairobi-Kigali ☐
2. **What is your trip purpose?**
    - Business/Work ☐

- Commuting ☐
- Leisure ☐
- Schooling ☐
- Other………………………………..

3. What is your average Single trip Distance?

- Between 500-700Km ☐
- Between 701-900km ☐
- Between 901-1100Km ☐
- Between 1101-1300Km ☐
- Between 1301-1500Km ☐
- Between 1501-1700Km ☐
- Between 1701-2000Km ☐

4. What is your travel time for one trip (In Vehicle Travel Time)

- Between 5-10h ☐
- Between 11-15h ☐
- Between 16-20h ☐
- Between 20h-25h ☐
- Between 26-30h ☐
- Between 31-40h ☐
- Between 41-45h ☐

5. How much Time do you lose in the Borders and Check points?

- Between 30min-1h ☐
- Between 1h-1h30min ☐

- Between 1h30-2h ☐
- Between 2h-3h ☐

6. How much time do you wait to start the trip?

- Between 10min-30min ☐
- Between 31min-50min ☐
- Between 51min-70min ☐
- Between 71min-90min ☐
- Between 1h30min-2h ☐

7. What is the fare cost of your trip?

- 10,001-15,000Rwf ☐
- 15,001 -25,000Rwf ☐
- 25,001-35,000Rwf ☐
- 35,001- 45,000Rwf ☐
- 45001-50000Rwf ☐
- 50001-55000Rwf ☐
- 55001-60000Rwf ☐
- 60001-65000Rwf ☐
- 65001-70000Rwf ☐
- 70001-75000Rwf ☐
- 75001-80000Rwf ☐

8. Suppose that you are currently using a mode of transport that can reduce 5h on your trip IVT. How much money would you be willing to pay to reach your destination?

- 5,000-10,000Rwf ☐
- 10,001-15,000Rwf ☐
- 15,001 -25,000frw ☐
- 25,001-35,000frw ☐
- 35,001- 45,000frw ☐
- 45001-50000frw ☐
- 55000-60,000Rwf ☐

9. Suppose that you are currently using a mode of transport that can reduce 30min on your waiting time. How much money would you be willing to pay to reach your destination?

- 5,000-10,000Rwf ☐
- 10,001-15,000Rwf ☐
- 15,001 -25,000frw ☐
- 25,001-35,000frw ☐
- 35,001- 45,000frw ☐
- 45001-50000frw ☐
- 55000-60,000Rwf ☐

10. How much is the other cost incurred in your trip?

- 0-1,000Rwf ☐
- 1001-5000Rwf ☐
- 5,001-10,000Rwf ☐

- 1,001-15,000Rwf ☐
- 15,001-20,000Rwf ☐

11. How many times do you execute such a trip per year?

- Between 1-2 ☐
- Between 2-4 ☐
- Between 5-7 ☐
- Between 8-10 ☐
- Between 11-13 ☐
- Between 14-16 ☐
- Between 16-18 ☐
- Between 18-20 ☐
- Other……………………….

12. How much is your monthly income

- Less than 100,000Rwf ☐
- 100,001Rwf – 200.000Rwf ☐
- 200,001Rwf – 300,000Rwf ☐
- 300,001Rwf – 400,000Rwf ☐
- 400,000Rwf – 500,000Rwf ☐
- 500,001Rwf – 600,000Rwf ☐
- 600,001Rwf – 700,000Rwf ☐
- 700,001Rwf – 800,000Rwf ☐
- 800,001Rwf – 900,000Rwf ☐
- 900,001Rwf – 1,000,000Rwf ☐

- More than 1,000,000Rwf ☐

B-3: LONG DISTANCE SURVEY, TRUCK **Date.../.../2014**

Dear Respondent, My name is.....

This survey intends to capture information and suggestions approximately the transport industry in Rwanda. It was designed for academic purposes only and has nothing to do with business; therefore filling it, is voluntarily. This research is conducted in order to develop a transport demand model for HLTA and see the preference of transport users approximately this new mode as compared to the existing ones. It is a pleasure for us having you taking part of this interesting work. May God bless you.

Your privacy and secrecy will be secured by the researcher.

Description of Terms:

Waiting time: Waiting time is the time you spend by waiting for the truck to start the trip carrying goods.

In Vehicle time: In Vehicle time is the time you use from when you get in the Vehicle up to leaving it.

Travel Cost: All the monetary cost expensed to accomplish the trip: (out of pocket money)

Tick according to your opinion.

1. **What is your origin and Destination?**
   - Kigali-Dar-Es-Salaam ☐
   - Dar-Es-Salaam-Kigali ☐
   - Kigali-Mombasa ☐
   - Mombasa-Kigali ☐
   - Kigali-Nairobi ☐
   - Nairobi-Kigali ☐
2. **What is your trip purpose?**
   - Business/Work ☐
   - Other ☐

3. What is your average Single trip Distance?

- Between 500-700Km ☐
- Between 701-900km ☐
- Between 901-1100Km ☐
- Between 1101-1300Km ☐
- Between 1301-1500Km ☐
- Between 1501-1700Km ☐
- Between 1701-2000Km ☐

4. What is your travel time for one trip (IVT)

- Between 2-3 days ☐
- Between 3-4 days ☐
- Between 4-5 days ☐
- Between 6-7days ☐
- Between 7-10days ☐
- More than 10days ☐

5. How much Time do you lose in the Borders, Weighbridges and Check points?

- Between 1-2 days ☐
- Between 3-4 days ☐
- Between 4-5 days ☐
- Between 6-7days ☐
- Between 7-10days ☐
- More than 10days ☐

6. How much time do you wait to get ready to start the trip?

- Between 1-2 days
- Between 2-3 days
- Between 3-4 days
- Between 4-5 days
- Between 6-7days
- Between 7-10days
- More than 10days

7. **How much time do you spend not moving due to traffic regulation (The Trip having had started)**

- Between 1-2 days
- Between 3-4 days
- Between 4-5 days
- Between 6-7days
- Between 7-10days
- More than 10days

8. What is the main product carried:

- Construction Materials
- Agricultural Products
- Mining products
- Chemical products
- Electronic devices
- Other……………………………..

9. What is the cost per 40 ft ISO container of the main goods to your destination?

- 3000-4000$ ☐
- 4001-5000$ ☐
- 5001-6000$ ☐
- 6001-7000$ ☐
- 7001-8000$ ☐
- 8001-9000$ ☐
- 9001-10000$ ☐

10. Suppose that you are currently using a mode of transport that can reduce 3days on your trip IVT. How much money would you be willing to pay per 40 ft ISO container to your destination?

- 3,000-4,000$ ☐
- 4,001-5,000$ ☐
- 5,001-6,000$ ☐
- 6,001-7,000$ ☐
- 7,001-8,000$ ☐
- 8,001-1,0000$ ☐
- 10,000-12,000$ ☐
- 12,000-14,000$ ☐

11. Suppose that you are currently using a mode of transport that can reduce 2days on your waiting time. How much money would you be willing to pay per 40 ft ISO container to your destination?

- 3,000-4,000$ ☐
- 4,001-5,000$ ☐

- 5,001-6,000$
- 6,001-7,000$
- 7,001-8,000$
- 8,001-1,0000$
- 10,000-12,000$
- 12,000-14,000$

12. How much is the other cost incurred in your trip?

- 1-10$
- 11-20$
- 21-30$
- 31-40$
- 41-50$
- Other...

13. How many tonnes do you manage to carry per year?

- Between 0-10
- Between 11-20
- Between 21-30
- Between 31-40
- Between 41-50
- Between 51-70
- Between 71-90
- Between 91-110
- Between 111-130

- Between 131-150 ☐
- Between 151-170 ☐
- Between 171-190 ☐
- Other…………………………..

14. How much is your monthly income?

- Less than 500,000Rwf ☐
- 500,001Rwf – 1,000,000Rwf ☐
- 1,000,001Rwf – 2,000,000Rwf ☐
- 2,000,001Rwf – 3,000,000Rwf ☐
- 3,000,001Rwf – 4,000,000Rwf ☐
- 4,000,001Rwf – 5,000,000Rwf ☐
- 5,000,001Rwf – 10,000,000Rwf ☐
- Between 10,000,000-50,000,000Rwf ☐
- More than 50,000,000 Rwf ☐

B-4: MEDIUM DISTANCE SURVEY, AIR-PASSENGER **Date.../.../2014**

Dear Respondent, My name is.....

This survey is intended to capture information and suggestions approximately the transport industry in Rwanda. It was designed for academic purposes only and has nothing to do with business; therefore filling it, is voluntarily. This research is conducted in order to develop a transport demand model for HLTA and see the preference of transport users approximately this new mode as compared to the existing ones. It is a pleasure for us having you taking part of this interesting work. May God bless you.

Your privacy and secrecy will be secured by the researcher.

Description of Terms:

Waiting time: Waiting time is the time you spend waiting for Air Vehicle to take off and start your trip.

In Vehicle time: In Vehicle time is the time you use from when you get in the Vehicle up to leaving it.

Travel Cost: All the monetary cost expensed to accomplish the trip: (out of pocket money)

Tick according to your opinion.

1. **What is your origin and Destination?**
    - Kigali-Kampala ☐
    - Kampala-Kigali ☐
2. **What is your trip purpose?**
    - Business/Work ☐
    - Commuting ☐
    - Leisure ☐
    - Schooling ☐
    - Other..
3. **What is the travel time for one trip (IVT)**
    - Between 31-35min ☐
    - Between 36:40min ☐
    - Between 41-45min ☐
    - Between 46-50min ☐
    - Between 51-55min ☐
    - Between 56-60min ☐
4. **How much time do you wait to start the trip (e.g.: checking time...)?**
    - Between 30-1h ☐
    - Between 1-1:30min ☐

- Between 1:30-2h ☐
- Between 2-2h30min ☐
- Between 2h30-3h ☐

5. What is the average fare cost of your trip?

- 101-150$ ☐
- 151-200$ ☐
- 200-250$ ☐
- 251-300$ ☐
- 301-350$ ☐

6. Suppose that you are currently using a mode of transport that can reduce 20min on your trip IVT. How much money would you be willing to pay to reach your destination?

- 50-100$ ☐
- 101-150$ ☐
- 151-200$ ☐
- 200-250$ ☐
- 251-300$ ☐
- 301-350$ ☐
- 351-400$ ☐
- 401-450$ ☐

7. Suppose that you are currently using another mode of transport that can reduce 1h on your waiting time. How much money would you be willing to pay to reach your destination?

- 50-100$ ☐
- 101-150$ ☐

- 151-200$
- 200-250$
- 251-300$
- 301-350$
- 351-400$
- 401-450$

8. How much is the other cost incurred in your trip?

- 1-10$
- 11-20$
- 21-30$
- 31-40$
- 41-50$
- Other...

9. How many times do you execute such a trip per year?

- Between 1-2
- Between 2-4
- Between 5-7
- Between 8-10
- Between 11-13
- Between 14-16
- Between 16-18
- Between 18-20
- Other……………………….

10. How much is your monthly income?

- Less than 500,000Rwf ☐
- 500,001Rwf – 1,000,000Rwf ☐
- 1,000,001Rwf – 2,000,000Rwf ☐
- 2,000,001Rwf – 3,000,000Rwf ☐
- 3,000,000Rwf – 4,000,000Rwf ☐
- 4,000,001Rwf – 5,000,000Rwf ☐
- 5,000,001Rwf – 10,000,000Rwf ☐
- Between 10,000,000-50,000,000Rwf ☐
- More than 50,000,000 Rwf ☐

B-5: MEDIUM DISTANCE SURVEY, BUS **Date.../.../2014**

Dear Respondent, My name is.....

This survey is intended to capture information and suggestions approximately the transport industry in Rwanda. It was designed for academic purposes only and has nothing to do with business; therefore filling it, is voluntarily. This research is conducted in order to develop a transport demand model for HLTA and see the preference of transport users approximately this new mode as compared to the existing ones. It is a pleasure for us having you taking part of this interesting work. May God bless you.

Your privacy and secrecy will be secured by the researcher.

Description of Terms:

Waiting time: Waiting time is the time you spend by waiting for Bus for you trip

In Vehicle time: In Vehicle time is the time you use from when you get in the Vehicle up to leaving it.

Travel Cost: All the monetary cost expensed to accomplish the trip: (out of pocket money)

Tick according to your opinion.

1. **What is your origin and Destination?**
    - Kigali-Kampala ☐
    - Kampala-Kigali ☐
2. **What is your trip purpose?**
    - Business/Work ☐
    - Commuting ☐
    - Leisure ☐
    - Schooling ☐
    - Other ☐
3. **What is your average Single trip Distance?**
    - Between 200-300Km ☐
    - Between 301-400km ☐
    - Between 401-00Km ☐
    - Between 501-600Km ☐
    - Between 601-700Km ☐
    - Between 701-800Km ☐
4. **What is your travel time for one trip (IVT)**
    - Between 5h-6h ☐
    - Between 6h-7h ☐
    - Between 7h-8h ☐
    - Between 8h-9h ☐
    - Between 9h-10h ☐
    - Between 10h-11h ☐

- Between 11h-12h ☐
- Between 12h-13h ☐
- Between 13h-14h ☐
- Between 14h-15h ☐

5. How much time do you wait to start the trip?

- Between 10min-30min ☐
- Between 31min-50min ☐
- Between 51min-70min ☐
- Between 71min-90min ☐
- Between 1h30min-2h ☐
- Between 2h-2h30min ☐
- Between 2h30-3h ☐

6. How much Time do you lose in the Borders and Check points?

- Less than 1h. ☐
- Between 1-3h ☐
- Between 3-5h ☐
- More than 5h ☐

7. What is the average fare cost of your trip?

- 5000-6000Rwf ☐
- 6001-7000 Rwf ☐
- 7001-8000 Rwf ☐

- 8001-9000 Rwf ☐
- 9001-10,000 Rwf ☐
- 10,001-12,000Rwf ☐
- 12,001-14,000Rwf ☐

8. Suppose that you are currently using a mode of transport that can reduce 1.5h on your trip IVT. How much money would you be willing to pay to reach your destination?

- 5000-6000Rwf ☐
- 6000-7000 Rwf ☐
- 7000-8000 Rwf ☐
- 8000-9000 Rwf ☐
- 9000-10,000 Rwf ☐
- 10,000-12,000Rwf ☐
- 12,000-14,000Rwf ☐

9. Suppose that you are currently using another mode of transport that can reduce 30min on your waiting time. How much money would you be willing to pay to reach your destination?

- 5000-6000Rwf ☐
- 6000-7000 Rwf ☐
- 7000-8000 Rwf ☐
- 8000-9000 Rwf ☐
- 9000-10,000 Rwf ☐
- 10,000-11,000Rwf ☐
- 11,000-12,000Fr ☐
- 12,001-13000Rw ☐

10. How much is the other cost incurred in your trip?

- 1000-5000Rwf ☐
- 5001-10000Rwf ☐
- 10001-15000Rwf ☐
- 15001-20000Rwf ☐

11. How many times do you execute such a trip per year?

- Between 1-2 ☐
- Between 2-4 ☐
- Between 5-7 ☐
- Between 8-10 ☐
- Between 11-13 ☐
- Between 14-16 ☐
- Between 16-18 ☐
- Between 18-20 ☐
- Other……………………….

1. How much is your monthly income

- Less than 100,000Rwf ☐
- 100,001Rwf – 200.000Rwf ☐
- 200,001Rwf – 300,000Rwf ☐
- 300,001Rwf – 400,000Rwf ☐
- 400,000Rwf – 500,000Rwf ☐
- 500,001Rwf – 600,000Rwf ☐
- 600,001Rwf – 700,000Rwf ☐

- 700,001Rwf – 800,000Rwf ☐
- 800,001Rwf – 900,000Rwf ☐
- 900,001Rwf – 1,000,000Rwf ☐
- More than 1,000,000Rwf ☐

B-6: MEDIUM DISTANCE SURVEY, TRUCK **Date:..../..../2014**

Dear Respondent, My name is.....

This survey is intended to capture information and suggestions approximately the transport industry in Rwanda. It was designed for academic purposes only and has nothing to do with business; therefore filling it, is voluntarily. This research is conducted in order to develop a transport demand model for HLTA (Hybrid Lighter Than Air) and see the preference of transport users approximately this new mode as compared to the existing ones. It is a pleasure for us having you taking part of this interesting work. May God bless you.

Your privacy and secrecy will be secured by the researcher.

Description of Terms:

Waiting time: Waiting time is the time you spend by waiting for the truck to start the trip

In Vehicle time: In Vehicle time is the time you use from when you get in the Vehicle up to leaving it.

Travel Cost: All the monetary cost expensed to accomplish the trip: (out of pocket money).

Tick according to our opinion.

1. **What is your origin and Destination?**
   - Kigali-Kampala ☐
   - Kampala-Kigali ☐
2. **What is your trip purpose?**
   - Business/Work ☐
   - Other ☐
3. **What is your average Single trip Distance?**

- Between 200-300Km ☐
- Between 301-400km ☐
- Between 401-500Km ☐
- Between 501-600Km ☐
- Between 601-700Km ☐
- Between 701-800Km ☐
- Between 801-900Km ☐

4. What is your travel time for one trip (IVT)

- Between 5-10h ☐
- Between 11-15h ☐
- Between 16-1day ☐
- Between 1-2days ☐
- Between 2-3days ☐
- Between 3-4days ☐
- Between 4-5days ☐

5. How much time do you wait to start your trip?

- Between 10h-12h ☐
- Between 12h-14h ☐
- Between 14-16h ☐
- Between 16-18h ☐
- Between 18-20 ☐
- Between 20-22h ☐

- Between 22-24h ☐
- Between 24-26h ☐
- Between 26-28h ☐
- Between 28-30h ☐
- Between 30-32h ☐
- Other.................................

6. How much time do you spend not moving (The Trip having had started)

- Between 1-12h ☐
- Between 12-24h ☐
- Between 1-3days ☐
- Between 3-4days ☐
- Between 4-5days ☐
- Between 5-6days ☐
- Between 6-7days ☐

7. What is the main product carried:

- Construction Materials ☐
- Agricultural Products ☐
- Mining products ☐
- Chemical products ☐
- Electromechanical devices ☐
- Other...

8. What is the cost of carriage per 40ft ISO container to destination?

- 500-1000 ☐
- 1000-1500$ ☐
- 1501-2000$ ☐
- 2001-2500$ ☐
- 2501-3000$ ☐
- 3001-4000$ ☐
- 4001-5000$ ☐

9. Suppose that you are currently using a mode of transport that can reduce 15h on your trip IVT. How much money would you be willing to pay per 40ft ISO container to your destination?

- 500-1000 ☐
- 1000-1500$ ☐
- 1501-2000$ ☐
- 2001-2500$ ☐
- 2501-3000$ ☐
- 3001-4000$ ☐
- 4001-5000$ ☐
- 5001-6000$ ☐
- 6000-7000$ ☐
- 7000-8000$ ☐
- 8000-9000$ ☐
- 9000-10,000$ ☐

10. Suppose that you are currently using a mode of transport that can reduce 10h on your waiting time. How much money would you be willing to pay per Tonne to your destination?

- 500-1000 ☐
- 1000-1500$ ☐
- 1501-2000$ ☐
- 2001-2500$ ☐
- 2501-3000$ ☐
- 3001-4000$ ☐
- 4001-5000$ ☐
- 5001-6000$ ☐
- 6000-7000$ ☐
- 7000-8000$ ☐
- 8000-9000$ ☐
- 9000-10,000$ ☐

12. How much is the other cost incurred in your trip?

- 1-10$ ☐
- 11-20$ ☐
- 21-30$ ☐
- 31-40$ ☐
- 41-50$ ☐
- Other......................

13. How many tonnes do you manage to carry per year?

- Between 0-10
- Between 11-20
- Between 21-30
- Between 31-40
- Between 41-50
- Between 51-70
- Between 71-90
- Between 91-110
- Between 111-130
- Between 131-150
- Between 151-170
- Between 171-190
- Other…………………………..

14. How much is your monthly income?

- Less than 500,000Rwf
- 500,001Rwf – 1,000,000Rwf
- 1,000,001Rwf – 2,000,000Rwf
- 2,000,001Rwf – 3,000,000Rwf
- 3,000,000Rwf – 4,000,000Rwf
- 4,000,001Rwf – 5,000,000Rwf
- 5,000,001Rwf – 10,000,000Rwf
- Between 10,000,000-50,000,000Rwf
- More than 50,000,000 Rwf

B-7: SHORT DISTANCE SURVEY, AIR PASSENGER **Date.../.../2014**

Dear Respondent, My name is.......

This survey is intended to capture information and suggestions approximately the transport industry in Rwanda. It was designed for academic purposes only and has nothing to do with business; therefore filling it, is voluntarily. This research is conducted in order to develop a transport demand model for HLTA and see the preference of transport users approximately this new mode as compared to the existing ones. It is a pleasure for us having you taking part of this interesting work. May God bless you.

Your privacy and secrecy will be secured by the researcher.

Description of Terms:

Waiting time: Waiting time is the time you spend waiting for Air Vehicle to take off and start your trip.

In Vehicle time: In Vehicle time is the time you use from when you get in the Vehicle up to leaving it.

Travel Cost: All the monetary cost expensed to accomplish the trip: (out of pocket money)

Tick according to your opinion.

1. **What is your origin and Destination?**
    - Kigali-Rusizi ☐
    - Rusizi-Kigali ☐
2. **What is your trip purpose?**
    - Business/Work ☐
    - Commuting ☐
    - Leisure ☐
    - Schooling ☐
    - Other...............................
3. **What is your travel time for one trip (IVT)**
    - Between 20-30min ☐

- Between 31-40min
- Between 41-50min
- Between 51min-55min
- Between 56min-60min

4. How much time do you wait to get ready to start the trip (checking time)?

- Between 20-30min
- Between 31-40min
- Between 41-50min
- Between 51min-1h
- Between 1h-1h30min
- Between 1h30-2h
- Between 2h-2h30
- Between 2h30-3h
- Between 3h-3h30

5. What is the average fare cost of your trip?

- Between 50-70$
- Between 71-90$
- Between 91-110$
- Between 111-130$
- Between 131-150$
- Between 151-170$

6. Suppose that you are currently using a mode of transport that can reduce 15min on your trip IVT. How much money would you be willing to pay to reach your destination?

- Between 50-70$ ☐
- Between 71-90$ ☐
- Between 91-110$ ☐
- Between 111-130$ ☐
- Between 131-150$ ☐
- Between 151-170$ ☐

7. Suppose that you are currently using a mode of transport that can reduce 30min on your waiting time. How much money would you be willing to pay to your destination?

- Between 50-70$ ☐
- Between 71-90$ ☐
- Between 91-110$ ☐
- Between 111-130$ ☐
- Between 131-150$ ☐
- Between 151-170$ ☐

8. How much is the other cost incurred in your trip?

- 1-10$ ☐
- 11-20$ ☐
- 21-30$ ☐
- 31-40$ ☐
- 41-50$ ☐
- Other.....................

9. How much is your monthly income?

- Less than 500,000Rwf ☐
- 500,001Rwf – 1,000,000Rwf ☐
- 1,000,001Rwf – 2,000,000Rwf ☐
- 2,000,001Rwf – 3,000,000Rwf ☐
- 3,000,000Rwf – 4,000,000Rwf ☐
- 4,000,001Rwf – 5,000,000Rwf ☐
- 5,000,001Rwf – 10,000,000Rwf ☐
- Between 10,000,000-50,000,000Rwf ☐
- More than 50,000,000 Rwf ☐

B-8: SHORT DISTANCE SURVEY, BUS **Date.../.../2014**

Dear Respondent, My name is.......

This survey is intended to capture information and suggestions approximately the transport industry in Rwanda. It was designed for academic purposes only and has nothing to do with business; therefore filling it, is voluntarily. This research is conducted in order to develop a transport demand model for HLTA and see the preference of transport users approximately this new mode as compared to the existing ones. It is a pleasure for us having you taking part of this interesting work. May God bless You.

Your privacy and secrecy will be secured by the researcher.

Description of Terms:

Waiting time: Waiting time is the time you spend by waiting for PT (Bus) for you trip

In Vehicle time: In Vehicle time is the time you use from when you get in the Vehicle up to leaving it.

Travel Cost: All the monetary cost expensed to accomplish the trip: (out of pocket money)

Tick according to your opinion.

1. **What is your origin and Destination?**

- Kigali-Rusizi ☐
- Rusizi-Kigali ☐

2. **What is your trip purpose?**

- Business/Work ☐
- Commuting ☐
- Leisure ☐
- Schooling ☐
- Other……………………

3. **What is your average Single trip Distance?**

- Between 200-250Km ☐
- More than 250Km ☐

4. **What is your travel time for one trip (IVT)**

- Between 2-3h ☐
- Between 3-4h ☐
- Between 4-5h ☐
- Between 5-6h ☐
- Between 6-7h ☐
- Between 7-8h ☐

5. How much time do you wait to start your trip?

- Between 1-5min ☐
- Between 6-10min ☐
- Between 11-15min ☐

- Between 16-20min ☐
- Between 21-25min ☐
- Other.................................

6. How much Time do you lose in the Borders and Check points?

- Less than 1h. ☐
- Between 1-3h ☐
- Between 3-5h ☐
- More than 5h ☐

7. What is the average fare cost of your trip?

- 4000-5000Rwf ☐
- 5001-6000Rwf ☐
- 6001-7000 Rwf ☐
- 7001-8000 Rwf ☐
- 8001-9000 Rwf ☐
- 9001-10,000 Rwf ☐
- 10,001-12,000Rwf ☐

8. Suppose that you are currently using a mode of transport that can reduce 1h on your trip IVT. How much money would you be willing to pay to reach your destination?

- 5000-6000Rwf ☐
- 6000-7000 Rwf ☐
- 7000-8000 Rwf ☐
- 8000-9000 Rwf ☐

- 9000-10,000 Rwf
- 10,000-12,000Rwf
- 12,000-14,000Rwf

9. Suppose that you are currently using another mode of transport that can reduce 5min on your waiting time. How much money would you be willing to pay to reach your destination?

- 5000-6000Rwf
- 6000-7000 Rwf
- 7000-8000 Rwf
- 8000-9000 Rwf
- 9000-10,000 Rwf
- 10,000-11,000Rwf
- 11,000-12,000Fr
- 12,001-13000Rw

10. How much is the other cost incurred in your trip?

- 1000-5000Rwf
- 5001-10000Rwf
- 10001-15000Rwf
- 15001-20000Rwf

12. How many times do you execute such a trip per year?

- Between 1-2
- Between 2-4
- Between 5-7

- Between 8-10
- Between 11-13
- Between 14-16
- Between 16-18
- Between 18-20
- Other……………………….

13. How much is your monthly income?

- Less than 500,000Rwf
- 500,001Rwf – 1,000,000Rwf
- 1,000,001Rwf – 2,000,000Rwf
- 2,000,001Rwf – 3,000,000Rwf
- 3,000,000Rwf – 4,000,000Rwf
- 4,000,001Rwf – 5,000,000Rwf
- 5,000,001Rwf – 10,000,000Rwf
- Between 10,000,000-50,000,000Rwf
- More than 50,000,000 Rwf

B-10: SHORT DISTANCE SURVEY, TRUCK **Date.../.../2014**

Dear Respondent, My name is.......

This survey is intended to capture information and suggestions approximately the transport industry in Rwanda. It was designed for academic purposes only and has nothing to do with business; therefore filling it, is voluntarily. This research is conducted in order to develop a transport demand model for HLTA and see the preference of transport users approximately this new mode as compared to the existing ones. It is a pleasure for us having you taking part of this interesting work. May God bless you.

Your privacy and secrecy will be secured by the researcher.

Description of Terms:

Waiting time: Waiting time is the time you spend by waiting for the truck to start the trip.

In Vehicle time: In Vehicle time is the time you use from when you get in the Vehicle up to leaving it.

Travel Cost: All the monetary cost expensed to accomplish the trip: (out of pocket money)

Tick according to your opinion.

1. **What is your origin and Destination?**
   - Kigali-Rusizi ☐
   - Rusizi-Kigali ☐
2. **What is your trip purpose?**
   - Business/Work ☐
   - Commuting ☐
   - Other……………………….
3. **What is your average Single trip Distance?**
   - Between 200-250Km ☐
   - More than 250km ☐
4. **What is your travel time for one trip (IVT)**
   - Between 8h-10h ☐
   - Between 10h-12h ☐
   - Between 12h-14h ☐
   - Between 14-16h ☐
   - Between 16-18h ☐
   - Between 18-20h ☐

5. How much time do you wait to start the trip?

- Between 1-2h ☐
- Between 2h-4h ☐
- Between 4h-6h ☐
- Between 6h-8h ☐
- Between 8h-10h ☐
- Between 10h-12h ☐
- Other................................

6. How much time do you spend not moving due to traffic regulation (The Trip having had started)?

- Between 1h-2h ☐
- Between 2h-4h ☐
- Between 4h-6h ☐
- Between 6h-8h ☐
- Between 8h-10h ☐
- Between 10h-12h ☐

7. What is the main product carried?

- Construction Materials ☐
- Agricultural Products ☐
- Mining products ☐
- Chemical products ☐
- Electronic devices ☐
- Other.............................. ☐

8. What is the cost of carriage Per Ton to destination?

- 5,000-10,000Rwf ☐
- 10,001-15000Rwf ☐
- 15,001-20,000Rwf ☐
- 20,001-25000Rwf ☐
- 25001-30,000Rwf ☐
- 30,001-35000Rwf ☐
- 35,001-40,000Rwf ☐

9. Suppose that you are currently using a mode of transport that can reduce 5h on your trip IVT. How much money would you be willing to pay per ton to your destination?

- 5,000-10,000Rwf ☐
- 10,001-15000Rwf ☐
- 15,001-20,000Rwf ☐
- 20,001-25000Rwf ☐
- 25001-30,000Rwf ☐
- 30,001-35000Rwf ☐
- 3,5001-40,000Rwf ☐
- 40,001-45,000Rwf ☐

10. Suppose that you are currently using a mode of transport that can reduce 2h on your waiting time. How much money would you be willing to pay per ton to your destination?

- 5,000-10,000Rwf ☐
- 10,001-15000Rwf ☐

- 15,001-20,000Rwf ☐
- 20,001-25000Rwf ☐
- 25001-30,000Rwf ☐
- 30,001-35000Rwf ☐
- 3,5001-40,000Rwf ☐
- 40,001-45,000Rwf ☐

11. How much is the other cost incurred in your trip?

- 1000-5,000Rwf ☐
- 5,001-10,000Rwf ☐
- 10,001-15,000Rwf ☐
- 15,001-20,000Rwf ☐
- Other.................................

12. How many tonnes do you manage to carry per year?

- Between 0-10 ☐
- Between 11-20 ☐
- Between 21-30 ☐
- Between 31-40 ☐
- Between 41-50 ☐
- Between 51-70 ☐
- Between 71-90 ☐
- Between 91-110 ☐
- Between 111-130 ☐
- Between 131-150 ☐

- Between 151-170 ☐
- Between 171-190 ☐
- Other……………………….

14. How much is your monthly income?

- Less than 500,000Rwf ☐
- 500,001Rwf – 1,000,000Rwf ☐
- 1,000,001Rwf – 2,000,000Rwf ☐
- 2,000,001Rwf – 3,000,000Rwf ☐
- 3,000,001Rwf – 4,000,000Rwf ☐
- 4,000,001Rwf – 5,000,000Rwf ☐
- 5,000,001Rwf – 10,000,000Rwf ☐
- Between 10,000,000-50,000,000Rwf ☐
- More than 50,000,000 Rwf ☐

APPENDIX C: MAGNITUDES OF ATTRIBUTES' LEVELS

C-1 LONG DISTANCE

Table C-1: Number and magnitude of attributes' Levels of Bus on a long distance.

Bus Number and Magnitude of attributes			
LEVELS	IVT (Min)	W. Time (Min)	Travel Cost (Rwf/Person)
1	2280	90	68000
2	1680	54	45000
3	1080	18	22000

Table C-2: Number and magnitude of attributes' Levels of Air Passenger on a long distance

Air-P Number and Magnitude of attributes			
LEVELS	IVT (Min)	W. Time (Min)	Travel Cost (Rwf/Person)
1	128	160	244000
2	99	122	178000
3	70	84	112000

Table C-3: Number and magnitude of attributes' Levels of HLTA-Passenger on a long distance

HLTA-P Number and Values of Attributes			
LEVELS	IVT (min)	W. Time (Min)	Travel Cost (Rwf/Person)
1	432	0	60600
2	336	0	55300
3	240	0	50000

Table C-4: Number and magnitude of attributes' Levels of truck on a long distance

Truck Number and Magnitudes of attributes' levels			
LEVELS	IVT (h)	W. Time (h)	Travel Cost (Rwf/Container)
1	192	120	5950000
2	144	100	4550000
3	96	80	3150000

Table C-5: Number and magnitude of attributes' Levels of HLTA-Cargo on a long distance

HLTA-C Number and Magnitudes of Attributes' Levels			
LEVELS	IVT (h)	W. Time (h)	Travel Cost (Rwf/Container)
1	6	3	6560000
2	5.6	2	6197000
3	5.2	1	5834000

C-2: MEDIUM DISTANCE

Table C-6: Number and magnitude of attributes' Levels of Bus on a Medium Distance

Air-P Number and Magnitudes of attributes' levels			
LEVELS	IVT (Min)	W. Time (Min)	Travel Cost (Rwf/Person)
1	720	40	18 500
2	600	25	15 000
3	480	10	11 500

Table C-7: Number and magnitude of attributes' Levels of Air Passenger on a Medium Distance

Air-P Number and Magnitudes of attributes' levels			
LEVELS	IVT (Min)	W. Time (Min)	Travel Cost (Rwf/Person)
1	58	154	161 000
2	48	122	140 000
3	38	90	119 000

Table C-8: Number and magnitudes of attributes' Levels of HLTA Passenger on a Medium Distance

HLTA-P Number and Values of Attributes			
LEVELS	IVT (min)	W. Time (Min)	Travel Cost (Rwf/Person)
1	132	0	44 000
2	108	0	36 000
3	84	0	28 000

Table C-9: Number and magnitude of attributes' Levels of Truck on a Medium Distance

Truck Number and Magnitudes of attributes' levels			
LEVELS	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)
1	68	29	1770000
2	44	21	1150000
3	20	13	530000

Table C-10: Number and magnitudes of attributes' Levels of HLTA Cargo on a Medium Distance.

HLTA-C Number and Magnitudes of Attributes' Levels			
LEVELS	IVT (h)	W. Time (h)	Travel Cost (Rwf/Container)
1	2.5	3	3 310 000
2	2	2	2 150 000
3	1.5	1	990 000

C-3: SHORT DISTANCE

Table C-11: Number and magnitude of attributes' Levels of Bus on a Short Distance

Bus Number and Magnitudes of attributes' levels			
LEVELS	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)
1	360	16	8 400
2	300	13	7200
3	240	10	6 000

Table C-12: Number and magnitude of attributes' Levels of Air Passenger on a Short Distance

Number and Magnitude of attributes' Levels			
LEVELS	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)
1	44	150	102000
2	37	120	79000
3	30	90	56000

Table C-13: Number and magnitude of attributes' Levels of HLTA-Passenger on a Short Distance

HLTA-Passenger Number and Magnitudes of Attributes' Levels			
LEVELS	IVT (Min)	W. Time (Min)	Travel Cost (Rwf/Person)
1	84	0	28 000
2	72	0	24 000
3	60	0	20 000

Table C-14: Number and magnitude of attributes' Levels of Truck on a Short Distance

Truck Number and Magnitudes of attributes' Levels			
LEVELS	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Tonne)
1	960	360	32000
2	780	240	23000
3	600	120	14000

Table C-15: Number and magnitude of attributes' Levels of HLTA Cargo on a Short Distance

HLTA-C Number and Magnitudes of attributes' Levels			
LEVELS	IVT (Min)	W. Time (Min)	Travel Cost (Rwf/Tonne)
1	62	180	63 000
2	50	120	55 000
3	38	60	47 000

APPENDIX D: COMBINATIONS OF ATTRIBUTES' LEVELS

Table D-1: Attributes' levels combinations of Bus transport mode

BUS ATTRIBUTES' LEVELS COMBINATION								
LONG DISTANCE			MEDIUM DISTANCE			SHORT DISTANCE		
IVT (min)	W.T (Min)	T.C (Rwf/P)	IVT (Min)	W.T (Min)	T.C (Rwf/P)	IVT (Min)	W.T (Min)	T.C (Rwf/P)
2280	90	68000	720	40	18500	360	16	8400
2280	90	45000	720	40	15000	360	16	7200
2280	90	22000	720	40	11500	360	16	6000
2280	54	68000	720	25	18500	360	13	8400
2280	54	45000	720	25	15000	360	13	7200
2280	54	22000	720	25	11500	360	13	6000
2280	18	68000	720	10	18500	360	10	8400
2280	18	45000	720	10	15000	360	10	7200
2280	18	22000	720	10	11500	360	10	6000
1680	90	68000	600	40	18500	300	16	8400
1680	90	45000	600	40	15000	300	16	7200
1680	90	22000	600	40	11500	300	16	6000
1680	54	68000	600	25	18500	300	13	8400
1680	54	45000	600	25	15000	300	13	7200
1680	54	22000	600	25	11500	300	13	6000
1680	18	68000	600	10	18500	300	10	8400
1680	18	45000	600	10	15000	300	10	7200
1680	18	22000	600	10	11500	300	10	6000
1080	90	68000	480	40	18500	240	16	8400
1080	90	45000	480	40	15000	240	16	7200
1080	90	22000	480	40	11500	240	16	6000
1080	54	68000	480	25	18500	240	13	8400
1080	54	45000	480	25	15000	240	13	7200
1080	54	22000	480	25	11500	240	13	6000
1080	18	68000	480	10	18500	240	10	8400
1080	18	45000	480	10	15000	240	10	7200
1080	18	22000	480	10	11500	240	10	6000

Table D-2: Attributes' levels combinations of Air-Passenger transport mode

AIR PASSENGER ATTRIBUTES' LEVELS COMBINATION								
LONG DISTANCE			MEDIUM DISTANCE			SHORT DISTANCE		
IVT (min)	W.T (Min)	T.C (Rwf/P)	IVT (Min)	W.T (Min)	T.C (Rwf/P)	IVT (Min)	W.T (Min)	T.C (Rwf/P)
128	160	244000	58	144	161000	44	150	102000
128	160	178000	58	144	140000	44	150	79000
128	160	112000	58	144	119000	44	150	56000
128	122	244000	58	122	161000	44	120	102000
128	122	178000	58	122	140000	44	120	79000
128	122	112000	58	122	119000	44	120	56000
128	84	244000	58	90	161000	44	90	102000
128	84	178000	58	90	140000	44	90	79000
128	84	112000	58	90	119000	44	90	56000
99	160	244000	48	144	161000	37	150	102000
99	160	178000	48	144	140000	37	150	79000
99	160	112000	48	144	119000	37	150	56000
99	122	244000	48	122	161000	37	120	102000
99	122	178000	48	122	140000	37	120	79000
99	122	112000	48	122	119000	37	120	56000
99	84	244000	48	90	161000	37	90	102000
99	84	178000	48	90	140000	37	90	79000
99	84	112000	48	90	119000	37	90	56000
70	160	244000	38	144	161000	30	150	102000
70	160	178000	38	144	140000	30	150	79000
70	160	112000	38	144	119000	30	150	56000
70	122	244000	38	122	161000	30	120	102000
70	122	178000	38	122	140000	30	120	79000
70	122	112000	38	122	119000	30	120	56000
70	84	244000	38	90	161000	30	90	102000
70	84	178000	38	90	140000	30	90	79000
70	84	112000	38	90	119000	30	90	56000

Table D-3: Attributes' levels combinations of HLTA-Passenger and HLTA-cargo transport mode

HLTA-P ATTRIBUTES' LEVELS COMBINATION								
LONG DISTANCE			MEDIUM DISTANCE			SHORT DISTANCE		
IVT (h)	W.T (h)	T.C (Rwf/P)	IVT (Min)	W.T (Min)	T.C (Rwf/P)	IVT (Min)	W.T (Min)	T.C (Rwf/P)
432	0	60 600	132	0	44000	84	0	28000
432	0	55 300	132	0	36000	84	0	24000
432	0	50 000	132	0	28000	84	0	20000
336	0	60 600	108	0	44000	72	0	28000
336	0	55 300	108	0	36000	72	0	24000
336	0	50 000	108	0	28000	72	0	20000
240	0	60 600	84	0	44000	60	0	28000
240	0	55 300	84	0	36000	60	0	24000
240	0	50 000	84	0	28000	60	0	20000
HLTA-C ATTRIBUTES' LEVELS COMBINATION								
LONG DISTANCE			MEDIUM DISTANCE			SHORT DISTANCE		
IVT (h)	W.T(h)	T.C (Rwf/C)	IVT (h)	W.T(h)	T.C (Rwf/C)	IVT (Min)	W.T (Min)	T.C (Rwf/C)
6	3	6560000	3	3	3310000	62	180	63000
6	3	6197000	3	3	2150000	62	180	55000
6	3	5834000	3	3	990000	62	180	47000
6	2	6560000	3	2	3310000	62	120	63000
6	2	6197000	3	2	2150000	62	120	55000
6	2	5834000	3	2	990000	62	120	47000
6	1	6560000	3	1	3310000	62	60	63000
6	1	6197000	3	1	2150000	62	60	55000
6	1	5834000	3	1	990000	62	60	47000
5.6	3	6560000	2	3	3310000	50	180	63000
5.6	3	6197000	2	3	2150000	50	180	55000
5.6	3	5834000	2	3	990000	50	180	47000
5.6	2	6560000	2	2	3310000	50	120	63000
5.6	2	6197000	2	2	2150000	50	120	55000
5.6	2	5834000	2	2	990000	50	120	47000
5.6	1	6560000	2	1	3310000	50	60	63000
5.6	1	6197000	2	1	2150000	50	60	55000
5.6	1	5834000	2	1	990000	50	60	47000
5.2	3	6560000	1.5	3	3310000	38	180	63000
5.2	3	6197000	1.5	3	2150000	38	180	55000

5.2	3	5834000	1.5	3	990000	38	180	47000
5.2	2	6560000	1.5	2	3310000	38	120	63000
5.2	2	6197000	1.5	2	2150000	38	120	55000
5.2	2	5834000	1.5	2	990000	38	120	47000
5.2	1	6560000	1.5	1	3310000	38	60	63000
5.2	1	6197000	1.5	1	2150000	38	60	55000
5.2	1	5834000	1.5	1	990000	38	60	47000

Table D-4: Attributes' levels combinations of Truck transport mode

TRUCK ATTRIBUTES' LEVELS COMBINATION								
LONG DISTANCE			MEDIUM DISTANCE			SHORT DISTANCE		
IVT (h)	W.T(h)	T.C (Rwf/C)	IVT (h)	W.T(h)	T.C (Rwf/C)	IVT (Min)	W.T (Min)	TC (Rwf/T)
192	120	5950000	68	29	1770000	960	360	32000
192	120	4550000	68	29	1150000	960	360	23000
192	120	3150000	68	29	530000	960	360	14000
192	100	5950000	68	21	1770000	960	240	32000
192	100	4550000	68	21	1150000	960	240	23000
192	100	3150000	68	21	530000	960	240	14000
192	80	5950000	68	13	1770000	960	120	32000
192	80	4550000	68	13	1150000	960	120	23000
192	80	3150000	68	13	530000	960	120	14000
144	120	5950000	44	29	1770000	780	360	32000
144	120	4550000	44	29	1150000	780	360	23000
144	120	3150000	44	29	530000	780	360	14000
144	100	5950000	44	21	1770000	780	240	32000
144	100	4550000	44	21	1150000	780	240	23000
144	100	3150000	44	21	530000	780	240	14000
144	80	5950000	44	13	1770000	780	120	32000
144	80	4550000	44	13	1150000	780	120	23000
144	80	3150000	44	13	530000	780	120	14000
96	120	5950000	20	29	1770000	600	360	32000
96	120	4550000	20	29	1150000	600	360	23000
96	120	3150000	20	29	530000	600	360	14000
96	100	5950000	20	21	1770000	600	240	32000
96	100	4550000	20	21	1150000	600	240	23000
96	100	3150000	20	21	530000	600	240	14000
96	80	5950000	20	13	1770000	600	120	32000
96	80	4550000	20	13	1150000	600	120	23000
96	80	3150000	20	13	530000	600	120	14000

Note; Rwf/P Rwandan francs per Passenger

Rwf/C Rwandan francs per Container

APPENDIX E: DEVELOPMENT OF CHOICE GAMES BETWEEN ALTERNATIVES

Table E-1: Choice games between Bus and Air Passenger on a long distance.

Suppose that you need to make a trip from Kigali to Mombasa, Nairobi, or Dar-Es-Salaam. What mode of transport would you choose in different options below? (Tick according to your preference)

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	128	160	244000	
BUS	2280	90	68000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	128	160	112000	
BUS	2280	90	22000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	128	122	178000	
BUS	1680	90	45000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	128	84	244000	
BUS	1080	90	45000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	128	84	112000	
BUS	1080	18	22000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	99	160	178000	
BUS	2280	90	22000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	99	122	244000	
BUS	1680	54	45000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	99	122	112000	
BUS	1080	90	45000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	99	84	178000	
BUS	2280	18	22000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	99	84	112000	
BUS	1680	18	68000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	70	160	244000	
BUS	2280	54	45000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	70	160	112000	
BUS	1680	54	68000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	70	122	178000	
BUS	1080	54	68000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	70	84	244000	
BUS	2280	90	68000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	70	84	112000	
BUS	1080	18	22000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf _ Per Person)	CHOICE
Air Passenger	128	122	112000	
Bus	1680	90	22000	

Table E-2: Choice games between Bus and Air Passenger on a medium distance.

Suppose that you need to make a trip from Kigali to Kampala. What mode of transport would you choose in different options below? (Tick according to your preference)

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	58	144	161000	
Bus	720	40	18500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	58	90	119000	
Bus	480	10	11500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	58	144	119000	
Bus	580	40	18500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	58	90	161000	
Bus	480	25	18500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	58	122	140000	
Bus	720	10	15000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	48	144	161000	
Bus	720	40	18500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	48	122	140000	
Bus	480	25	15000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	48	90	161000	
Bus	580	40	18500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	48	90	140000	
Bus	480	40	18500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	48	90	119000	
Bus	720	25	18500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	38	144	140000	
Bus	580	40	11500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	38	122	161000	
Bus	720	25	18500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	38	122	119000	
Bus	480	10	11500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	38	90	140000	
Bus	720	40	18500	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	38	90	161000	
Bus	480	40	15000	

ALTERNATIVE	IVT (Min)	W.T(Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	58	90	161000	
Bus	720	25	18500	

Table E-3: Choice games between Bus and Air Passenger on A Short Distance

Suppose that you need to make a trip from Kigali to Rusizi. What mode of transport would you choose in different options below? (Tick according to your preference)

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	44	150	102000	
Bus	360	16	8400	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	44	150	56000	
Bus	300	16	7200	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	44	135	79000	
Bus	240	10	7200	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	44	90	102000	
Bus	240	13	8400	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	44	90	56000	
Bus	360	10	7200	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	37	150	79000	
Bus	360	16	7200	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	37	135	102000	
Bus	300	13	8400	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	37	135	56000	
Bus	240	16	8400	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	37	90	79000	
Bus	240	13	6000	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	37	90	56000	
Bus	360	10	8400	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	30	150	79000	
Bus	240	16	6000	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	30	135	102000	
Bus	300	16	6000	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	30	135	56000	
Bus	360	10	8400	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	30	90	102000	
Bus	360	16	6000	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	30	90	56000	
Bus	300	10	8400	

ALTERNATIVE	IVT (Min)	W. T (Min)	TRAVEL COST (Rwf/Person)	CHOICE
Air Passenger	30	135	102000	
Bus	240	13	6000	

Table E-4: Choice games between Bus and HLTA- Passenger on a long distance

Suppose that you need to make a trip from Kigali to Mombasa, Nairobi or Dar-Es-Salaam. What mode of transport would you choose in different options below? (Tick according to your preference)

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	240	0	68000	
Bus	2580	90	60600	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	240	0	68000	
Bus	2580	90	22000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	240	0	55300	
Bus	1680	90	45000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	240	0	55300	
Bus	1080	90	45000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	240	0	50000	
Bus	1080	18	22000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	240	0	50000	
Bus	2580	90	22000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	336	0	68000	
Bus	1680	54	45000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	336	0	68000	
Bus	1080	90	45000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	336	0	55300	
Bus	2580	18	22000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	336	0	55300	
Bus	1680	18	60600	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	336	0	50000	
Bus	336	0	50000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	432	0	68000	
Bus	1680	54	60600	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	432	0	68000	
Bus	1080	54	60600	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	432	0	55300	
Bus	2580	90	60600	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	432	0	55300	
Bus	1080	18	22000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA Passenger	432	0	50000	
Bus	1680	90	22000	

Table E-5: Choice games between Bus and HLTA Passenger on A Medium Distance

If you need to make a trip from Kigali to Kampala. What mode of transport would you choose in different options below? (Tick according to your preference)

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	108	0	36000	
Bus	600	10	18500	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	132	0	44000	
Bus	720	10	11500	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	132	0	36000	
Bus	720	40	11500	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	132	0	36000	
Bus	600	25	18500	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	132	0	28000	
Bus	720	25	18500	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	132	0	28000	
Bus	720	25	15000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	108	0	44000	
Bus	720	10	18500	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	108	0	44000	
Bus	600	40	18500	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	108	0	36000	
Bus	600	40	15000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	108	0	36000	
Bus	480	25	15000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	108	0	28000	
Bus	600	40	11500	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	108	0	28000	
Bus	600	25	18500	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	84	0	44000	
Bus	720	10	18500	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	84	0	44000	
Bus	480	40	15000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	84	0	36000	
Bus	720	40	15000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	84	0	36000	
Bus	480	25	18500	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	84	0	36000	
Bus	720	25	15000	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	84	0	36000	
Bus	480	10	18500	

Table E-6: Choice games between Bus and HLTA Passenger on a Short Distance

Suppose that you need to make a trip from Kigali to Rusizi. What mode of transport would you choose in different options below? (Tick according to your preference)

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	72	0	20000	
Bus	360	13	6800	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	90	0	30000	
Bus	240	13	7200	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	90	0	24000	
Bus	360	16	6800	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	90	0	24000	
Bus	360	13	8400	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	90	0	20000	
Bus	360	13	7200	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	90	0	20000	
Bus	240	16	7200	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	72	0	30000	
Bus	360	10	8400	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	72	0	30000	
Bus	336	13	8400	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	72	0	24000	
Bus	360	10	6800	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	60	0	24000	
Bus	336	16	8400	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	72	0	20000	
Bus	336	16	7200	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	72	0	20000	
Bus	240	13	7200	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	60	0	30000	
Bus	336	13	8400	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	60	0	30000	
Bus	240	10	6800	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	60	0	24000	
Bus	240	13	6800	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	60	0	24000	
Bus	360	13	8400	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	72	0	30000	
Bus	360	13	7200	

ALTERNATIVE	IVT (Min)	W. Time (Min)	TRAVEL COST (Rwf/Person)	CHOICE
HLTA-Passenger	60	0	24000	
Bus	240	16	7200	

Table E-7: Choice games between HLTA Cargo and Truck on a long Distance

Suppose that you need to transport a container from Kigali to Mombasa, Nairobi or Dar-Es-Salaam. What mode of transport would you choose in different options below? (Tick according to your preference)

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	6	3	6560000	
Truck	192	120	5950000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	6	3	6197000	
Truck	144	120	3150000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	6	2	5834000	
Truck	96	100	3150000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.6	1	6560000	
Truck	96	80	3150000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	6	1	6197000	
Truck	144	100	4550000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.6	3	5834000	
Truck	96	80	5950000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.6	2	6560000	
Truck	192	120	5950000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.6	2	6197000	
Truck	192	100	4550000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.6	1	5834000	
Truck	144	100	4550000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.6	1	6197000	
Truck	144	80	3150000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.2	3	5834000	
Truck	192	80	4550000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.2	3	6197000	
Truck	192	80	4550000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.2	2	5834000	
Truck	96	80	4550000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.2	1	6560000	
Truck	20	120	4550000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.2	1	6197000	
Truck	144	120	5950000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	5.2	2	6197000	
Truck	192	80	5950000	

Table E-8: Choice games between HLTA Cargo and Truck on a Medium Distance

Suppose that you need to transport a container from Kigali to Kampala. What mode of transport would you choose in different options below? (Tick according to your preference)

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	2.5	3	3310000	
Truck	68	29	1150000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	2.5	3	990000	
Truck	44	29	530000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	2.5	2	2150000	
Truck	20	21	530000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	2.5	1	3310000	
Truck	20	13	530000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	2.5	1	990000	
Truck	44	21	1770000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	2	3	2150000	
Truck	20	13	1150000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	2	2	3310000	
Truck	68	29	1150000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	2	2	990000	
Truck	68	21	1770000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	2	1	2150000	
Truck	44	21	1770000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	2	1	990000	
Truck	44	13	530000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	1.5	3	2150000	
Truck	68	13	1770000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	1.5	5	990000	
Truck	68	21	1770000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	1.5	2	2150000	
Truck	20	13	1770000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	1.5	1	3310000	
Truck	20	29	1770000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	1.5	1	990000	
Truck	44	29	1150000	

ALTERNATIVE	IVT (h)	W. Time (h)	TRAVEL COST (Rwf/Container)	CHOICE
HLTA-Cargo	2	2	990000	
Truck	68	13	1150000	

Table E-9: Choice games between HLTA Cargo and Truck on a short Distance

Suppose that you need to transport a container from Kigali to Rusizi. What mode of transport would you choose in different options below? (Tick according to your preference)

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	62	180	63000	
Truck	960	360	32000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	62	180	47000	
TRUCKS	780	240	14000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	62	120	55000	
TRUCKS	600	360	23000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	62	60	47000	
TRUCKS	600	120	23000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	62	60	63000	
TRUCKS	780	360	32000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	50	180	55000	
TRUCKS	780	240	14000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	50	180	47000	
TRUCKS	600	120	32000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	50	120	55000	
TRUCKS	960	360	23000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	50	60	63000	
TRUCKS	600	120	23000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	50	60	55000	
TRUCKS	780	120	14000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	50	60	47000	
TRUCKS	600	120	14000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	38	180	55000	
TRUCKS	960	240	23000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	38	120	63000	
TRUCKS	780	240	23000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	38	120	47000	
TRUCKS	600	360	32000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	38	60	55000	
TRUCKS	960	360	32000	

ALTERNATIVE	IVT (Min)	W.T (Min)	TRAVEL COST (Rwf/Tonne)	CHOICE
HLTA-Cargo	38	60	47000	
TRUCKS	600	360	32000	

APPENDIX F: RESULTS OF SPSS ANALYSIS

Table F-1: Model summary and Variables in the equation for Bus and Air Passenger on a long distance

Model Summary						
Step	-2 Log likelihood		Cox & Snell R Square		Nagelkerke's R Square	
1	25151.306[a]		0.541		0.722	
Variables in the Equation						
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	IVT_Min	-0.0069	0	6.479	1	0.0574	1
	W_Time_Min	-0.001	0	5.055	1	0.618	0.999
	T_C_Rwf	0.000046	0	3333.102	1	0	1
	Constant	4.141	0.09	2123.849	1	0	62.876

Table F-2: Model summary and Variables in the equation for Bus and HLTA on a long distance.

Model Summary							
Step	-2 Log likelihood		Cox & Snell R Square			Nagelkerke's R Square	
1	321.351[a]		0.42			0.561	
Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step1	IVT_Min	-0.002	0	20.249	1	0	0.998
	W_Time_Min	-0.0072	0.007	14.145	1	0	0.975
	T_C_Rwf	-0.00003	0	6.376	1	0.012	1
	Constant	3.39	0.748	20.527	1	0	29.674

Table F-3: Model summary and Variables in the equation for Truck and HLTA-Cargo on long distance

Model Summary							
Step	-2 Log likelihood	Cox & Snell R Square			Nagelkerke's R Square		
1	20.570[a]	0.525			0.699		
Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	IVT_h	-0.02	0.001	168.467	1	0	0.984
	W_Time_h	-0.021	0.002	75.706	1	0	0.979
	TC_Rwf	-0.000001	0	85.478	1	0	1
	Constant	1.551	0.387	16.042	1	0	0.212

Table F-4: Model summary and Variables in the equation for Bus and Air-P on a medium distance

Model Summary							
Step	-2 Log likelihood		Cox & Snell R Square			Nagelkerke's R Square	
1	1360.931[a]		0.392			0.523	
Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	IVT_Min	-0.003	0.0005	35.546	1	0	0.994
	W_Time_Min	-0.012	0.03	11.87	1	0.06	0.919
	T_C	0.000014	0	0.009	1	0	1
	Constant	2.714	0.421	21.112	1	0	13.654

Table F-5: Model summary and Variables in the equation for Bus and HLTA-P on a medium distance

Model Summary							
Step	-2Log likelihood	Cox & Snell R Square		Nagelkerke's R Square			
1	27.900[a]	0.393		0.526			
Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	IVT_Min	-0.004	0.0014	53.663	1	0.006	1.95
	W_Time_Min	-0.048	0.0021	7.43	1	0.23	0.549
	T_C	0.0000471	0	0.006	1	0	1
	Constant	4.361	1.014	23.003	1	0	18.74

Table F-6: Model summary and Variables in the equation for Truck and HLTA-C on medium distance

Model Summary							
Step	-2 Log likelihood	Cox & Snell R Square			Nagelkerke's R Square		
1	1458.456[a]	0.49			0.654		
Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	IVT_h	-0.046	0.004	104.942	1	0	0.955
	W_Time_h	-0.0128	0.011	146.701	1	0.09	0.88
	TC_Rwf	-4.43×10^{-7}	0	460.882	1	0	1
	Constant	6.031	0.26	536.57	1	0	415.935

Table F-7: Model summary and Variables in the equation for Bus and Air passenger on a short distance

Model Summary							
Step	-2 Log likelihood	Cox & Snell R Square		Nagelkerke's R Square			
1	75.292a	0.452		0.603			
Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1	IVT_Min	-0.023	0.006	13.271	1	0	0.977
	W_Time_Min	-0.004	0.017	0.068	1	0.794	0.996
	T_C_Rwf	-0.00013	0	12.97	1	0	1
	Constant	9.361	2.327	16.179	1	0	11625.47

Table F-8: Model summary and Variables in the equation for Bus and HLTA-P on a short distance

Model Summary							
Step	-2 Log likelihood	Cox & Snell R Square		Nagelkerke's R Square			
1	1353.993[a]	0.516		0.688			
Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	IVT_Min	-0.006	0.001	53.663	1	0	0.994
	W_Time_Min	-0.085	0.031	7.43	1	0.061	0.919
	T_C	-0.000006	0	0.006	1	0.009	1
	Constant	2.614	0.545	23.003	1	0	13.654