Analyzing BRT scenarios to maximize monetary value for bus operator and commuters

A case study in Dar es Salaam, Tanzania

<u>Author:</u>
D. (Daan) Mestrum

<u>Supervisors:</u>

Eng. E. (Enoch) Kitandu	(Dar es Salaam City Council)
Eng. M. (Mohamed) Kuganda	(Dar es Salaam City Council)
Dr. Eng. M.H.P. (Mark) Zuidgeest	(ITC)
Prof. Dr. Eng. M.F.A.M. (Martin) van Maarseveen	(University of Twente)

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Dar Rapid Transit (Dar es Salaam, Tanzania)

University of Twente (Enschede, The Netherlands)

International Institute for Geo-Information Science and Earth Observation (Enschede, The Netherlands)

Preface

This report is written to finish my Bachelor of Science project in Civil Engineering (& Management) at the University of Twente, The Netherlands. I have been in Dar es Salaam, Tanzania, for three months to do research related to the Dar Rapid Transit project. During this period I have worked closely together with Alphonse Nkurunziza, who was working on the same research subject. I have performed my research in the Transportation Unit of Dar es Salaam City Council (DCC).

The whole period in Dar es Salaam was a great experience for me. It was great to be involved in a large civil engineering project that will have a huge impact on the city and its citizens. I could spend three months in the heart of all developments around this project. On the one hand it gave me more insight in the process of a large infrastructure project. Because I worked in the central unit that was established for the DART project, I kept well informed about most of the developments. Also it was nice that a lot of people with different roles passed the office, so that I got better insight in the organization of an infrastructure project. The project also gave me better ideas about my interests with reference to my future job. On the other hand it was also interesting to be three months in a different part of the world. The experiences in Tanzania enriched me in several aspects, from which I can take advantage in the future.

I would like to use this preface to thank a number of persons and organizations who supported me during the research. First I want to thank the people of the DCC Transportation Unit. They gave me the opportunity to do research in Dar es Salaam, related to the DART system. And during my stay they were very helpful: from providing useful information about the project to assistance in the fieldwork; in all kinds of way valuable support was offered. When I mention the DCC Transportation Unit, I also have to mention the JICA (Japan International Cooperation Agency) project team that was working at the DCC Transportation Unit. They were helpful in supporting the research and providing their progress documents and data. Also we had a number of useful discussions about the design and the processing of the stated choice data.

There are also some people from the Netherlands I would like to thank. First Mark Zuidgeest (ITC), because he initiated this great opportunity to do research abroad on a very interesting project. Furthermore I have to thank Thijs Muizelaar, for offering his assistance in creating the stated choice questionnaire and processing the stated choice data. Also I want to express my thanks to the ITC, department of urban and regional planning, because they gave permission for this research. Furthermore I would like to thank the Centre for Transport Studies, University Twente, The Netherlands, because the realization of this final report is assisted by their financial support. And last but not least I have to thank Alphonse Nkurunziza, who was my research partner and with who I had good discussions about the research and with who I could exchange knowledge.

Enschede, March 17, 2008

Daan Mestrum

Management summary

Dar Rapid Transit (DART) is a BRT (Bus Rapid Transit) system for Dar es Salaam, Tanzania. In a few years the first phase of this BRT system will be operating. The current idea is to have the whole city covered by DART in 2035. DART will replace the current public transport system of daladala's, which are minibuses or small buses. Compared to the daladala's, DART will have higher comfort levels, a higher capacity, and will cut down the total travel time for most of the commuters. Also the reliability and the operational hours will be increased.

The initial objective of this research is: *"Making recommendations to harmonize the operational characteristics of the proposed DART system with the preferences of the targeted users by making a comparison between the planned characteristics of the DART system and the preferences of these users."* During this research the focus changed from providing advice to maximize the benefits of DART to introducing a comparison method to evaluate different scenario's of BRT systems. This has been performed by means of a case study in Dar es Salaam.

This research includes the following four operational characteristics: bus comfort level, travel fare, in-vehicle travel time and the walking time to the bus stop. The objective indicates that two sets of information have to be obtained. On the one hand the characteristics of the proposed DART system have to be determined; on the other hand research has to be done to the preferences of Dar es Salaam's commuters.

The information about the proposed DART characteristics was relatively easy to find out, and was found in proposals for the DART system. To obtain information about the preferences of the commuters, a stated choice survey was held over almost 700 citizens of Dar es Salaam. This stated choice survey included 9 different questions. These questions contained two different sets of bus characteristics and the respondents had to choose the bus type they preferred most. The four characteristics were travel fare, the comfort level, the in-vehicle travel time and the walking time to the bus stop. One example of a question is shown below in Figure 1

Bus A:
- Travel fare: 300 Tsh
- In-vehicle travel time: 25 mintues
- Walking time to bus stop: 15 minutes
- Comfort: Overcrowded Standing

Bus B:
- Travel fare: 500 Tsh
- In-vehicle travel time: 15mintues
- Walking time to bus stop: 15 minutes
- Comfort: Comfortable Seating

Figure 1: Example of a stated choice question

Does the respondent prefer the cheaper, but less comfortable and slower bus? Or is he or she prepared to pay more money for a higher comfort level and a shorter travel time? Every respondent was offered 9 questions of this kind and in the same interview some socio-economic data were obtained about the respondent. The interviews were held in 30 different wards in Dar es Salaam, and as such people with different socio-economic backgrounds were interviewed.

After the fieldwork was finished, the data from the interviews were used to estimate the valuation of the four characteristics in terms of costs. This was performed with help of the maximum likelihood estimation procedure for the MNL model. (Multinomial Logit Model) This is by far the most used method for processing choice data in transportation research. Two adjustments were made to the available data set. First, because fieldwork experience showed that most of the respondents added the in-vehicle travel time and the walking together, these two attributes were considered to have the same utility and thus were taken together in a willingness-to-pay (WTP) estimation. Second, since many respondents gave inconsistent answers. For example: respondents

indicated that they were prepared to pay Tsh 200 (Tanzanian Shilling) for a higher comfort level, but they were not prepared to pay Tsh 200 for the same comfort increase and in addition also a travel time reduction of 20 minutes. About 40% of the respondents had at least one inconsistency in his or her answers. If this inconsistent data is added to the calculations, unrealistic outcomes are obtained, such as a positive travel fare valuation. Thus, to improve the external validity this inconsistent data has been removed.

The results when using the reduced data set indicate that commuters in Dar es Salaam have a travel time valuation of 9,61 Tsh/min or 577 Tsh/hour. Compared to overcrowded standing (like often is the case in the informal current travel mode, called daladala's) they are prepared to pay 372 Tsh for a trip with comfortable standing and 492 Tsh for a trip with a seat guaranteed.

Given this information, a comparison between the DART characteristics and the people's preferences can be made and improvements can be suggested. However, at the moment of writing this report there was no definitive decision made about the design of DART. Moreover, because of some adjustments in the data set, the estimated WTP-values could be biased to a certain extent. For this reason it is decided to do only research to the effects of a frequency change. Furthermore a list is formulated, which contains other DART characteristics that can be influenced, including the effects for bus operators and commuters because of the changes. It is more relevant to investigate changes in these characteristics when the DART characteristics are confirmed and when more certainty is obtained about the WTP values.

Taking a closer look at the effects of a frequency change in the different trunk and feeder routes during peak periods, the conclusion can be made that the frequency is almost optimized on most corridors: a frequency increase leads to a higher comfort level and a shorter waiting time, but these benefits are outweighed by the higher costs for the bus operator. A frequency decrease generally results in a travel demand that is larger than the capacity, which is not desired.

A comparison for changes in other DART variables has not been made, as already explained. However it is very interesting to make these comparisons and to determine whether certain changes in DART are beneficial for both bus operator and commuter. After all, both parties can benefit from a change. Therefore the suggestion is made to carry out a new stated choice survey to verify the valuation of the different travel attributes, like the comfort level and the waiting time. To increase the quality of future research, this report offers a number of recommendations for a new stated choice survey:

- Even though the survey design was kept simple and very visual, a significant number of inconsistencies were found in the collected data. Decreasing the task complexity will lead to less inconsistent data and thus to better estimations of the WTP-values.
- Research should be done to determine how to decrease lexicographic choice behavior.
- It is more realistic to measure the comfort valuation per minute instead per trip like in this research.
- A lot of respondents added the in-vehicle travel time and the access walking time to the bus stop together. Changing the access walking time to access walking *distance* will prevent respondents from adding both attributes together.
- Data has to be screened prematurely to determine whether the collected data is useful.
- Developing a stated choice survey according to the principles of statistical efficient designs, will improve the quality of the results.
- An additional suggestion is to estimate separate WTP-values for different socio-economic groups.

In conclusion this report shows a method to maximize the value of a BRT system for both commuters and bus operators together. An adequate analysis of the preferences of the commuters and a clear overview of the characteristics of the BRT system makes it possible to express all consequences of changes in the BRT system in terms of costs. In this way different BRT scenario's can be evaluated easily by comparing the monetary value the different alternatives generate.

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List of abbreviations

BRT	Bus Rapid Transit
CBD	Central Business District
DART	Dar Rapid Transit
DCC	Dar es Salaam City Council
IVTT	In-vehicle travel time
MNL	Multinomial logit
RP	Revealed Preference
SP	Stated Preference
Tsh	Tanzanian Shilling
WTP	Willingness-to-pay

1. Introduction

A well-functioning public transport system is an important factor for social life and the economic development of a city. Those systems decrease the travel resistance to undertake social or economic activities. However Dar Es Salaam, Tanzania, currently lacks a well-functioning public transport system. Therefore the city wants to implement a Bus Rapid Transit (BRT) system. This BRT system is expected to contribute considerably to the development of Dar Es Salaam. The system is expected to be in operation in 2010. At this moment, the project is finalizing the planning phase.

The initial main objective of this research is to determine in which extent the proposed characteristics of the DART system are in line with the preferences of Dar es Salaam's commuters, and how these can be more harmonized. During the research the focus changed to presenting a research method to compare the value of different BRT alternatives. Another important component of this research is the suggestion of recommendations to improve the quality of similar stated choice research.

Chapter 2 is an introduction to the current public transport system in Dar es Salaam and the proposed DART system. It explains the problems of the current public transport system and shows how the new DART system can solve these problems. Chapter 3 introduces the research objective, research questions and research strategy. In chapter 4 the design of the survey is explained. It strarts with an introduction to the survey technique, stated choice. Then the content of the survey and the sampling method are discussed, followed by a paragraph about the content of the questionnaire. Finally some practical matters are discussed, like the interviewer training and the pilot survey. The results of the survey are shown in chapter 5. First an explanation is given about the mathematical background of the data processing. Then a description will be given about the data that has been used and why not all data has been used. This is followed by a presentation of the results, based on the selected data set. Finally a short comparison is made to other research. Besides chapter 5 will also pay attention to the difficulties experienced in the data analysis and will come up with some recommendations to improve further stated choice research. In chapter 6 a comparison is made between the DART characteristics and the people's preferences. Research is done into the proposed frequency and how this variable can be changed to fit the DART system better with the interests of the commuters. Furthermore chapter 6 includes an explanation of a number of other variables that can be varied to maximize the value of the DART system. Finally chapter 7 concludes about the main findings and looks back on the research objective. This chapter also includes a number of recommendations for further research, because experience from this research can be used to obtain higher quality stated choice data in the future.

2. Public Transport in Dar es Salaam

This chapter introduces to the current public transport system in Dar es Salaam and discusses the proposed DART system.

2.1 Growing transportation demand in Dar es Salaam

Dar es Salaam is the largest city in Tanzania. It a coastal city in the eastern part of the country. (See Figure 2) Although Dodoma is the official capital, Dar es Salaam is the country's economic centre. The total area of Dar es Salaam is about 1800 km^2. Its population has grown from about 356.000 in 1967 to more than 3 million in 2007. Currently the population is still growing every year with more than 4% and the city is expected to reach a population of 4,5 - 6,7 million around 2035 (Population and housing census, 2002; Dar es salaam Transport Policy and System Development Master Plan, 2007; Dar es Salaam BRT Planning and Design, Final report, 2007). This population growth has led to an enormous increase in transportation demand. However the current infrastructure and public transport is not sufficient to meet the travel demand needs (Dar es Salaam BRT Planning and Design, Final report, 2007).

Figure 2: Location of Dar es Salaam in Tanzania (Source: CIA Factbook, 2008)

2.2 Current public transport situation and related problems

Currently daladala's take account for the vast majority of the public transport in Dar es Salaam (Kanyama, Carlsson-Kanyama, Lindén & Lupala, 2004). Daladala's are small buses with a capacity of 15 or 30 passengers. However, experience of both the author and several local people showed that the number of passengers often exceeds the capacity. An overcrowded small daladala (capacity 15 passengers) can carry 25-30 passengers. The Dar es Salaam Regional Transport Licensing Authority estimated that there were about 6000[1] daladala's operating in the city in 2003. The actual fare level of the daladala's is 250-350 Tsh, independent of the travel distance. Students have to pay a reduced fare (Kanyama *et al.*, 2004).

Although the daladala's are by far the most important transportation mode, there are a lot of problems relating to the daladala's. The main problems are: (Kanyama *et al.*, 2004)

- Overloading of buses: because daladala operators want to maximize their profits, they try to transport as many people as possible in one daladala. This overloading results in pick-pocketing, impaired air circulation, bad smells, sexual abuse and passenger worrying about the spread of diseases.
- Travel time: the majority of the travelers considers the travel time as long. For a lot of travelers it takes a few hours to reach the city centre during peak-hours. (including the

[1] Other documents report an estimation of 8000 daladala's in 2006.

waiting time) An interesting quote which indicates the problem of a long travel time: *"in order to minimize travel time during the morning rush hour, some commuters who live in the middle of bus routes, especially those in a hurry to work, board buses going in the opposite direction so as to return with them to the desired destination. In this way, commuters are prepared to pay the fare two-fold in order to save waiting time"* (Kanyama *et al.*, 2004).

- <u>Low comfort level:</u> a large number of passengers considers the daladala's as noisy and unclean. Also the passengers remarked the poor treatment by conductors and the dangerous driving style of the daladala drivers.
- <u>Air pollution:</u> the current transportation system has a significant negative impact on air pollution in Dar Es Salaam.

2.3 A Bus Rapid Transit as solution

The solution to these problems is to implement a high capacity transport alternative in Dar es Salaam (Dar es Salaam BRT Planning and Design, Final report, 2007). Research to different alternatives of high capacity public transport modes, concluded that a *Bus Rapid Transit (BRT)* system would fit best in Dar es Salaam. A BRT system has a high capacity and the implementation costs are relatively low: it can transport up to 40.000-45.000 passengers per hour per direction and has implementation costs of ±5 million US dollar per kilometer. In comparison, a metro has a higher capacity (60.000 pax/hr/direction) but its implementation costs are much higher, about 100 million US$ per kilometer. Trams provide a lower capacity against a higher price. And a normal bus system has a maximum capacity that won't fit the transportation needs in Dar es Salaam (Dar es Salaam BRT Planning and Design, Final report, 2007).

Figure 3: a daladala in Dar es Salaam (left) and a BRT bus in Curitiba (right)

Besides the excellent price/capacity-ratio offered by a BRT, other advantages of the system are its relatively high commercial speed; in comparison with the current daladala system the travel times will decrease considerably. Furthermore the air pollution caused by public transport will decrease, as a BRT system replaces the daladala's. Moreover, experience in other cities showed that BRT systems can operate without subsidy, despite a low travel fare (Cain, Darido, Baltes, Rodriguez & Barrios, 2006) .

In the 1980s the first successful BRT system has been implemented in Curitiba, Brazil, called the *Rede Integrada de Transporte*. Its success is illustrated by the ridership numbers in Curitiba: these numbers increased with 2,36% per year over more than two decades, while all other Brazilian cities experienced a decrease in public transport share (Wright, 2002).

Another example of a highly successful BRT system is the *Transmilenio* in Bogota, Colombia. (Population size around 7 million) The first part of the system is operating since 2000. In 2006 the system was carrying more than one million passengers per weekday. When the complete proposed network is finished, the Transmilenio is expected to carry no less than 5 million passengers per weekday. This illustrates that the BRT system has an enormous impact on the mobility in Bogota. Furthermore, it is suggested that the Transmilenio has positive impacts on the land development and the air quality around the BRT corridor (Cain *et al.*, 2006). Other advantages of the Transmilenio are the reduction in travel time by 20%, accident reduction, noise reduction and reduction on city aggressiveness (McKinsey, 2003).

Figure 4: Transmilenio in Bogota, Colombia (Source: Dar es Salaam BRT Planning and Design - Final report, 2007)

2.4 Dar Rapid Transit

As already stated, DART (Dar Rapid Transit) is the name of the proposed BRT system in Dar es Salaam. The long-term plan is to cover the whole city of Dar es Salaam by the DART system. The first part of the DART system is planned to be finished in 2010 and the whole network should be finished in 2035. If the current plans will be developed, the total corridor length will contain more than 130 kilometers in 2035.Figure 5 shows the proposed DART network (Dar es Salaam BRT Planning and Design, Final report, 2007).The DART system is designed according to the trunk-feeder concept. In the trunk-corridor high capacity buses will be used, which use segregated bus lanes. The feeders are normal buses or microbuses and will use the existing road network. These feeders will meet the trunk system on terminals, large bus stations. The presence of these feeders will affect positively the accessibility of the DART system and this will result in a higher demand on the DART system.

Later in this research, when the comparison is made between the preferences of the commuters and the characteristics of DART, more aspects of DART are discussed.

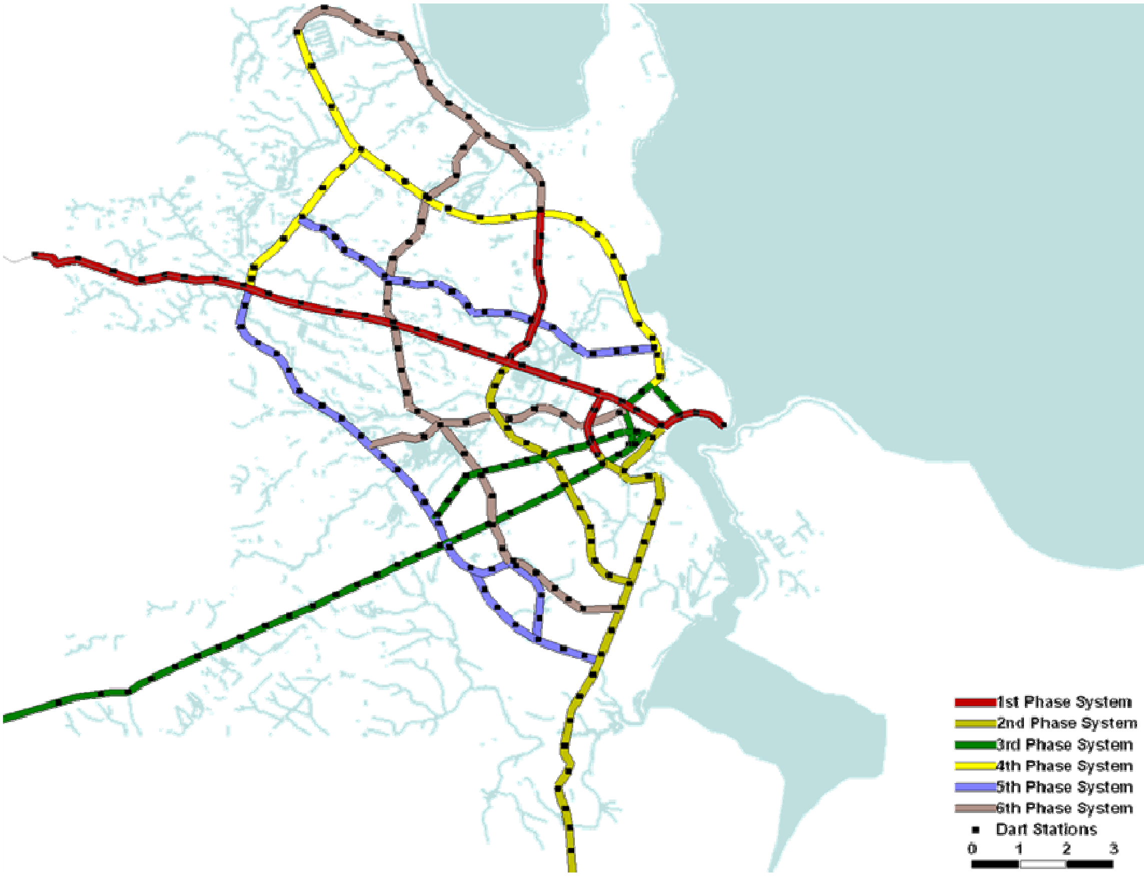

Figure 5: the complete proposed DART network

2.5 Research idea

To maximize the benefits for both bus operator and commuters, the characteristics of the DART system and the preferences of the expected users should match each other as much as possible. One could wonder whether the current set of characteristics is optimal related to the expectations and wishes of the future users. To make this point more clear, a few examples will follow:

- Do the aimed users prefer fewer stops, so that the access/egress time increases but the in-vehicle travel time decreases?
- Do they like a travel fare reduction if this has the consequence that the bus frequency lowers and the busses get busier so the comfort level decreases?

We can evaluate these kinds of questions with use of a *stated choice research*. In such a research people have to determine what set of bus characteristics they like most. People will have to make trade-offs between BRT alternatives with different characteristics. Paragraph 4.1 goes more into detail about stated choice researches. First the general research strategy is discussed in the next chapter.

3. Research plan

First this chapter introduces shortly the research goal and research question. This is followed by a more detailed description of the research questions in paragraph 3.3.

3.1 Research goal

The main research objective is:

"Making recommendations to harmonize the operational characteristics of the proposed DART system with the preferences of the targeted users by making a comparison between the planned characteristics of the DART system and the preferences of the targeted users."

3.2 Research questions

The following research questions have been determined:

1. What operational characteristics and attribute levels will be considered?
2. What sample is needed for the research?
3. How will the questionnaire be designed (visual and with respect to the content)?
4. What are the preferences of the aimed users?
5. What are the planned operational characteristics of the DART system?
6. What are the differences and similarities between the proposed characteristics of the DART system and the preferred characteristics of the future users?

More details about the questions will be given in the next paragraph.

3.3 Research design

Figure 6 shows a visualization of the research design. There is one box for every research question. First the attributes that will be taken into the research will be defined. Then the level values of these attributes have to be determined for the different hypothetical BRT alternatives. Useful data for this research part are documents about the DART system, documents about the current public transport in Dar Es Salaam, and similar researches for other cities. Paragraph 4.2 shows the result of this part of the research.

The second box on the left side mentions the sampling process. Research should be done about the size of the sample and the sampling method must be studied. Which characteristics are useful to account for in the sample? For example, think about sampling based on socio-economic characteristics of the respondent. Or sampling based on the distance to the city centre. Paragraph 4.3 goes into detail about this study object.

The third part of work before undertaking the questionnaire is the development of the questionnaire and deciding on the survey techniques. First it is required to gather information about the characteristics of an adequate stated choice survey. How many questions should the questionnaire contain? Which choice sets will be presented to the respondents? What are the visual requirements for the survey and how should the survey be conducted? (Drop-and-pick or face-to-face interview) And finally, there must be determined how to find and how to train the interviewers. Paragraph 4.4 and 4.5 are concerned with these kinds of questions.

When the initial research about the attributes, sampling and questionnaire is finished, the field work can start. It took a few weeks to attain enough completed questionnaires.

The next part of study is to define the DART characteristics (research question 5). This is performed with help of documents about DART and by interviewing members of the DART Agency. When enough data is obtained, then it is time for the next step: the processing and (statistical) analysis of the data. This will result in conclusions about the preferences of the future users of DART. *Biogeme* is used for data processing. The last step is to compare these preferences with the characteristics of the DART system and to make recommendations to harmonize the DART operational characteristics with the preferences of the aimed users. It is important to mention that the research goal is not to give *concrete* solutions to improve the DART system, but this research aims in advising which operational characteristics of the DART system should be improved or changed according to the respondents. For example, the research can conclude that the comfort of the proposed DART system should be increased, even if this needs be accompanied with a fare increase. (Paragraph 6.2) However, how this comfort increase has to be performed in practice is not part of this research.

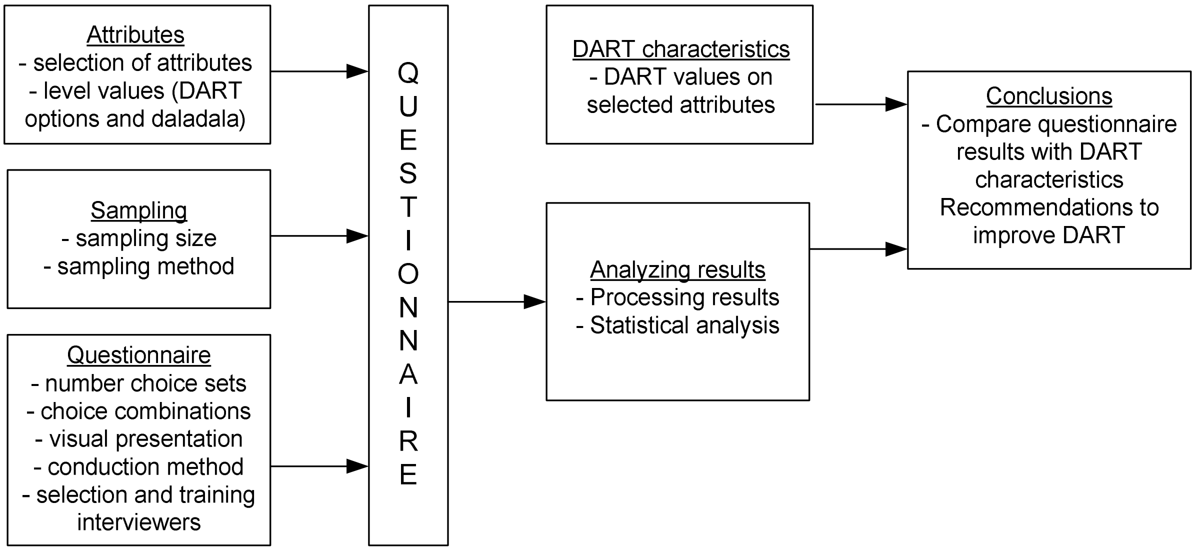

Figure 6: Research design

During the research the perspective of the objective changed to some extent. Finally the emphasis has been put on the *process* for comparing BRT alternatives instead of a concrete application of the process to compare different DART alternatives.

4. Survey design

Chapter 4 describes the methodology of the survey design. The chapter opens with an introduction to the research technique, stated choice analysis. After that the selected attributes for the research are explained. This is followed by a description of the sampling technique. Then the design of the questionnaire is described, attention is paid both to the contents and to the visualization. Finally, some practical matters are discussed, like the interviewer training and the pilot survey.

4.1 Survey technique

To determine the travel preferences of the commuters in Dar es Salaam, a stated choice survey has been carried out. This paragraph introduces the stated choice technique. After this introduction, the benefits of stated choice are pointed out to motivate the use of stated choice for this research. Also some limitations of stated choice are mentioned. The mathematical background of processing the stated choice data will follow in chapter 5.

4.1.1 Stated choice

Stated choice is one of the research techniques of the Stated Preference (SP) family. In SP studies people are offered hypothetical choices among different alternatives. Stated choice research techniques are used to obtain information about the preferences of decision makers (Shen, 2005). A stated choice questionnaire contains a number of choice sets, which include two or more alternatives. The alternatives are combinations of attributes (like travel time or comfort level) and differ on the value assigned to the attributes. The respondents have to choose their desired option from the presented set of alternatives.

To illustrate this principle, we show an example of one choice set in a stated choice research:

Transport mode	Comfort level	Travel time (in-vehicle)	Price	Choose one
Royal class bus	Seating guaranteed	30 minutes	$ 6	[ ]
Normal bus	Seating not guaranteed	40 minutes	$ 3	[ ]

The table shows an easy example of a possible choice set. Respondents have to choose the option they like most. Do they prefer to take the cheaper, but slower bus without a seat guarantee? Or do they like the more expensive bus, which is faster and guarantees a seat? The alternative labels in this example are the “Royal Class Bus” and the “Normal bus”, and the attributes are travel time, comfort level and price.

A stated choice questionnaire includes a number of this kind of questions (called choice sets). By creating a questionnaire with a large enough number of questions and distribute the questionnaire over a large enough number of respondents, one can say how people value the different attributes in relation to each other. The more attributes are covered, the better the estimation of the systematic utility. But if a higher number of attributes used, more choice sets per questionnaire are needed (Louviere *et al.*, 2000).

We can distinguish labeled and unlabeled experiments. In a labeled experiment a label is attached to each alternative, so each alternative contains extra information in addition to the attribute information. In an unlabeled experiment the choices do not contain labels. This means that respondents choose solely on basis of differences in attribute level values among the presented options (Louviere *et al.*, 2000). This research is about determining people’s travel preferences when traveling with the proposed BRT system. This means that only BRT options will be shown to the respondent, so an unlabeled questionnaire can be used. Other alternative transport options are not included in this research.

4.1.2 Benefits stated choice

Using the stated choice technique to determine the travel preferences has several benefits. Firstly, Hensher and Sullivan (2003) state that SP models are very useful for estimating marginal willingness-to-pay (WTP) values. WTP values will be an important result of this research. Those values can be used to determine whether a certain change in operational characteristics (like the average comfort level) is worth the change in costs accompanied with the operational change.

Secondly, Adamowicz, Louviere and Swait (1998) state that a wider range of attribute levels and attribute level combinations can be applied than found in real markets. The survey designer theoretically can create every attribute level value and combination he wants. A wider range of attribute level values results in more robust and statistically more efficient models. So stated choice data can be statistically more powerful than revealed preference (RP) data.

Furthermore the experiment designer is offered high flexibility (Louviere *et al.*, 2000). The designer can add alternatives or attributes levels which are currently not available. This means that it is possible to measure the utility of products or services which are not yet available. So the expected use of a new service or product can be calculated. Another advantage is that the designer has the opportunity to cut down the number of attributes of a certain product or service to only two (or three) attributes. This is highly effective for determining a certain relationship between two attributes, like travel costs and travel time.

4.1.3 Limitations stated choice

Besides a lot of benefits, stated choice has also some limitations. The first important limitation is that stated choice indicates how people they are going to choose. However, this does not indicate the way they are actually choosing when facing a real choice. There is strong evidence that most survey respondents exaggerate their WTP-values (List and Gallet, 2001). In other words: in a stated choice research respondents indicate to pay more for services or goods than they are prepared in reality.

A second limitation is suggested by Shen (2005). Here it is suggested that a stated choice research is quite sensitive to errors in the research process. A failure in one step of the research will obviously lead to incorrect results. An inadequate research design or a sampling error for example will not be compensated by other steps in the research process and thus will lead to poor outcomes.

4.2 Attributes and levels

This part of chapter 4 firstly discusses which considerations have been made for deciding on the attributes and the attribute levels. This is followed by a description of the attributes used in this research, including the attribute levels.

4.2.1 Attribute considerations

Most important reason for keeping the number of attributes small is that the task complexity for the respondent increases by the number of attributes and a higher task complexity leads to preference instability (Shen, 2005). The consequence of this instability is that less accurate results will be obtained.

Another factor that determines the number of attributes and attribute levels is the sample size. This is because a higher number of attributes requires a higher number of choice sets. Because a respondent can only answer a limited number of choice sets, the consequence is that questionnaire has to be divided in different parts which will be shown to different respondents. This will lead to higher costs to attain the same number of respondents *per choice set*. As both our financial and time resources are limited, the number of samples is limited. The budget allowed about 600-700 surveys. To make efficient use of the financial resources, the sample will be used not only for this research but also for the research of Nkurunziza. Because Nkurunziza (2008) needs a stratified sample for spatial and socio-economic analysis, the number of attributes and attribute levels should be kept small. Otherwise statistical insignificant results will be attained for the stratified samples, given the maximum number of samples of 600-700.

On the other hand, the attributes included in the research should cover all the main factors, on which choice makers make a decision (Shen, 2005). If this is not the case, then this will result in less valid stated choice data. Shen (2005) suggests organizing a pilot survey to examine whether the number of attributes in the questionnaire is appropriate.

To decide which attributes and attribute levels will be taken into the experimental design, several criteria have been set. The following criteria have been established for selecting the attributes for this research:

- The majority of the commuters has to regard the value of the attribute as important. In other words: they consider the attribute level value when choosing whether to use the bus for a trip or not. Literature research and discussion with local staff can contribute to clarify the characteristics, which people value mostly when considering a bus as transport alternative.
- It should be possible to influence and vary the attribute. Otherwise the attribute is not relevant for the second part of this research, namely the part where the characteristics will be varied to determine whether certain changes in the operational characteristics are beneficial.

Also criteria have been formulated to set the attribute level values:

- A relative large range will result in better statistical efficiency (Louviere *et al.*, 2000). However, the level values should be realistic for the study object and acceptable to the respondents (Shen, 2005). In practice this means that the maximum level should be still acceptable for the respondent and the minimum level should still be realistic for the proposed DART system.
- Louviere *et al.* (2000) suggests avoiding unbalanced designs, because unbalanced designs will lead to different statistical power between attributes. Unbalanced designs are defined as designs for which attributes have a different number of levels, which levels are not multiples of each other. So for example a design with numbers of attribute levels of 3 and 4 is unbalanced. A design with attributes having 3 and 6 levels is balanced, because 6 is a multiple of 3. For this research it means that the design should be balanced.
- The middle level value of an attribute should be about the same as the expected DART value on a certain attribute. One of the other level values should be higher than the proposed DART value and the other level value should be lower. Reason for this is that this research can accurately show the effects of both an increase and a decrease in the DART attribute level value.

There has been discussion about whether to take the trunk and feeder separately into the research or together. The choice has been made to take only one bus in the research. If we would treat the trunk and the feeder different, then the number of attributes would become too large. Moreover, it is a fair assumption that people value the attributes (like in-vehicle travel time) of the trunk about the same as the attributes of the feeder. And finally, the task complexity would become too difficult if we would treat them separately and take them in one choice alternative.

The final decision for the attributes and levels is based on the criteria stated above, on our available resources, on literature and on discussion with the local staff. The results can be found in the next paragraph.

4.2.2 Chosen attributes

The following attributes have been taken into account in the design of the experiment:

- Travel fare
- In-vehicle travel time
- Walking time to bus stop
- Comfort level

Each of those attributes will be described in the next paragraphs accompanied with a rationale for taking this attribute into the design. Also the different attribute levels will be identified.

4.2.2.1 Travel Fare

Travel fare is together with travel time one of the two primary attributes and therefore it cannot be excluded in a stated choice research to obtain a proper utility function for the BRT system in Dar es Salaam. DART will operate according to a flat fare system so every ringzone (see paragraph 4.3) will be presented the same travel fare. According to the Logit DART Investors Document (2007) the travel costs for a one-way BRT-only or feeder-only trip will be Tsh 400. The travel costs for a combination of a BRT-trip and a feeder-trip will be Tsh 500. For this reason it is a fair choice to vary the travel time around Tsh 500 to see the impact of a fare reduction of fare increase compared to the current DART proposal.

The fare intervals used for the research were intervals of 200 Tsh. A smaller difference would apparently result in that a lot of respondents who wouldn't care much about the price compared to other attributes, because the price difference was too small. On the other side, a price interval of for example 300 Tsh would be too much for a lot of commuters for a fair trade-off. This was determined after some discussion with local people from the Dar es Salaam City Council (DCC) and the interviewers (see paragraph 4.5.1). After the pilot survey there have been some doubts about increasing the interval, because larger intervals increase the statistical efficiency (Louviere, *et al.*, 2000). However, an interval between levels of Tsh 300 ought to be too much for the low-income wards. To ensure that the research would provide useful results for all socio-economic groups, the choice is made to not increase the intervals.

	All ringzones
Low	300 Tsh
Medium	500 Tsh
High	700 Tsh

Table 1: Attribute level values for travel fare

Tsh (Tanzanian Shillings) is the local currency. 1000 Tsh is equal to 0,59 euro. (October 2007)

4.2.2.2 In-vehicle travel time

The in-vehicle travel time is defined as the time that the commuter spends in the DART-vehicle to reach its destination. As the commercial speed is one of the main characteristics of a transport system and is influenced by a lot of factors, it is important to know how commuters value this characteristic. After that it is possible to find out how measures that affect the in-vehicle travel time will influence the commuters.

Given the fact that the CBD (Central Business District) is the main trip attractor (Logit 2007, Dar Es Salaam BRT Planning and Design), it is not realistic to show same travel time to people living nearby the city centre as to people living in the outskirts. For this reason the travel time considered in the stated choice questionnaire will vary among the different ringzones. (see paragraph 4.3) Respondents in wards far away from the CBD will be presented BRT alternatives with substantial higher travel times than people living only a few kilometers from the CBD. Generally the medium level of travel time is obtained by multiplying the expected trunk speed of 23 km/h with the distance to the city centre.

The amount of variation among the different attribute levels depends on the estimated travel time. The higher the estimated travel time, the higher the absolute difference among the attribute levels. However, the difference in terms of percentage is about the same: 30-40%, rounded to the nearest 5 minutes. Differences in terms of percentage are taken, because 5 minutes difference in travel time is a significant difference for a trip of 15 minutes, but almost negligible for a 60 minutes trip.

The current set of travel times is a good middle value between realism in travel times and a large enough interval for statistical efficient results. On the one hand DART will not be able to vary the travel time very much. Simply because commercial speed of a bus cannot be increased very much and also a much lower commercial speed is not to be expected. For this reason the intervals shouldn't be larger. On the other hand the intervals are large enough to have a substantial impact on the value (utility) of a BRT alternative and thus it influences the choice of a respondent.

	0-5 km	5-10 km	10-15 km	15+ km
Low	10 min	15 min	25 min	40 min
Medium	15 min	25 min	40 min	60 min
High	20 min	35 min	55 min	80 min

Table 2: Attribute level values for travel time

4.2.2.3 Walking time to bus stop

The walking time to bus stop is the walking time it takes a respondent to reach the nearest BRT trunk or feeder stop from his home. Together with the in-vehicle travel time valuation, this is an important variable for determining whether the number of bus stops should be increased or decreased. For example, when people indicate to value the walking time to the bus stop much more than the in-vehicle travel time, than an advice could be to increase the number of bus stops. As a result people have on average a shorter walking time to the nearest bus stop, while the in-vehicle travel time will increase. Also by determining the value of this attribute we can conclude whether it would be better to increase or decrease the number of feeder routes.

GIS software, ArcGIS, is used to determine the average walking time to the nearest BRT stop using the proposed BRT network in 2035. The result indicates that the walking time to the nearest BRT stop for most people lies between 0 and 25 minutes and a visualization of the results is shown in Figure 7. With help of this information, the attribute levels have been set.

	All ringzones
Low	5 min
Medium	15 min
High	25 min

Table 3: Attribute level values for walking time to bus stop

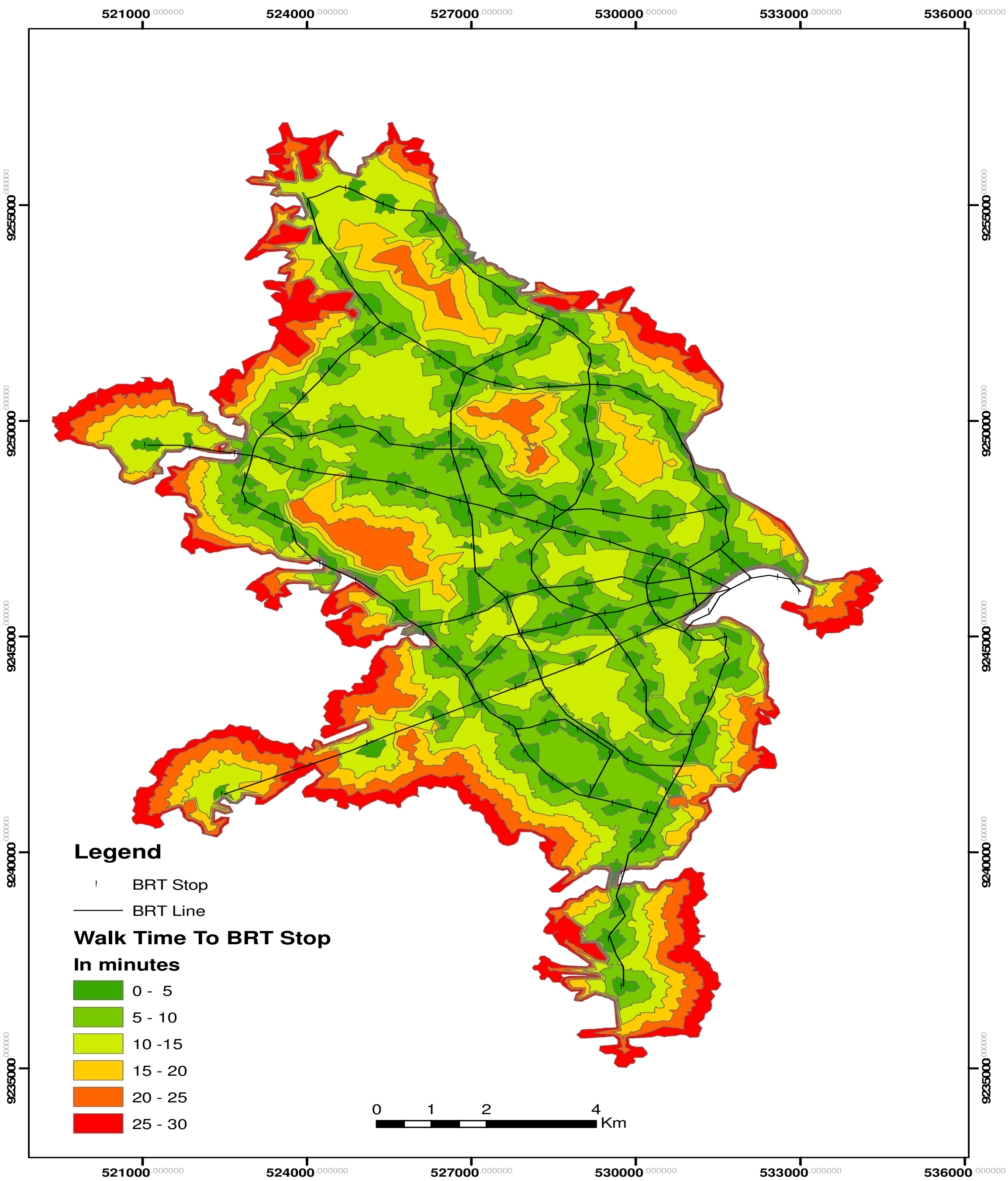

Figure 7: Walking time to nearest BRT stop

4.2.2.4 Comfort level

The fourth and last attribute of the stated choice survey is the comfort level during the trip. Comfort level is put into the research because people indicate that the low comfort level is one of the main disadvantages of the current daladala's (Kanyama *et al.*, 2004). Also it is interesting to know how much people want to pay for more comfort, because then it is for example possible to advise about the frequency and about the bus design. After all, changes in these characteristics influence the comfort level.

Also for this attribute three different level values have been defined, as shown in the table below. Idea for these three levels is obtained from a comparable study in Kolkata, India (Phanikumar and Maitra, 2006). Because the comfort level values are subjective to interpretation by the respondent, the level values should be clearly defined (Shen, 2005). In this way the interviewers can give an explanation of the values, so that the interpretation bias will be minimized. The following explanations have been used to clarify the three comfort levels:

- *Comfortable seating* means that the commuter can sit during the complete journey.
- *Comfortable standing* means that the commuter can only stand during the trip. The standing conditions are comfortable, so the commuter can easily move and leave the bus.
- *Overcrowded standing* means also that the commuter has no seat available during the trip. However, in this case the standing conditions are worse than at the comfortable standing level. People are all packed together and cannot move much. Walking through the bus is almost impossible, because of the high number of people standing.

	All ringzones
Low	Overcrowded standing
Medium	Comfortable standing
High	Comfortable seating

Table 4: Attribute level values for comfort level

4.2.2.5 Attributes not in experiment

There are some attributes not taken into this research, which one could expect in a research like this. The first one is the waiting time at the bus stop. Because the BRT trunk is expected to have a very high frequency, the waiting time is negligible compared to the in-vehicle travel time and the walking time to the bus stop. For the feeder it could be more interesting to determine the people's attitude to the waiting time. However, it is decided to not measure the valuation of this factor, because already two other attributes for time valuation were taken into the research (in-vehicle travel time and walking time to bus stop) and the number of attributes should be limited. Furthermore, it should be possible to estimate the valuation of waiting time, using the valuation of the walking time to the bus stop and/or the valuation of the in-vehicle travel time.

Other attributes like travel safety or noise are not taken into the research. The reason for this is that the number of attributes should be kept small en the assumption has been made that the importance of these attributes would be much lower than the valuation of the current attributes in the research.

4.3 Sampling method

This paragraph discusses the sampling methodology designed for this research. It is important to mention that the sample is used both for this research and for the research of Nkurunziza (2008). Because the sampling restrictions of Nkurunziza (2008) are stricter than the sample needed for this research, the sampling method strongly depends on the research of Nkurunziza (2008).

4.3.1 Sampling method

To harmonize the DART characteristics with the commuters' preferences the commuters will be treated as one homogenous group. Therefore it is important that the sample at least will cover respondents from different socio-economic backgrounds. The sampling restrictions for Nkurunziza (2008) are extracted from important parts of his research:

- Spatial analysis: the goal in this research part is to evaluate the accessibility of the DART system for people in relation to their spatial location of residence.
- Socio-economic analysis: this part of the research is concerned with determining the accessibility of the DART system for the different socio-economic groups.

The implication of the spatial analysis is that the sample should include many different wards in Dar es Salaam. Thirty wards have been selected. From every ward about the same number of questionnaires should be obtained. Given a maximum sample size of 600 samples, at least 20 samples per ward have to be obtained.

To obtain samples from the different socio-economic groups was slightly more difficult. Usually the assistance of the local ward leaders was asked and often they were prepared to provide socio-economic information about the different sub-wards.[2] In that case samples could be taken from the different sub-wards to increase the chance of getting input from the different socio-economic groups.

Finally, it was tried to exclude commuters of 15 years old and younger. Reason for this exclusion is that they usually don't have to pay trips themselves and therefore they cannot properly make assessments between money and the other attributes.

4.3.2 Sampling size

The sample size hugely depended on the available resources, both time and money. The budget allowed about 600-700 samples. Because in this research the respondents will be considered as one homogenous group, this size is large enough to obtain statistical significant results. Especially because every respondent will be presented a number of choices, so more than one choice observation per respondent will be obtained (Shen, 2005). In total 6136 choices from 684 respondents have been obtained.

4.3.3 Sampling result

The map on the next page (Figure 8) shows the spatial distribution of the wards in which the interviews have been carried out. An overview of the ward names and time schedule can be found in appendix A.1.

[2] The wards in Dar es Salaam are divided in different sub-wards.

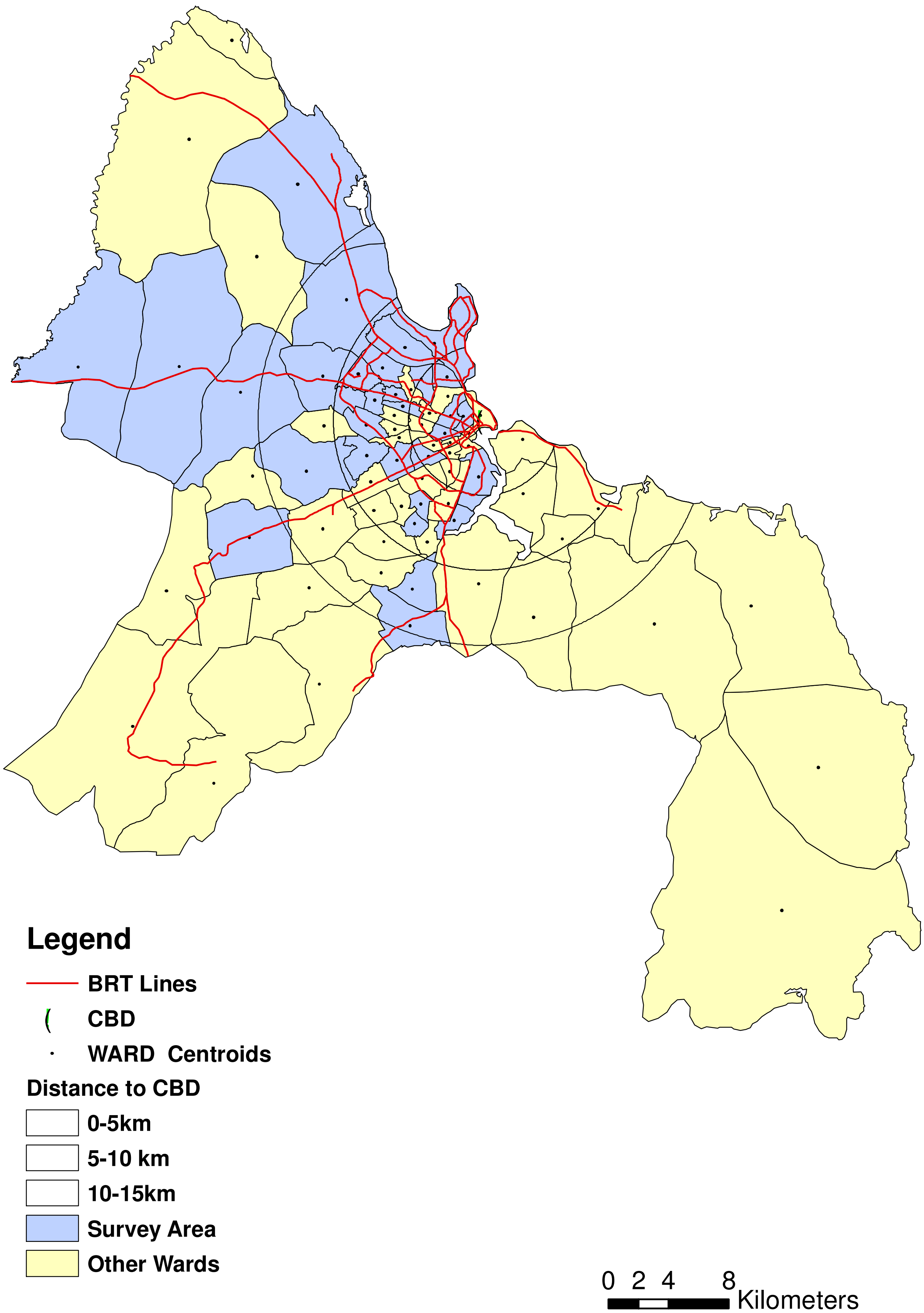

Figure 8: wards in survey

4.4 Questionnaire Design

4.4.1 Creating choice sets

The full factorial design contains 3^4 = 81 different BRT alternatives. In other words, 81 different BRT alternatives can be created with the current set of attributes and levels. However, it is not possible to include all of these alternatives in one questionnaire. Simply because the questionnaire will be too time-consuming for respondents. Moreover, a full factorial design is not needed to obtain adequate β-estimations. For this reason a *fractional factorial design* has to be used. A fractional factorial design consists of a subset of the choice sets from the full factorial design (Louviere *et al.*, 2000).

Because of limited time and limited financial resources, the decision has been made to create only one type of questionnaire. This questionnaire will be presented to every respondent. The only difference is that the level values for travel time will increase as the respondents have a longer distance from their house to the city centre. In theory it is also possible to create different questionnaires containing different choice sets and thus different trade-offs. In that way it is possible to obtain information about more trade-offs and this results in a statistical more powerful data. However, as already stated, not enough time was available to study about creating different designs.

So one type of questionnaire had to be developed and for this it is firstly needed to create a fractional factorial design. This can be done by using different methods.

- One can hold an extensive study about how to create an optimal design for a given set of alternatives, attributes and attribute levels.
- It is possible to create a design with help of a statistical computer programme like SPSS.
- The last option is to create a design by hand by randomly selecting a number of BRT alternatives and then grouping them to choice sets

The most preferred option is the first one. There have been developed a lot of sampling methods by statistical design theorists, which result in fractional factorial designs with certain statistical characteristics (Louviere *et al.*, 2000). It is useful to study some different design techniques and choose the one which would result in the most powerful data for this research. However, this option was too time-consuming, given the time available and the pre-knowledge of the researchers about stated choice.

Another option is to create a design with help of SPSS. However the design calculated by SPSS consisted too much non-realistic, thus not useful, choice alternatives. For example, SPSS came up with an alternative which had for every attribute the most negative level value. (assuming that people value time and costs negative and comfort positive) If we would add such questions into the research, then the choice outcomes were already predictable and therefore not useful. Clearly unequal alternatives cause that respondents don't take the questionnaire seriously (Louviere *et al.*, 2000).

Hence, the questionnaire design is initially created by SPSS but it is adjusted significantly by hand. The disadvantage of creating a design by hand is that the loss of statistical information can be large (Louviere *et al.*, 2000). The SPSS design created 9 different BRT alternatives. Grouping them resulted in 9 choice sets of two alternatives, so every BRT alternative appeared two times in the survey. But as already pointed out some BRT alternatives were not useful and also some choices between two realistic alternatives were not useful, because it was already known in advance which of both alternatives would be chosen. For this reason a number of alternatives has been changed by hand to realize more equal trade-offs.

A pilot was held to determine whether the generated choice sets were adequate. After the pilot survey a few changes have been made to the design. (see paragraph 4.5.3) The final design can be found in appendix A.2.1.

Not yet mentioned, but important to do, is that a calculation has been made to check whether the number of 9 choice sets is large enough for this research. The minimum number of questions needed to estimate the parameters is the same as the degrees of freedom (Louviere *et al.*, 2000). The degrees of freedom can be calculated with the following equation:

degrees of freedom = (Attribute levels-1) x Number of attributes + 1.

The degrees of freedom equals 9, and thus the number of 9 choice sets is sufficient.

4.4.2 Presentation

If attribute levels are visualized, then respondents will perceive the attribute levels more homogenously. The consequence is that the parameter (beta) estimation will be more accurately (Adamowicz, Louviere & Swait, 1998). This statement will be valid especially for the non-numeric attributes, in this research the comfort level, because different interpretations are possible for the comfort attribute levels. An example of the visualization can be found in Appendix A.2.4.

4.5 Practical issues

This chapter is concerned with several practical subjects related to the research.

4.5.1 Interviewers

To ensure the quality of the interviews and the validity of the data, capable interviewers were used. The interviewers were people with a Bachelor degree, or students currently studying for a Bachelor degree. Furthermore, the interviewers were tested in a pilot survey, to see whether they were suited for the job (see paragraph 4.5.3).

The initial idea was to use four interviewers to carry out the questionnaires. However, we experienced several problems with the availability of interviewers. This meant that in total seven interviewers were used for the questionnaire: six external interviewers and one researcher. All but one of the interviewers were presented at the training day. This meant that only one of the seven interviewers had not got the full instructions before carrying out the survey. This interviewer was instructed on the day of his first survey. After his first working day his results were checked, however, his survey data and interviewing skills didn’t give a reason for concern about the quality.

4.5.2 Training

A week before start of the fieldwork a training day has been organized. The goals of the training day were the following:

- Making the interviewers familiar with DART and our specific research goals and strategy. When an interviewer is better informed about the subject, he can better approach respondents and handle questions of respondents. This goal was realized by informing the interviewers about the DART system and about our research goals. Also an explanation is given of the research technique (stated choice) to ensure that the interviewers understand the idea of stated choice.
- The second goal was to teach the interviewers the method of interviewing. Therefore first the set-up of the questionnaire was explained to show the different parts of the questionnaire. After that the interviewers were instructed how to carry out the survey. This was followed by some test surveys, to recognize which common mistakes were made. By recognizing these mistakes during the training day, we could give instructions to the interviewers to prevent them of making these mistakes again.
- The third goal was to get input from local people to improve our research, especially to improve the questionnaire. Because both researchers are not familiar with the situation in Dar es Salaam, the interview could not be appropriate for Dar es Salaam.

The training day was held on Friday, 7 September 2007, in which test surveys were held. This was very useful, because the interviewers made several mistakes during the test surveys. The interviewers were explained how to improve their interviews. The interviewers had also some useful input to our research and design.

4.5.3 Pilot survey

On Wednesday, 12 September, a pilot survey has been carried out in Ubungo, a ward in Dar es Salaam, between 15.00 and 17.30. Every interviewer had the task to carry out six interviews. The interviewers were divided in two groups of two, both supervised by one of the researchers.

4.5.3.1 Purpose of pilot survey

The pilot survey was held for two sorts of reasons. On the one hand it was to determine whether the questionnaire was appropriate. On the other hand it was organized to prepare the interviewers for the fieldwork.
The following purposes were set for the testing of the questionnaire:

- To determine how respondents choose. If a large majority is choosing for the same alternative, it indicates that the trade-off is not good. In that case the most chosen alternative should be made less attractive or the least chosen alternative should be made more attractive.
- To determine whether the non-stated choice part of the research was suitable.
- To find out how much time the survey takes and whether the respondents like the survey. If the survey would take too much time or it would be boring for respondents, then the quality of the data will be lower.

With respect to the interviewers the following goals have been established:

- Investigate whether the interviewers are adequate to perform the survey fieldwork.
- To make the interviewers familiar with the fieldwork.
- To give interviewers information about how they can improve the interview, after observing the interviews and the interview results.

4.5.3.2 Results of pilot survey

The pilot survey was very useful, both for the research design and the interviewers. The research has undergone minor changes after the pilot. The pilot results showed that some trade-offs were not equal, and therefore two choice sets have been changed after the pilot survey. Another question has been changed, because people didn't really understand the trade off. This was a trade-off between in-vehicle time and walking time to bus stop with equal other attributes. Because the total time (in-vehicle time + walking time to bus stop) was the same, respondents found it difficult to choose or they even didn't want to make a choice.

Also the non-stated choice part of the questionnaire was changed after the pilot survey. As we already expected, a lot of people didn't want to give their income per month. Others gave unrealistic answers and this resulted in some data that was not useful. To solve this problem a question was added to the survey: the respondent was asked for his or her daily expenditures. People would be more willing to give their daily expenditures than to give information about their income.

The pilot survey appeared to be useful for the interviewers too. At first to get some experience with interviewing. They learned to start the interviews with a good introduction and explanation of the research. Also the interviewers made several mistakes during this pilot survey. Some were not asking all the questions. Others forgot to fill in the form occasionally. After the survey the interviewers were informed about the mistakes they made, so that they didn't repeat the mistakes in the real survey.

4.5.4 Survey language

The survey has been printed and carried out in Swahili. Both English and Swahili are spoken in Dar es Salaam, however English is not well-understood by everybody in the city. To be able to reach everybody in the city the questionnaire was translated into Swahili. The interviewers themselves have assisted in translating the questionnaire. First they all made an individual translation. After that the interviewers came together to discuss about the translation and to finalize the translated questionnaire.

5. Survey results

This chapter discusses the method of data processing and the results of the survey. In the first paragraph the theoretical background of the data processing is explained. After that an analysis of the quality of the data is made and summary of the used data is given. This is followed by an overview of the results of the data processing. Finally the survey results are compared with other research.

5.1 Method of data processing

Before relevant conclusions can be made about the people's travel preferences, the stated choice data has to be transformed into utility parameters (beta-values) for the different attributes. These utility parameters indicate in which extent people value a certain attribute.

5.1.1 Mathematical background

The stated choice data has been processed using the MNL (Multinomial Logit) model. This is by far the most used model for processing data from choice experiments in transportation research (Ben-Akiva and Lerman, 1985; Louviere *et al.*, 2000). This model assumes that individuals choose the alternative that maximizes the individual's utility. The utility function is defined as follows: (Louviere *et al.*, 2000)

$$U_i = V_i + \varepsilon_i \quad (1)$$

U_i = the utility of alternative i
V_i = the systematic utility component of alternative i
ε_i = the random utility component of alternative i

The formula to calculate V_i depends on the attributes that will be considered in the research. The basic form of the formula looks as follows:

$$V_i = \sum_S (\beta_S X_{iS}) \quad (2)$$

V_i = the systematic utility component of alternative i
X_{iS} = the value of alternative i on attribute S
β_S = the utility coefficient associated with attribute S

Applying this equation on this DART case, generates the following equation:

$$V_i = \beta_{Fare} X_{i,Fare} + \beta_{TT} X_{i,TT} + \beta_{CF2} X_{i,CF2} + \beta_{CF3} X_{i,CF3} \quad (3)$$

This equation shows that four different β-parameters need to be estimated, respectively for the travel fare, the travel time, and two β-parameters for the comfort valuation. (in-vehicle travel time and access walking time will be taken together, see paragraph 5.2.2) Because the travel fare valuation and the travel time valuation are considered to be linear (i.e. the difference between 300 Tsh and 500 Tsh is the same difference as the difference between 500 Tsh and 700 Tsh), just one β-parameter has to be estimated for these attributes. For the comfort valuation two different parameters have to be estimated, since the difference between comfort levels is not linear: the difference between comfortable standing and comfortable seating is not the same as the difference between overcrowded standing and comfortable standing. This implies that *n-1* β-estimations are needed, with *n* the number of attribute levels, and in this case *n = 3*. In this research a β-estimation has been made for overcrowded standing and comfortable seating. However, for the survey results it does not matter which two comfort levels will be estimated.

According to the MNL model the probability that individual *q* is choosing alternative *i* is calculated as following:

$$P_{iq} = \frac{\exp(V_{iq})}{\sum_{j=1}^{J} \exp(V_{jq})} \quad (4)$$

P_{iq} = the probability that individual q chooses alternative i from a set alternatives j
V_{jq} = the utility for individual q on alternative j

To be able to calculate the utility, the β-values need to be estimated. This can be done by using the maximum likelihood method for the MNL model (Louviere *et al.*, 2000). The equation below shows the log likelihood function:

$$L^* = \sum_{q=1}^{Q} \sum_{j=1}^{J} f_{jq} \ln P_{jq} \quad (5)$$

L* = the log-likelihood
f_{jq} = a dummy variable for individual q on alternative j; if individual q chooses alternative j, then f_{jq} = 1, if individual doesn't choose alternative j, then f_{jq} = 0

Goal is to maximize the log-likelihood L* by changing the β-values. The set β-s that generates the maximum likelihood is the best estimation of β-values, given the available dataset. Maximizing the likelihood is performed by using *Biogeme*, a computer programme. *Biogeme* is a mathematical tool to maximize the log-likelihood and estimate the β-values (Bierlaere, 2003).

5.1.2 Statistical significance tests

To measure the statistical significance of the results a number of tests should be performed. There is a test to measure the overall goodness-of-fit of the model and a test to measure the significance of the utility parameters.

The overall goodness-of-fit of the model:

$$\rho^2 = 1 - \left(\frac{L^*(\hat{\beta})}{L^*(0)}\right) \quad (6)$$

L*(β) = the maximized value of the log-likelihood function
L*(0) = the value of the log likelihood evaluated such that the probability of choosing alternative i is exactly equal to the observed aggregate share in the sample of the ith alternative (Louviere *et al.*, 2000).

ρ^2-values between 0,2 and 0,4 are indicative for an extremely good model fit (Louviere *et al.*, 2000).

The statistical significance of the utility parameters should also be tested, to determine whether the estimated β-values are significant and thus useful. A test for significance of the β-values is the t-test. A t-test value of 1,96 or higher means that there is a 95% or greater confidence that the mean is statistically significantly different from 0. A t-value of 3,29 indicates that there is a 99,9% confidence that the mean is different from 0 (Bierlaire, 2003).

5.1.3 Willingness-to-pay values

The WTP-values can be calculated from the obtained set of β-parameters. This calculation is simple:

$$WTP_S = \frac{\beta_S}{\beta_{travel\ costs}} \qquad (7)$$

WTP_S = the willingness-to-pay for a certain travel attribute
β_S = the estimated β-parameter for attribute S
$\beta_{travel\ costs}$ = the estimated β-parameter for the travel costs

5.2 Data analysis

During two weeks data is collected from 30 different wards in Dar es Salaam. However, not all the data has been used to calculate the WTP-values for the operational characteristics of the DART system. This paragraph mentions which data is selected for the calculation of the utility parameters and which data is excluded.

5.2.1 Inconsistent data

The initial data set has the following characteristics:

Variable	Number
Total sample	684
Net observations	6136

Table 5: Summary of all data

However this data set is not useful for estimating the β-parameters. Estimating the β-parameters with use of this data set produces unrealistic results (see appendix A.3.1): the in-vehicle travel time, the walking time to the bus stop and the travel fare all have a positive β-estimation. This indicates that commuters prefer to pay a *higher* travel fare and prefer to have a *longer* travel time, which of course doesn't correspond to the reality.

One reason that causes this poor result is that a lot of inconsistencies were found when analyzing the answers of single individuals. With inconsistencies are meant choices of single respondents that are not consistent with previous or subsequent answers of the same individual (Saelensminde, 2002).

A concrete example is needed to clarify this definition: suppose a stated choice survey in which the respondent has to answer two choice sets, like in Figure 9. These choice sets contain three attributes: travel time, travel costs and the comfort level. In the first choice set is determined whether the respondent is prepared to pay 200 Tsh for a higher comfort level. The second choice sets determines whether the respondent is prepared to pay 200 Tsh for both a higher comfort level and a shorter travel time. Given the assumption that higher travel costs and higher travel time are valued negative and a better comfort level is valued positive, then one combination of choices is not logic: choosing 1B and then 2A. This implies that the respondent is prepared to pay 200 Tsh for better comfort, but he or she doesn't want to pay 200 Tsh for better comfort, and also a shorter travel time.

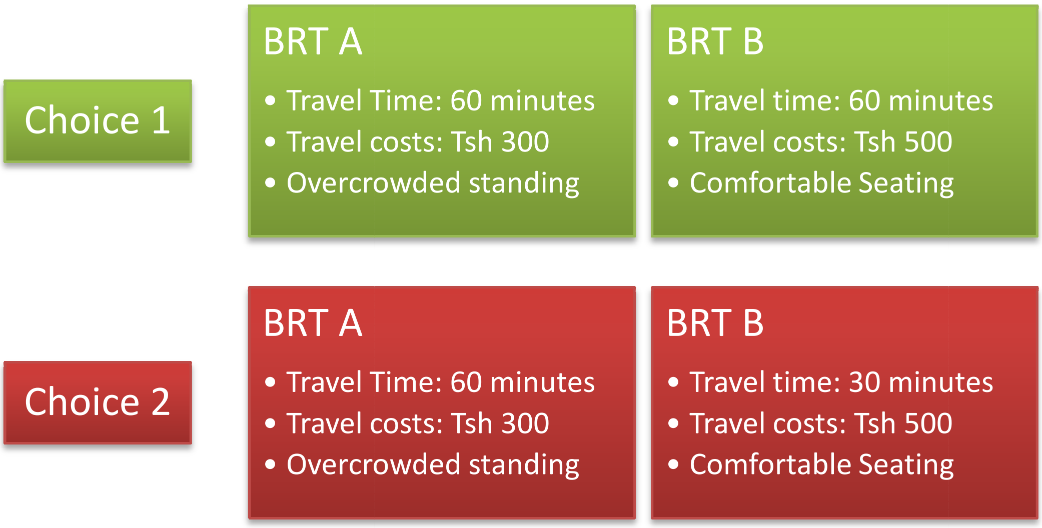

Figure 9: Two hypothetical choice sets

This kind of inconsistencies were made quite regularly. Data analysis shows that almost 40% of the respondents had at least one inconsistency in his or her answers. This has a negative impact on the results of the data processing, as shown earlier in this paragraph.

One of the causes of the inconsistencies can be the task complexity. Research shows that the task complexity has a significant impact on the quality of the collected data (Arentze, Borgers, Delmistro & Timmermans, 2003). The most important variables which determine the task complexity, are the number of attributes and the number of alternatives per choice set. This study minimized the number of alternatives per choice set. However the number of attributes could be too large, as fieldwork experience showed that respondents sometimes considered it difficult to make a choice based on all attributes.

Another reason for the inconsistencies could be that people become used to several aspects of the questionnaire. A good example are the answers regarding the last two choice sets, which are the only two choice sets with a fare difference of 400 Tsh between the two alternatives. Both choice sets offer a trade-off between a fare reduction of 400 Tsh, and a better comfort level *plus* a shorter travel time. However, the extra comfort and travel time reduction in choice set 9 are smaller than in question 8. Nevertheless, a significant number of respondents (about 15%) was prepared to pay an additional 400 Tsh in choice set 9, but they were not prepared to pay the additional 400 Tsh in choice set 8. (for a higher travel time reduction *plus* a higher increase in comfort compared to choice set 9). The explanation could be that respondents become used to the large fare difference in choice set 9, and therefore they don't consider the fare difference anymore that much as in choice set 8.

Finally, the survey is held in a developing country. Bulmer and Warwick (1983) and van der Reis (1997) indicate that conducting surveys in developing countries is more difficult than in developed countries, and this negatively influences the quality of the collected data. There are a number of causes related to this subject, which could be explanations for the less satisfactory results of *this* research (van der Reis, 1997):

- Respondents in developing countries find it difficult to make choices for *hypothetical* alternatives (in this research the BRT system), because they consider it hard to imagine the hypothetical situation
- Respondents have little familiarity with the interrelationships within the survey and therefore they are unable to make valid judgments based on previous choice sets
- Respondents choose alternatives they think the interviewer or the organization prefers

- Task complexity plays a larger role in developing countries than in developed countries; the effect of task complexity is already described earlier in this paragraph

To minimize the effect of these causes, the questionnaire was translated into Swahili, the choices sets were visualized, and a proper introduction to DART and to the survey technique was presented to the respondents. Also discussion was held with the interviewers to determine whether the survey was adequate for Dar es Salaam.

To increase the external validity of the data, the inconsistent data has been removed. Assuming that the travel time and the travel costs are valued negatively and that higher comfort levels are valued positively, four choice combinations are not consistent. Only choice combinations that are under this assumption unquestionable inconsistent have been removed. There are also some other choice combinations unlikely, but for these choice combinations it cannot be taken for granted that they are really inconsistent. It can also be the case that the respondent has a very high or a very low valuation for one or more attributes.

In appendix A.3.2 an overview is given of the four choice combinations that are considered as inconsistent. Respondents that made at least one inconsistent choice combinations have been removed from the data set to estimate the utility parameters.

5.2.2 Travel time

To estimate the utility-parameters the in-vehicle travel time and the walking time to the bus stop are taken together. The motivation for this is that the observation was made that most respondents added both the in-vehicle travel time and the walking time together to determine their preferred alternative. They didn't consider those two attributes separately. Moreover, the results from the pilot survey support this observation. In the pilot survey there was one question with the same total travel time but a different in-vehicle travel time and walking time to the bus stop. The comfort level and the travel fare were equal. During this pilot several respondents didn't understand this question or didn't want to answer the question, because they considered the two alternatives as equal.

5.2.3 Lexicographic choices

During the fieldwork the observation was made that a significant part of the respondents turned out lexicographic choice behavior. Lexicographic behavior means that people are making choices based on only one attribute. Lexicographic behavior is for example the case when respondents always choose the cheapest alternative, without considering the level values of the other attributes. However, lexicographic choices do not imply that respondents have lexicographic preferences (Saelensminde, 2006).

Despite this theory, lexicographic choices have not been excluded from the data set. Reason is that it is not possible to ensure whether a respondent is choosing lexicographic or whether a respondent has a very positive or negative valuation of one of the attribute levels. For example, a significant part of the respondents avoided choosing for alternative with comfort level 'overcrowded standing'. It is incorrect to remove the data of the respondents who avoided the alternatives with overcrowded standing, since they can value this situation very negative and they can be prepared to offer much money or time for a better comfort valuation. The trade-offs in this research are not large enough to verify whether lexicographic behavior is really the case.

5.2.4 Data used in calculations

After exclusion of the data of respondents that made at least one inconsistency, 415 (61%) of the 684 questionnaires were still useful to estimate the utility parameters. The following table is a summary of the used data for the calculations made in paragraph 5.3; this is the data excluding the inconsistent data.

Variable	Number of respondents
Total sample	415
Net observations	3719 (observations)
Male	227
Female	187
Unknown	1
Age < 15	3
15-24	95
25-44	238
45-64	63
>65	9
Not given	7
Monthly income <50.000 Tsh	33
50.000-100.000 Tsh	61
100.000-200.000 Tsh	78
200.000-500.000 Tsh	66
>500.000 Tsh	25
Not given	152
Ringzone 1 (0-5 km)	79
Ringzone 2 (5-10 km)	216
Ringzone 3 (10-15 km)	45
Ringzone 4 (15+ km)	75

Table 6: Summary of all consistent data

Table 6 indicates that the sample was diverse over the two sexes, age-groups and socio-economic groups. The sample for the highest income group (more than 500.000 Tsh per month) is smaller than the other groups, but it should be mentioned that the relatively wealthy people are usually less prepared to give details about their income level.

5.3 Results

The table below shows the β-estimations, using the data set described in paragraph 5.2.3. Estimation of the utility parameters has been performed using the methodology described in paragraph 5.1.

Attribute or level	β-estimation	t-test
Overcrowded Standing	-1,36	-17,43
Comfortable Seating	0,440	5,08
Travel Fare	-0,00366	-11,42
Total Travel Time	-0,0352	-13,36

Table 7: Utility parameter estimations

The ρ^2-value is 0,080, which indicates relatively poor model fit. Nevertheless all parameter estimations are in the good direction (plus or minus sign): a higher travel time and a higher travel fare are valued negatively, overcrowded standing is valued negatively compared to comfortable standing, and comfortable seating is valued positively compared to comfortable standing. Besides this, all t-test values are very high. Later in this paragraph, a number of remarks are made regarding these results.

The WTP-values are shown below and are calculated with help of the equation from paragraph 5.1.

Travel characteristic	WTP
Comfortable Standing (per trip)*	372 Tsh
Comfortable Seating (per trip)*	492 Tsh
Total travel time (per minute)	-9,61 Tsh

Table 8: WTP values

** compared to overcrowded standing*

The WTP for the comfort levels (i.e. comfortable standing and comfortable seating) is compared to the comfort level overcrowded standing. Hence, the *average* commuter is prepared to pay an additional 372 Tsh for a trip with a comfort level of comfortable standing instead of overcrowded standing. If a seat is guaranteed he wants to pay for this seat an additional amount of (372 + 120 =) 492 Tsh compared to a trip with overcrowded standing. Furthermore, if a trip is shortened by 1 minute, the *average* commuter is prepared to pay 9,61 Tsh. This correspondents with a travel time valuation of 577 Tsh per hour.

A few comments have to be made with regard to estimated utility parameters and the calculated WTP-values. Firstly, one should realize that it is questionable to talk about the term *average commuter.* A socio-economic analysis falls outside the scope of this research, but it is very obvious that the different socio-economic groups have quite diverse perceptions about the value of the travel characteristics. Also other characteristics of commuters can have impact on the perception of the commuter.

Secondly, the WTP-values for comfort have been calculated per trip. However, it is likely that the comfort valuation will depend on the trip duration. This means for example that the WTP-estimations will not be valid for very short trips. A recommendation for future research is to estimate the WTP-valuation for comfort *per minute* instead of *per trip*.

Thirdly, in paragraph 5.2 a number of remarks has been made about the data, and some adjustments have been made (adding in-vehicle travel time and access walking time together, and removing the inconsistent data). These factors have a negative impact on the quality of the data.

Finally a remark to the estimated values is that people usually overestimate their WTP in stated choice surveys (List and Gallet, 2001). This comment is supported by some research, which suggests lower WTP-values. (see paragraph 5.4)

5.4 Comparison to other research

The estimated WTP-values are interesting information. However, this information cannot be considered as the undisputable truth. Several factors can have biased this research; a number of them have been discussed already earlier in this chapter. Therefore it is good to make a comparison to other research. In this paragraph a comparison will be made for the travel time valuation. A comparison for the comfort valuation hasn't been made, as there are no relevant sources to compare the WTP-values calculated in this research.

In 2007, another stated preference survey in Dar es Salaam was held by the Japan International Cooperation Agency (JICA) to determine the travel time valuation of the current daladala commuters. JICA concluded that the travel time valuation of the commuters in Dar es Salaam is 1,88 Tsh/min. (Source not yet available) This is considerably lower than the 9,61 Tsh/min found in this study. One obvious reason for this difference is that the average monthly income of the respondents from the JICA study is about 89.000 Tsh, while the average monthly income from the respondents in this study is 225.000 Tsh. A reason for this difference in average income can be that JICA carried out their interviews on daladala terminals, while this research was held in 30 different wards in Dar es Salaam, including a substantial amount of respondents from high-income socio-economic groups.

Besides the WTP-values from the JICA research, local experts on transportation research (from the DCC Transportation Unit) indicated that the travel time valuation in Dar es Salaam was around 5 Tsh/min. Furthermore, the BRT Planning Guide (2007) introduces another method to estimate the valuation of travel time. This guide suggests that it is possible to estimate the travel time valuation with help of the following formula:

$$Travel\ time\ valuation = 50\% * Average\ salary\ per\ hour \qquad (8)$$

The formula suggested by the BRT Planning Guide results in the following valuations of travel time: assuming 160 working hours per month and using the salary found by the JICA survey, then the travel time valuation is 4,64 Tsh/min. Using the average monthly salary found in this research results in a travel time valuation of 11,72 Tsh/min.

The conclusion can be made that the WTP-value for travel time, estimated with data of this research, is significantly higher than the other sources indicate. But also the WTP estimations of the other documents are not unanimous.

Finally, a remark with respect to the difference between the in-vehicle travel time and the access walking time: Ward (2004) suggests that the ratio of *access walking time valuation : in-vehicle travel time valuation* is 2:1 or 2,5:1. In other words, people dislike walking to a bus stop 2 – 2,5 times more than travelling in the bus. This is not in line with the experience in this research. Many respondents added the in-vehicle travel time and the walking time to the bus stop together to determine their preferred alternative. Hence, this indicates that both durations are valued equally by respondents in this research.

6. Comparison of the proposed DART system to the people's travel preferences

Chapter 4 and 5 informed about obtaining information regarding travel preferences of the commuters in Dar es Salaam. Because the goal of this research is to make a comparison between those preferences and the actual proposed DART system, the next step is to determine whether certain changes in the DART system are beneficial. Paragraph 6.1 describes the comparison method. Paragraph 6.2 determines the effects of changing the frequency of the trunk and feeder system. Finally paragraph 6.3 discusses other variables that can be varied and that will have effect on the value of the BRT system.

In advance it is very important to underline that the comparison and the related suggestions are based on the WTP-values estimated in paragraph 5.3. As already discussed, these estimations are uncertain and further research has to be done to obtain more certainty about these WTP-values. Furthermore, the DART characteristics haven't been confirmed yet. Currently there are still studies going on about the design of the DART system. The basis for this comparison is a report of Logit (Logit 2007, Dar Es Salaam BRT Planning and Design). However, during the course of this research a new report has been published, with a new operational plan for DART phase 1.

Thus at this moment there is still uncertainty about both the preferences of the commuters and the DART characteristics. For this reason this report only discusses extensively the effects of a frequency change. Of course there are also other DART characteristics that can be varied to increase the value of the DART system. Therefore this report mentions these characteristics and shortly explains how a comparison can be made to optimize these characteristics.

6.1 Comparison

Paragraph 6.2 discusses the effect of a frequency change of the DART system. Before those effects will be shown, the method of comparison will be described and relevant assumptions have to be discussed.

6.1.1 Method of comparison

In the comparison the current proposed DART system will be considered as the DART 0-alternative, which will be compared to the DART new-alternative. The frequency will be evaluated to find out whether a certain change in this characteristic is beneficial for the commuters and the bus operator. It is important to mention that a change in one operational characteristic will affect also other elements of the DART system: a change in frequency will not only change the average waiting time, but also the bus comfort level and the operating costs for the bus operator. To make an adequate comparison all affected attributes will be taken into the comparison.

Because this is not a financial research, price elasticity (or better: utility elasticity) is excluded from this research. This seems to be wrong, but this is not the case: it is possible to keep the generalized utility for the commuter the same by varying the travel fare. And if the generalized utility is kept the same, then utility elasticity effects are excluded. To illustrate this idea, consider the next example: a frequency increase will lead to shorter waiting times, and because people value waiting time negative, the shorter waiting time will result in a positive utility increase. If the travel fare would be kept the same, then the utility of a trip would increase and more people would make a trip with the BRT. But given the current data set and information it is not possible estimate the extra number of travelers. However, it is possible to keep the utility unchanged by increasing the travel fare with the same amount as the decrease in generalized costs. (which decreased as a result of the shorter waiting time). Because the commuters' utility will remain the same, now the travel demand for the DART system will stay the same as before the change. (Note that the effect of a frequency increase on the comfort level is excluded from this example.)

The next step is to compare the commuters' total extra WTP for the frequency increase, with the extra costs for the bus operator. (as the bus operator has more operating costs since the frequency is increased). If the extra WTP of all commuters is higher than the extra operating costs, then the change is beneficial: the bus operator can increase the amount of travel fare with the same amount as the decrease in generalized costs for the commuter. The difference between the total extra revenues and the total extra costs is the extra profit for the bus operator.

So in fact it is an optimization to maximize the benefits of the bus operator. However, it is possible to share the benefits of the operational change by the bus operator and the commuters. This can be performed by increasing the travel fare with less money than the decrease in generalized travel costs. But a already stated, this results in a change in the commuters' utility and a utility change will lead to a change in travel demand, which is not part of this research.

6.1.2 Assumptions

Given the limited time available and some other practical matters a number of assumptions has been made. The most important assumption is that all the commuters will be treated as one homogenous group with the same travel preferences. More mathematically, this means that the estimated beta-parameters and WTP-values (see paragraph 5.3) are valid for every commuter. This assumption has been made because the comparison would be too complex and too time-consuming if distinction was made among different groups.

A second assumption is made about the comfort valuation. The stated choice research produced utility parameters for the different comfort levels: comfortable seating, comfortable standing and overcrowded standing. However, the comfort valuation for standing should be considered on a continuous scale. It is not realistic to assume that the comfort level will change from comfortable standing to overcrowded standing vice versa, if only *one* passenger enters or leaves the bus. The comfort valuation will increase and decrease gradually. Therefore, the following set of rules have been established to determine the comfort in a bus:

- If a passenger can have a seat, then the passenger will have a comfort valuation that is obtained from the WTP-estimation for comfortable seating – independent from the number of passengers standing in the bus.
- If the standing capacity is used for 0-50% (i.e. 0-3,2 passengers per m^2), then it is assumed that people can stand comfortably. The passengers that have a seat will value the comfort still as comfortable seating and the passengers standing will value the trip as comfortable standing.
- If the standing capacity is used for 50-100% (i.e. 3,2-6,4 passengers per m^2), then the standing passengers will experience the trip as overcrowded. Because there is a difference between 3,2 passengers per m^2 and 6,4 passengers per m^2, the comfort valuation will become lower as the number of passengers increases from 3,2 to 6,4 per m^2. If the maximum number of passengers is reached (i.e. 6,4 passengers per m^2), than all standing passengers have a comfort valuation that is the same as the WTP-estimation for overcrowded standing. See appendix A.4.1 for a more extensive explanation of the comfort valuation.
- The comfort level for the whole trunk or feeder corridor is calculated on basis of the *average* number of passengers per bus over the whole corridor. In reality the comfort level changes after every bus stop, but it is far too complicated to calculate the comfort level between every two bus stops.

The third assumption is about the number of passengers per corridor. Logit (2007, Dar Es Salaam BRT Planning and Design) provides information about the number of passengers per hour per corridor. Additionally this Logit document provides a visualized overview of the number of passengers between two connecting stations, for every corridor. This information contributed to the following assumptions with respect to the number of passengers:

- The maximum number of passengers per bus (on a certain section of a corridor) on a certain corridor is calculated by dividing the total number of passengers in the peak direction per hour by the number of buses per hour.
- The average number of passengers *per bus* is estimated with help of the following equation:

$$Avg.\,passengers\ per\ bus = \frac{Passengers\ per\ hour}{Frequency\ per\ hour * Avg\ trip\ length\ \ in\ \%\ of\ total\ corridor\ length} \qquad (9)$$

The average trip length in percentage of the total corridor length can be estimated from the Logit study (2007, Dar Es Salaam BRT Planning and Design).

See appendix A.4.3 for an overview of the passenger data used for the calculations.

6.2 Frequency

First this paragraph explains the theoretical background specific for the optimization of the frequency. After that the results of the calculations are discussed.

6.2.1 Theoretical background

The characteristic that will be discussed is the frequency of the trunk and the feeder during peak-hours. Changing the frequency has several advantages and disadvantages for both the bus operator and the commuter. A higher frequency will result in a shorter waiting time for the commuter. Also the commuter will experience a higher comfort level, because there is more bus capacity and thus less passengers per bus will be transported. For the bus operator the effect of a higher frequency is that the operating costs will increase. A frequency increase in the off-peak hours results in higher variable costs per hour:

- More operating buses result in higher bus costs like fuel, maintenance, etc.
- More operating buses require more bus drivers so the labor costs will increase

During the peak-hours an extra cost object has to be added if the bus operator wants to offer a higher frequency:

- The proposed DART system uses 100% of the bus capacity during the peak hours (excluding reserve fleet; Logit 2007, Dar Es Salaam BRT Planning and Design). If the peak-frequency increases then the fleet size should increase too, which leads to higher bus investment costs.

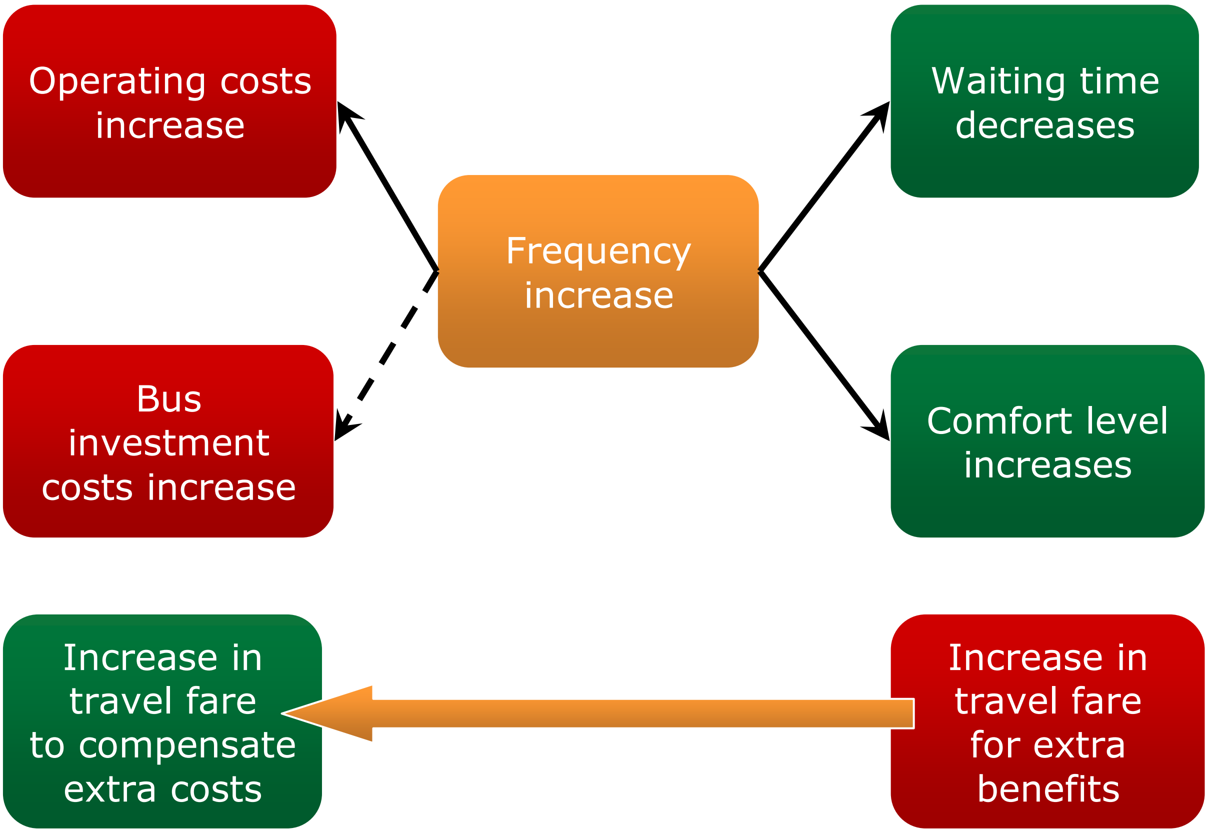

Figure 10: Effects of a frequency increase

For a frequency *de*crease the other way applies: the waiting time increases and the comfort level decreases for the commuter. For the bus operator the operating costs and the bus investment costs will decrease. In this case the bus operator has to compensate the commuter for the lower quality of the transport level. Notice that also this change can be beneficial: if the money savings by the bus operator are higher than the loss in transport value for the commuter, than the change is favorable. To determine the value of a change the following basic equation has been defined:

$$\frac{\Delta Value}{hr} = \frac{\Delta Value\ (all\ passengers) + \ \Delta Value\ (bus\ operator)}{hr} \qquad (10)$$

Thus the value of a new alternative compared to the 0-alternative is the sum of the change in value for all passengers together and the change in value for the bus operator.

The change in value for the passengers is calculated with help of the following equation:

$$\frac{\Delta Value\ (pass)}{hr} = Pass.per\ hour * \ \left(\Delta Avg\ WTP_{comfort} + \Delta Waiting\ time * WTP_{wt}\right) \qquad (11)$$

An additional note is needed for the comfort valuation. During peak hours the travel demand will be higher in the direction of the CBD. This implies that the average number of passengers per bus will be higher in this direction, and thus the comfort level will be lower. For this reason two calculations have been made to determine the comfort level: one for both directions. These comfort values are multiplied with the number of passengers per hour in the certain direction.

The change in value for the bus operator can be calculated using the following equation:

$$\frac{\Delta Value\ (bus\ operator)}{hr} = \Delta Operational\ fleet * \left(\frac{Bus\ costs}{hr} + \frac{Bus\ inv\ costs}{hr} + \frac{Labor\ costs}{hr}\right) \quad (12)$$

Appendix A.4.4 includes a detailed explanation of the equations shown above.

6.2.2 Changing the frequency of DART

For every trunk and feeder route a calculation has been done to determine whether the frequency change is beneficial. This calculation considers the changes in the attributes, as shown in Figure 10 and uses the equations from paragraph 6.2.1 and Appendix A.4.4. The calculation is performed only for the peak hours (6.00-8.00 and 17.00-19.00; Dar es Salaam BRT Planning and Design, Final report, 2007), because there is not enough information available about the off-peak hours.

The calculations show that the bus frequency in the current DART proposal is almost optimized during the peak hours for 6 out of 7 trunk lines. A frequency decrease leads to a travel demand that exceeds the capacity. This is not preferred at all. A frequency increase leads to higher travel costs per kilometer for the bus operator and to a lower waiting time and higher comfort level for the commuter. However, these benefits for the commuter are lower than the extra costs for the bus operator. This indicates that a certain change will lead to a lower total value and thus the change is not desired.

Only a frequency change for trunk line 3 is beneficial.[3] Logit (2007, Dar Es Salaam BRT Planning and Design) suggests a bus fleet of 33 buses for trunk line 3 during peak hours. However, increasing this number by 10 buses to 43 will generate more value. The extra benefit in terms of money per hour equals about 300.000 Tsh. A remark that has to be made is that the passenger data of trunk service 3 might be incorrect, because a fleet of 33 buses is clearly not sufficient to meet the transportation demand. This remark is supported by the fact that the data suggests that the number of passengers in the busiest direction is *smaller* than the demand in the other travel direction. And of course, this cannot be the case.

Just like the trunk services, a comparison can be made between the people's preferences and DART characteristics for the feeder services. The comparison for the feeder services also indicates that most feeder services the frequency (or assigned fleet size). There is one change that can increase the value of a service with a small amount: increasing the fleet size for feeder 6 from 12 buses to 15 buses. This will result in a frequency change from 26.7 to 33.3 buses/hour. The extra value that will be created equals almost 100.000 Tsh per hour.

The conclusion is that the frequency for the proposed trunk and feeder services of DART is optimized during the peak periods for almost all of the services. The solution with the highest value is generally a capacity that just exceeds the travel demand. Commuters are not prepared to pay a higher travel fare for a shorter waiting time and a higher comfort level. The finding that people hardly value the changes in waiting time is logical, because in the 0-alternative the frequency is already very high during peak periods, which means a short average waiting time. The average reduction in waiting time as a result of a frequency increase is marginal in that case: less than a minute or only a few minutes, and this has not much value for the commuter.

[3] An overview of the trunk and feeder services can be found in the Logit document (2007, Dar Es Salaam BRT Planning and Design)

6.3 Other relevant characteristics

This paragraph suggests other characteristics that can be considered within the framework of maximizing the value of DART. As already explained, the WTP-values and the DART characteristics are not yet certain, and therefore the choice has been made to not make a calculation for changes in these characteristics.

6.3.1 Changing the number of stations

An interesting object for study is to evaluate the number of stations. Is the distance between the stations of a proper length, or should the distance between the stations be increased or decreased?

The commuter is affected in the following ways by a change in the number of stations:

- The number of stations is positively correlated with the in-vehicle travel time. Thus, more stations will lead to a longer in-vehicle travel time.
- The number of stations is negatively correlated with the average walking time to the bus stop. An increase in the number of stations will decrease the average walking time to the bus stop.

The costs for the DART system are also affected by the number of bus stations:

- The number of stations determines the total investment costs of the whole DART system. Furthermore the yearly maintenance costs are affected by the number of bus stations.

The BRT Guide also comes up with a method to determine the optimal number of bus stations. The following quote can be found in the document: *"Optimizing the distances between stops is done by minimizing the generalized travel costs for the walking distances to the stations and the travel speed of the passengers passing along the corridor"* However, this method has to be disputed, because it leaves out the construction and maintenance costs for the stations. Especially in a situation with a relatively low travel time valuation, like in Dar es Salaam, these cost objects need attention. Because the DART system hasn't been developed yet, it is better to include these costs in the calculation of the number of stations. Take in mind that this holds less for the feeder stations, as these stations costs are considerable lower than the trunk stations.

6.3.2 Changing the bus design

The comfort valuation of the commuters can be used to determine the optimal bus design. Two different variables can be changed to maximize the benefits for the commuter and the bus operator: the total capacity per bus and the ratio between seating- and standing capacity.

Increasing the capacity has the following effects for the commuter:

- The comfort level experienced by the commuter becomes higher (in case of an equal frequency)

The bus operator is affected in the following way:

- A higher capacity per bus results in larger bus investments costs.

Increasing the number of seats at the cost of the standing capacity has the following effects for the commuter:

- There is more seating capacity, thus a higher number of commuters can take advantage of the seats available and thus experience the highest possible comfort level.
- Because seating capacity requires more space than standing capacity, the total capacity per bus will decrease. This will lead to a decrease in the comfort valuation of the standing passengers, because an overcrowded situation is attained earlier.

The consequence for the bus operator is the following:

- A change in the number of seats will change the price per bus.

A final remark with respect to a change in the bus design it that it is likely that this change will be combined with a frequency change. For example, decreasing the total capacity can have the effect that the travel demand exceeds the available capacity. In this case the frequency has to be increased, because otherwise the BRT system cannot cope with the travel demand.

6.3.3 Changing the DART network

The final suggestion for further research is to study whether a change of the routes of the DART system can improve the value of the BRT system. It is possible to change the number of trunk and/or feeder routes. Also one can study the effects of route changes of certain corridors. However, the ideal situation is more difficult to determine, compared to changes regarding the number of stations and the bus design. Firstly because they cannot be calculated by using only a set of equations. GIS software like ARCGIS is needed to optimize these characteristics. Secondly because there is in fact an unlimited number of options.

Changes in the routes have the following effect for commuters:

- The distance to the nearest bus stop will change for a number of people, which results in changes in the walking time to the bus stop.
- The travel time will change, because buses will use other routes.
- The travel demand per route will change, so the comfort level will change.

The changes for bus operator and the investor of the DART network are the following:

- The number of stations depends on the number and length of the routes, so this variable is affected by a change in the DART network, and thus the initial investment costs for stations are influenced.
- The number of bus kilometers and the fleet size also depend on the structure of the network. This means that the operating costs and the bus investment costs are affected.

7. Conclusions and recommendations

This research introduces a method to compare the preferences of commuters with the operational characteristics of a BRT system. To make the comparison possible the following steps have been undertaken: first a stated choice survey has been carried out to determine the preferences of the commuters towards a selected set of operational characteristics of a BRT system: i.e. in-vehicle travel time, access walking time to bus stop, comfort and travel fare. These preferences have been expressed in willingness-to-pay (WTP)-values for each characteristic. The WTP-values specify the preferences of the commuters towards the travel characteristics in terms of costs (Tanzanian Shillings). Furthermore, information has been obtained for different characteristics of the DART system: what are the proposed operational characteristics and what are the effects in terms of monetary value of changes in one or more DART characteristics? In this way all relevant effects of a change (both for commuter and for bus operator) in DART's operational characteristics can be expressed in terms of money and the monetary value of different scenario's can be evaluated easily. The monetary value for the bus operator and the commuters together will be calculated for the proposed alternative and compared with the monetary value for both parties in the new alternative. If the total value (thus for bus operator and commuters together) of the new alternative is higher than the value of the proposed alternative, than a change is advantageous.

Because uncertainty about the DART characteristics and the quality of the WTP estimations, a comparison for all characteristics of DART that can be influenced has not been made. As an example on how to use the results, this research presents how the frequency during peak-hours can be optimized to maximize the total monetary value of DART for both commuters and the bus operator. The conclusion is that the frequency is optimized for almost all trunk and feeder routes. A few minor frequency changes increase the monetary value of DART somewhat, but in order to draw appropriate conclusions more certainty has to obtained about exact WTP-values of the commuters and the final proposed characteristics of the DART system. Other characteristics that can be investigated are the number of stations, the bus design and the DART network. However -as already mentioned- it is not yet relevant to make a comparison, because there is still too much uncertainty about the input for the comparison.

Besides a description of a comparison method and a practical example (effects of a frequency change), several experiences from this study can be used to support future research. Therefore, a number of problems and limitations experienced in this research are listed here. Some improvements to overcome the constraints in order to increase the quality of future research are proposed, i.e.:

- A large number of inconsistencies in the answers of the respondents were found in this research. A higher task complexity leads to a higher number of inconsistencies. And the following factors lead to a higher task complexity: the number of alternatives, the number of attributes per alternative, the number of attribute levels and the number of attributes that have different levels in one choice set. Because the current stated choice survey showed a high number of inconsistencies in the respondent answers, the advice is to decrease the number of *different* attributes levels per choice set. Decreasing the number of attributes, however, is not desired, because in this way less different WTP-values are obtained. And decreasing the number of attribute levels or the number of alternatives is also not desired, because these are already few in this research.
- It was experienced that a significant part of the respondents made their choices based on only one attribute (most often comfort) without properly considering the other attribute values. This is called *lexicographic* choice behavior and this has the effect that the WTP

estimations are biased. Research should be done about how to minimize this lexicographic behavior.

- The WTP-values for comfort valuation in this research are estimated *per trip*. However, it is better to make an estimation of the comfort valuation *per minute*, because commuters will be prepared to pay more money for a higher comfort level for a trip with a long duration than for a short trip.
- In the stated choice questionnaire this research expressed both the in-vehicle travel time and the access walking time in terms of time (in minutes). The result was that a lot of respondents added both travel times together, and then made the comparison. Nonetheless, goal of this research was to obtain separate WTP-values for both attributes, because literature indicates that people value both types of travel time different. Therefore, one has to think about solving this problem. A possible solution is to express the access walking time in terms of distance (to nearest bus stop) instead of time, so that respondents are forced to consider both attributes separately.
- Because of limited time available for this research it was not possible to check the collected data prematurely on usefulness and quality. It is strongly suggested to screen the data after 10% or 20% of the intended total sample. The sample should now be large enough to verify whether the final result is expected to be of good quality. If the data quality is not sufficient then it is still early enough to change the questionnaire and to restart the survey.
- The stated choice questionnaire in this research was not developed according to the principles of maximizing the statistical efficiency. There is a lot of literature available dealing with this issue and it is useful to study this literature to increase the quality of the choice sets.
- In this research there hasn't been made distinction among the different socio-economic groups in Dar es Salaam. Data of all respondents has been taken together to estimate the utility parameters. A nice challenge is to estimate different WTP-values for the different socio-economic groups, and to maximize the value of DART for these different groups. It is also an idea to investigate whether the spatial location of respondents has an effect on the WTP-values.
- A general remark with respect to stated choice is that one has to take in mind that people are just indicating what they prefer. This doesn't imply that they are really going to act in the way they indicate. Several studies suggest that people generally show a higher hypothetical WTP than they are prepared in reality. Combining stated preference data with revealed preference data might be a solution to overcome this problem.

Summarizing this research presents a method to optimize the benefits of a BRT system for bus operator and commuters jointly. Also it discusses several problems experienced during this study, from which future research can take advantage. Taking in consideration the suggestions mentioned above will make the method proposed in this report a valuable tool to maximize the monetary value of a BRT system.

8. Literature

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A. Appendix

A.1 Survey wards

Date	Ward
Saturday, 15 September 2007	Upanga East
Saturday, 15 September 2007	Ilala
Saturday, 15 September 2007	Buguruni
Monday, 17 September 2007	Jangwani
Tuesday, 18 September 2007	Kinondoni
Tuesday, 18 September 2007	Upanga West
Tuesday, 18 September 2007	Manzese
Tuesday, 18 September 2007	Mabibo
Wednesday, 19 September 2007	Sinza
Wednesday, 19 September 2007	Kijtonyama
Wednesday, 19 September 2007	Mwanayamala
Thursday, 20 September 2007	Ndugumbi
Thursday, 20 September 2007	Msasani
Thursday, 20 September 2007	Mikocheni
Friday, 21 September 2007	Tandika
Friday, 21 September 2007	Mtoni
Friday, 21 September 2007	Temeke
Friday, 21 September 2007	Kurasini
Saturday, 22 September 2007	Tabata
Saturday, 22 September 2007	Kiwalani
Monday, 24 September 2007	Ubungo
Monday, 24 September 2007	Kawe
Monday, 24 September 2007	Mbagala
Monday, 24 September 2007	Charambo
Tuesday, 25 September 2007	Kibamba
Tuesday, 25 September 2007	Mbezi
Tuesday, 25 September 2007	Kunduchi
Tuesday, 25 September 2007	Kimara
Wednesday, 26 September 2007	Sogerea
Wednesday, 26 September 2007	Ukonga

Table 9: List of visited wards

A.2 Survey design

A.2.1 Definitive choice sets

The choice sets for ringzone 2 are presented below. Notice that ringzone 1, 3 and 4 have different values for the in-vehicle travel time. However, the lowest IVTT value for ringzone 1 means that the IVTT for the certain choice set has also the lowest IVTT value (10 minutes) for ringzone 1, 3 and 4. The same accounts for the middle IVTT value (15 minutes) and the highest IVTT value (20 minutes). The other values are the same for each ringzone.

	Alternative A				Alternative B			
C	**WT**	**IVTT**	**Comfort level**	**Fare**	**WT**	**IVTT**	**Comfort level**	**Fare**
1	15 min	15 min	Overcrowded Standing	500 Tsh	25 min	35 min	Comfortable Standing	500 Tsh
2	25 min	35 min	Comfortable seating	300 Tsh	15 min	25 min	Comfortable seating	500 Tsh
3	15 min	35 min	Comfortable standing	300 Tsh	15 min	15 min	Overcrowded Standing	300 Tsh
4	5 min	25 min	Comfortable standing	700 Tsh	5 min	15 min	Overcrowded Standing	500 Tsh
5	25 min	35 min	Comfortable standing	300 Tsh	25 min	25 min	Comfortable seating	500 Tsh
6	5 min	15 min	Overcrowded Standing	500 Tsh	15 min	35 min	Comfortable Standing	300 Tsh
7	25 min	15 min	Comfortable Standing	500 Tsh	5 min	35 min	Comfortable seating	700 Tsh
8	5 min	15 min	Comfortable seating	700 Tsh	25 min	35 min	Overcrowded Standing	300 Tsh
9	15 min	25 min	Comfortable standing	300 Tsh	5 min	15 min	Comfortable seating	700 Tsh

Table 10: Choice sets in questionnaire

C = Choice set
WT = Walking time to bus stop
IVTT = In-vehicle travel time

A.2.2 Choice sets in pilot survey

The following choice sets have been used for the pilot survey (in ringzone 2). The attribute levels that have been marked bold, have been changed after the pilot survey.

	Alternative A				Alternative B			
C	**WT**	**IVTT**	**Comfort level**	**Fare**	**WT**	**IVTT**	**Comfort level**	**Fare**
1	15 min	15 min	Overcrowded Standing	500 Tsh	25 min	35 min	Comfortable Standing	500 Tsh
2	25 min	35 min	Comfortable seating	300 Tsh	15 min	25 min	Comfortable seating	500 Tsh
3	15 min	35 min	Comfortable standing	300 Tsh	15 min	15 min	Overcrowded Standing	300 Tsh
4	5 min	25 min	Comfortable standing	700 Tsh	5 min	15 min	Overcrowded Standing	500 Tsh
5	25 min	35 min	**Overcrowded standing**	300 Tsh	25 min	25 min	Comfortable seating	500 Tsh
6	5 min	15 min	Overcrowded Standing	500 Tsh	15 min	35 min	Comfortable Standing	300 Tsh
7	25 min	15 min	Comfortable Standing	**700 Tsh**	5 min	35 min	**Comfortable standing**	700 Tsh
8	5 min	15 min	Comfortable seating	700 Tsh	25 min	35 min	Overcrowded Standing	300 Tsh
9	15 min	25 min	Comfortable standing	**500 Tsh**	5 min	15 min	Comfortable seating	700 Tsh

Table 11: Choice sets in pilot survey

A.2.3 Questionnaire

The following questionnaire has been used. This is the version translated to English, however the interviews have been held in Swahili and the questionnaires have been made up in Swahili.

QUESTIONAIRE FORM

Survey Information

Name of Interviewer ________________________________

Survey Ward ________________________________

Buffer-Ring Zone ________________________________

Date of Interview ________________________________

Time ________________________________

<u>ASK</u> Home location of respondent (Ward) ______________________

If this is not the same as the survey zone: do not carry out the survey

<u>ASK</u> Do you go at least twice a week to the city center? _____________

If not: do not carry out the survey

Part A: General Information

<u>1. Sex</u>

Male [ ] Female [ ]

<u>2. What is your age?</u> ___

<u>3. What is your Employment Status?</u>

Employed full-time [ ] Employed part-time [ ] Unemployed [ ]

Student [ ] Retired [ ]

Other, specify ______________

<u>4. How many days a week do you visit the city center on average?</u> ___

<u>5. What is your main trip purpose to visit the city center?</u>

Work [ ] School [ ]

Business [ ] Other, specify [ ] _____________

<u>6. Which means of transport do you mostly use?</u>

Daladala [ ] Bicycle [ ] Walking [ ]

Own car [ ] Taxi [ ]

Other, specify _____________

<u>7. How much **walking** time does it take you to reach the nearest daladala stop?</u>

0-10 Minutes [ ] 10-20 Minutes [ ]

20-30 Minutes [ ] Over 30 minutes [ ]

<u>8. How much time does it take to reach the city center from your home on average?</u>

____ hours and ____ minutes

Part B: Stated Choice Questionnaire

Choice Set	**Chosen choice set**		**Would you like to use this bus for daily travel?**	
Choice set 1/9:	A [ ]	B [ ]	Yes [ ]	No [ ]
Choice set 2/9:	A [ ]	B [ ]	Yes [ ]	No [ ]
Choice set 3/9:	A [ ]	B [ ]	Yes [ ]	No [ ]
Choice set 4/9:	A [ ]	B [ ]	Yes [ ]	No [ ]
Choice set 5/9:	A [ ]	B [ ]	Yes [ ]	No [ ]
Choice set 6/9:	A [ ]	B [ ]	Yes [ ]	No [ ]
Choice set 7/9:	A [ ]	B [ ]	Yes [ ]	No [ ]
Choice set 8/9:	A [ ]	B [ ]	Yes [ ]	No [ ]
Choice set 9/9:	A [ ]	B [ ]	Yes [ ]	No [ ]

Part C: Socio-economic Information

1. Do you own any vehicle?

Yes [ ] No [ ]

2. Do you own a house?

Yes [ ] No [ ]

If yes, Which type of house?

Mud house [ ] Block house [ ]

3. What is your highest education level?

None [ ] Primary school [ ] Secondary school [ ]
College [ ] University [ ]

4. What is your main occupation?

____

5. How much is your average monthly income (in Tsh)? _________Tsh

6. To which socio-economic group do you think you belong?

Wealthy [ ] Comfortable [ ]
Poor [ ] Very poor [ ]

A.2.4 Visualization

Figure 11 shows an example of a visualization of one choice set.

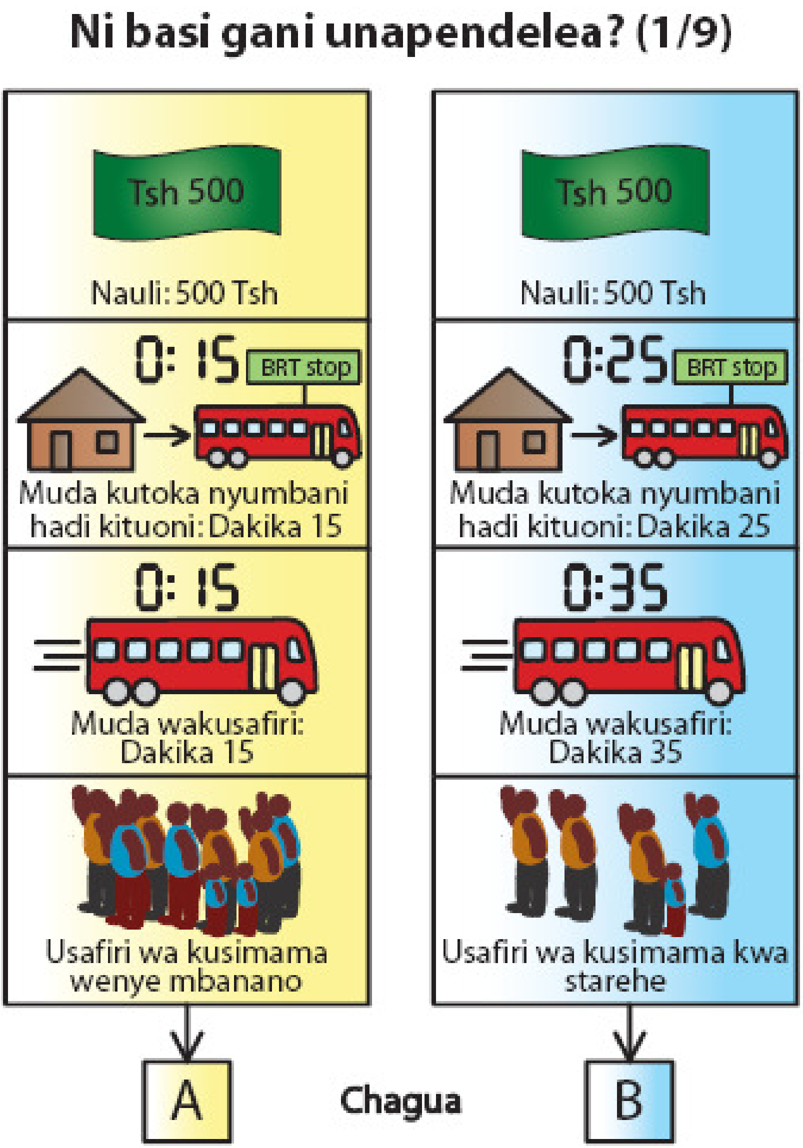

Figure 11: visualization of a choice set

A.3 Survey results

A.3.1 Results using all data

All data, two travel time attributes		
Attribute	Utility	t-test
Travel fare	0,00204	10,28
In-vehicle travel time	0,00506	2,38
Walking time to bus stop	0,0298	6,97
Overcrowded Standing	-0,277	-6,84
Comfortable Seating	0,146	2,14
Rho square:	*0,034*	

Table 12: Parameter estimations using all data

A.3.2 Inconsistent choice combinations

The following choice combinations have been defined as inconsistent: (the time intervals are different for the 4 ringzones; this overview mentions the time intervals for ringzone 2)

- *1B and 3B:*

By choosing 1B the respondent indicates:
Comfortable standing instead of overcrowded standing is more preferable than 30 minutes less travel time.

By choosing 3B the respondent indicates:
20 Minutes less travel time is more preferable than comfortable standing instead of overcrowded standing.

- *1B and 6A:*

By choosing 1B the respondent indicates:
Comfortable standing instead of overcrowded standing is more preferable than 30 minutes less travel time.

By choosing 6A the respondent indicates:
30 Minutes less travel time is more preferable than comfortable standing instead of overcrowded standing *plus* a fare reduction of Tsh 200.

- *5A and 7B:*

By choosing 5A the respondent indicates:
A fare reduction of 200 Tsh is more preferable than 10 minutes less travel time *plus* comfortable seating instead of comfortable standing.

By choosing 7B the respondent indicates:
Comfortable seating instead of comfortable standing is more preferable than a fare reduction of Tsh 200

- *8A and 9A:*

By choosing 8A the respondent indicates:
A fare reduction of Tsh 400 is more preferable 40 minutes less travel time *plus* comfortable seating instead of overcrowded standing.

By choosing 9A the respondent indicates:
20 Minutes less travel time *plus* comfortable standing instead of overcrowded standing is more preferable than a fare reduction of Tsh 400.

A.4 Comparison DART and commuters' preferences

A.4.1 Comfort

Expressing comfort valuation in terms of monetary value is less easy than expressing the other attributes in terms of monetary value. Therefore this paragraph explains how the comfort level valuation is calculated.

WTP-estimations have been made for three different levels:

- comfortable seating (492 Tsh, compared to overcrowded standing)
- comfortable standing (372 Tsh, compared to overcrowded standing)

- overcrowded standing (0 Tsh, compared to overcrowded standing)

The average comfort valuation per bus commuter is calculated with help of the following formula:

$$Avg\ WTP_{comf} = WTP_{seating} * Number\ of\ Seating\ Passengers + WTP_{standing} * Number\ of\ Standing\ Passengers$$

The comfort valuation per seating passenger, compared to overcrowded standing, is easy to calculate. This WTP-value follows from the estimated parameter in paragraph 5.3.

$$WTP_{seating} = 492\ Tsh$$

If 0-50% of the standing capacity is occupied, then the assumption is that commuters can stand comfortably. This implies that the $WTP_{comfort}$ of each standing passenger equals the estimated WTP_{value} for comfortable standing (see paragraph 5.3):

$$WTP_{standing} = WTP_{comf\ standing} = 372\ Tsh$$

The assumption has been made that commuters start experiencing the bus as overcrowded, if more than 50% of the standing capacity is used. The comfort valuation will decrease, as the number of passengers per m^2 becomes larger. An equation has been formed to express this effect in terms of monetary value. If 50-100% of the standing capacity is used, than the $WTP_{comfort}$ is calculated with the following equation:

$$WTP_{standing} = WTP_{comf\ standing} - WTP_{comf\ standing} * \frac{(Capacity_x - 50\%)}{50\%}$$

In this formula $Capacity_x$ is the percentage of standing capacity that is occupied.
Figure 12 shows a visualization of the comfort valuation ($WTP_{comfort}$) as function of the occupied standing capacity.

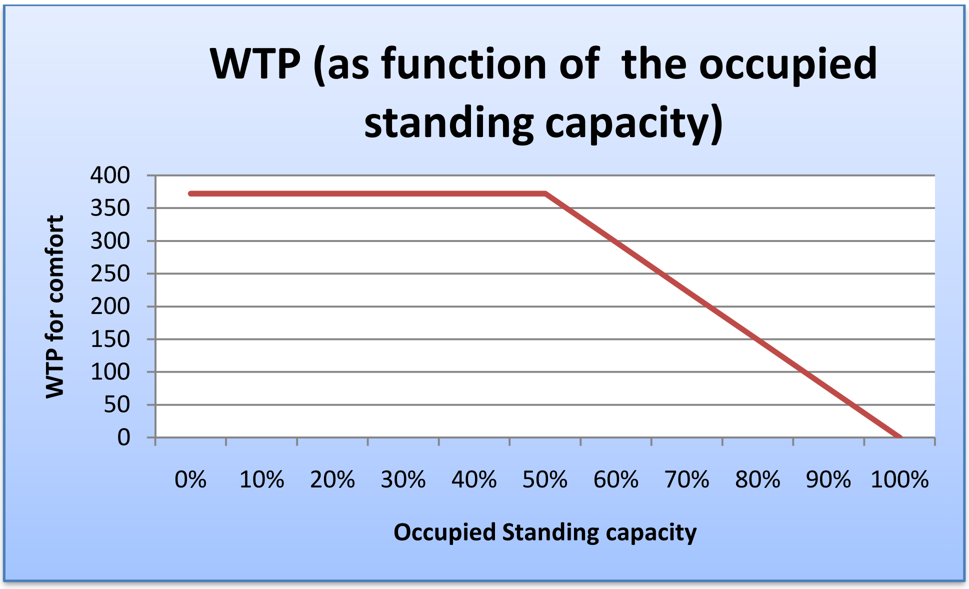

Figure 12: WTP as function of occupied standing capacity

A.4.2 Waiting Time

The waiting time has been excluded from the research. Reason for this exclusion is that the survey would become too complex for the respondent if each choice set contained 5 different attributes. Moreover, the number of different choice sets would become too large, given the limited resources available. Also, DART will have a very high frequency (up to 40 buses per hour), so the waiting time would be very small compared to the in-vehicle travel time and the walking time to the bus stop, and thus almost negligible for the respondent. Before the research the idea already was to derive the waiting time from the estimated utility parameters for walking time and in-vehicle travel time.

In this research was already explained that the in-vehicle travel time and the walking time to the bus stop were assigned the same utility parameter, because most respondents didn't consider those two attributes separately. It is likely that people would add also the waiting time to the other two time variables, if it was included in the questionnaire. For this reason the waiting time is assigned the same utility parameter and this means that the WTP for a decrease of 1 minute waiting time is 9,61 Tsh.

A.4.3 Passenger data

The following data is the basis for the calculations in paragraph 6.2:

Service	Length	Avg %	Fleet (0)	Pass/hour (Total)	Pass/hour (high)	Pass/hour (low)
DR001	17,8	70%	15	4155	2329	1826
DR002	28	70%	37	8054	4501	3553
DR003	30,8	60%	33	8191	3343	4848
DR004	14,2	70%	9	3315	1775	1540
DR005	17,6	60%	21	6346	3592	2754
DR006	17	65%	11	2765	1875	890
DR007	20,5	65%	12	2789	1804	985
FR001	10	70%	11	1223	777	446
FR002	8	75%	2	183	96	87
FR003	14	95%	2	103	87	16
FR004	9	75%	4	464	233	231
FR005	34	75%	27	609	609	10
FR006	14	95%	12	2039	1196	843
FR007	8	85%	12	2397	1492	905
FR008	9	60%	10	1680	896	784
FR009	9	60%	6	613	406	207
FR010	5	80%	2	346	235	111
FR011	13	80%	6	399	309	90
FR012	7	60%	3	338	250	88
FR013	3	90%	6	2192	1655	537
FR014	5	95%	2	169	125	44
FR015	2	95%	7	1564	1190	374

Table 13: List of details of DART services

Service: number of the trunk (DR) or feeder (FR) service
Length: length in km of the service (one-way)
Avg %: the average trip length in percentage of the total corridor length
Fleet (0): the assigned fleet size for the corridor during peak hours
Pass/hour (total): the total number of passengers per hour during peak hours
Pass/hour (high): the number of passengers per hour during peak hours in the busiest direction
Pass/hour (low): the number of passengers per hour during peak hours in the least busy direction

The routes of the services can be found in Logit 2007, Dar Es Salaam BRT Planning and Design.

A.4.4 Effects of frequency change

This paragraph shows how the effect of a frequency change during peak-hours is calculated. To determine whether a change in frequency is beneficial the following basic formula is used:

$$\Delta Value = \Delta Value\ (passengers) + \Delta Value\ (bus\ operator)$$

If ΔValue is positive, then the frequency change is of positive monetary value. Once again, take in mind that it is not needed that the change is beneficial for both the commuters and the bus operator. The bus operator can compensate the commuter vice versa by changing the travel fare.

A.4.4.1 Changes in value for passengers

The change in value (compared to the DART 0-alternative) for all commuters on a certain corridor is calculated as following:

$$\frac{\Delta Value\ (pass)}{hr} = Passengers\ per\ hour * \left(\Delta Avg\ WTP_{comfort} + \Delta Waiting\ time * WTP_{wt}\right)$$

The WTP values are estimated in paragraph 5.3. Notice that the WTP-value for waiting time is negative in this case.
The differences in comfort value is calculated in the way described in paragraph A.4.1. The difference is simply the value of the comfort in the new situation minus the comfort value in the 0-alternative:

$$\Delta Avg\ WTP_{comfort} = Avg\ WTP_{comfort,new} - Avg\ WTP_{comfort,DART0}$$

Notice that passengers in the busiest direction (usually to the CBD in the morning peak hours and away from the CBD in evening peak hours) will experience a different comfort level than passengers those are making a trip in the other direction. This is evident, as the average number of passengers per bus will be different for the two directions. For this reason, two different calculations have been performed: one to determine the comfort valuation in the busiest direction, and one to determine the comfort valuation in the other direction.

The difference in waiting time is also easily to calculate:

$$\Delta Waiting\ Time = Waiting\ time_{new} - Waiting\ time_{DART0}$$

The data for the DART 0-alternative can be found in Logit 2007, Dar Es Salaam BRT Planning and Design.

A.4.4.2 Changes in value for bus operator (trunk)

The following formula is used to calculate the difference in value (costs) for the bus operator, if the new DART-alternative is introduced:

$$\frac{\Delta Value\ (bus\ operator)}{hr} = \Delta Operational\ fleet * \left(\frac{Bus\ costs}{hr} + \frac{Bus\ investment\ costs}{hr} + \frac{Labor\ costs}{hr}\right)$$

The operational bus costs per hour are calculated as following:

$$\frac{Bus\ costs}{hr} = \frac{fuel\ costs + lubricants + tyres + parts\ and\ replacements + maintenance}{km} * \frac{km}{hr}$$

The DART Investors document includes values for the variables above and with this information it is possible to calculate the operational bus costs per hour:

$$\frac{Bus\ costs}{hr} = \frac{681 + 34 + 50 + 216 + 394}{km} * 23 = 31602\ Tsh/hr$$

During peak periods the bus fleet use is 100%, excluding a small necessary reserve fleet. This means that if the frequency is increased during the peak periods, the fleet also has to be increased, and this will increase the bus investment costs for the bus operator.

$$\frac{Bus\ investment\ costs}{hr} = \frac{Bus\ price}{Bus\ lifetime * bus\ hrs/year}$$

The bus hrs/year is the number of hours that the additional buses will be in operation per year. These additional buses will operate only during the peak hours. Assuming 4 peak hours per day and 300 days of operation, this means that these additional buses will operate 1200 hours per year. Using this information and the information from the DART Investors Document, the bus investment costs *per hour* for the additional buses can be calculated:

$$\frac{Bus\ investment\ costs}{hr} = \frac{211.474.710}{10 * 1200} = 17623\ Tsh/hr$$

Information about labor costs can also be found in the DART investors document. The calculation below assumes an average number of working hours of 160 per month per driver.

$$\frac{Labor\ costs}{hr} = \frac{Salary + Other\ labor\ costs}{hr}$$

$$\frac{Labor\ costs}{hr} = \frac{2506 + 683}{hr} = 3188\ Tsh/hr$$

A.4.4.3 Changes in value for bus operator (feeder)

The feeder costs have been calculated with help of the same equations. However, different variables for the feeder were found in the DART Investors Document. The results are shown below:

$$\frac{Bus\ costs}{hr} = 12527\ Tsh/hr$$

$$\frac{Labor\ costs}{hr} = 3188\ Tsh/hr$$

$$\frac{Bus\ investment\ costs}{hr} = \frac{211.474.710}{10 * 1200} = 9987\ Tsh/hr$$