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Spatial variation of transit service quality preferences in Dar-es-Salaam

Alphonse Nkurunziza *, Mark Zuidgeest, Mark Brussel, Frans Van den Bosch

Department of Urban and Regional Planning and Geo-Information Management, Faculty of Geo-Information Science and Earth Observation, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

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ABSTRACT

Commuter preferences for transit service quality are of great importance to transit service providers and regulatory agencies. The point of view of potential passengers is fundamental for evaluating transit service quality as they are envisaged to be the real consumers of the planned services and can therefore be considered the most suitable judges. A stated preference survey of daily commuters to the central business district (CBD) in the city of Dar-es-Salaam, Tanzania, was carried out to elicit preferences towards the proposed Dar Rapid Transit (DART) service. Preferences towards the proposed DART service are considered to vary based on the residential location of the potential users. These preferences are evaluated on the attributes travel time, fare and comfort. A binary logit model was applied to establish utility functions that were analysed spatially in a GIS, where a utility value was computed for each spatial unit. This paper accordingly analyses spatial variation of transit service quality preferences for the proposed DART service using geo-spatial techniques. The study uses a scenario-based approach to evaluate the effect of the proposed DART service by comparing the 'without DART' scenario, a case representing the existing public transport (*daladala*), and a 'DART' scenario, representing the future proposed DART system. The results indicate that the proposed DART attributes considered in the study have a significant effect on DART service quality. The results further reveal that utility values are significantly varying spatially, particularly dependent upon distance to CBD. Comfort is the most important attribute in zones up to 5 km from the CBD, travel fare is more important in zones between 5 and 15 km from the CBD, while travel time is more important in zones beyond 15 km distance from the CBD. The overall results indicate that the DART is likely to be more attractive than the existing public transport system.

1. Introduction

Most cities in the developing world are experiencing rapid urbanisation, population growth and dispersal of amenities and activities. These have caused increased demand for and dependence on personal motorised transportation leading to problems such as congestion, accidents, environmental degradation, parking, pollution, stress, noise, and urban sprawl (Zhao, 2010; Abane, 2011; Salon and Aligula, 2012). More recently, however, planners, engineers and decision makers, worldwide, have started to give more and more attention to the development and promotion of more affordable, space and resource-efficient transport systems to alleviate those aforementioned problems (Menckhoff, 2002; Mavoa et al., 2012; Davison and Knowles, 2006). The development of sustainable transport options such as Bus Rapid Transit (BRT) systems has witnessed tremendous growth, most notably cities in developing countries. These large, city-wide transportation projects are often central to larger urban revitalisation plans intending to foster economic growth and sustainable development. Crucial to the success of such ambitions is a system that provides equitable access to all residents and one that provides access to a large number of urban opportunities (Delmelle and Casas, 2012). Improving access to opportunities and provision of different mobility options (e.g. accessible public transit) are key policy responses to the problem of low participation rates in urban activities, particularly for those who are transportation disadvantaged (Hine, 2003; Kamruzzaman et al., 2011; Tiwari and Jain, 2012).

The city of Dar-es-Salaam in Tanzania, like many others in the developing world, is urbanising at a faster rate than its infrastructure is able to cope with. The city being the largest in Tanzania with an estimated population of around 4 million in 2010 has experienced a major transportation crisis. Transport in the city is characterised by extreme traffic congestion, rapid population growth, environmental deterioration, increased automobile ownership, high accident rates, inefficient road space allocation, as well as an excessive and obsolete transit fleet (Olvera et al., 2003; Nkurunziza et al., 2012b). The pattern of urban mobility also reflects

* Corresponding author. Tel.: +31 (0)53 4874 241/455/497; fax: +31 (0)53 4874 575.

E-mail addresses: nkurunziza16117@itc.nl (A. Nkurunziza), zuidgeest@itc.nl (M. Zuidgeest), brussel@itc.nl (M. Brussel).

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the social exclusion existing in the city. The majority of the Dar-es-Salaam population does not own and use private vehicles. In order to save on the costs of transportation, the urban population (mainly the poor) end up landlocked in marginal peripheral areas, without adequate access to urban facilities in the city (Olvera et al., 2008). The current public transport service is provided by obsolete, polluting and unsafe para-transit, mainly dominated by small minibuses called '*daladala*'. The *daladala* service is characterised by the poor state of the majority of buses, untrained bus drivers and conductors driven by the pursuit of daily revenue targets payable to the bus owners, non-adherence to traffic rules and regulations and lack of an organised public transport system (Sohail et al., 2004; Kanyama et al., 2004). In response to those existing public transport challenges, the Dar-es-Salaam city proposed to introduce a bus rapid transit system "*The Dar Rapid Transit (DART)*" aiming at providing quality and affordable mass transit service for the city residents, which is planned to reduce emissions, enable poverty reduction, lead to sustainable economic growth and act as a pioneer of private and public investment partnership in the City (Logit, 2007; JICA, 2008).

1.1. The Dar Rapid Transit (DART) system

The city of Dar-es-Salaam is among the very few Sub-Sahara African cities that decided to adopt a bus rapid transit (BRT) system branded *"Dar Rapid Transit (DART)"*. Other cities that have considered/or are in the process of introducing BRT systems are: Lagos, Accra, Addis Ababa, Kampala and Nairobi (Deng and Nelson, 2011; UN-Habitat, 2011). Following the apparent success of Bogota's Transmilenio that was implemented in the year 2000 in Colombia, the BRT in Dar-es-Salaam 'DART' is developed along similar lines (Gilbert, 2008; Munoz-Raskin, 2010; Logit, 2007). Like the Transmilenio, DART is designed to work with a trunk-feeder set-up system. The DART trunk lines will be implemented on the four major road corridors in the city. It is planned that along those corridors the current minibuses are no longer able to operate. The DART promises to run with high-capacity articulated buses (minimum 140 passengers) operating on designated infrastructure at an average speed of over 22 km/h. The proposed DART ticket will cost a flat fare of approx. US$ 0.32 while a *daladala* ticket (one way) costs between approx. US$ 0.16 and US$ 0.19. The DART system will be implemented in six phases with the first phase – earlier planned to start in 2009 – is currently under construction since 2011. The last phase is planned to be completed in 2035 (Logit, 2007; JICA, 2008).

Bus Rapid Transit's popularity has increased worldwide, due to its promise for delivering a relatively low cost, rapidly implemented, flexible and high quality service solution to developing cities' transportation needs (Wright and Hook, 2007; Deng and Nelson, 2011). Despite the increased popularity, implementing a BRT inevitably encounters some challenging technical, operational and institutional issues (Deng and Nelson, 2011). The success of BRT systems elsewhere cannot be taken for granted, as each city has certain inherent characteristics and thus successful BRT experiences from elsewhere need proper modification to be applied in other contexts (Deng and Nelson, 2011). Moreover, the success of such systems will be dependent upon the ability of the operator to provide the level and quality of services expected by the users against a tariff that is affordable. The fundamental issue addressed in this paper therefore is whether the proposed DART system will deliver quality service expected by its potential riders. Also, while most studies on public transit service quality are based on qualitative measures of user perceived quality and satisfaction ratings, very few or hardly any studies exist that integrate behavioural models with geo-spatial models in the evaluation of public transit service quality. Hence, three underlying questions exist: How do potential users value the proposed DART service quality? How to integrate behavioural models into GIS for spatial analysis of the proposed DART service quality? Where is the proposed DART service highly or less valued compared to the commuting service rendered by the existing public transport? When a planning authority finds answers to these questions, it can compare the spatial distribution of potential user satisfaction derived from DART service to that of the existing public transport and devise means of providing a service desirable to its potential users. The main objective of this study is to answer these questions by deriving behavioural models from commuter stated preferences and integrating them into a GIS for spatial evaluation of the proposed DART system service quality.

The remainder of the paper is organised as follows. The next section discusses earlier studies on transit service quality evaluation and how this study relates to similar theoretical frameworks. The third section describes the applied integrated methods to evaluate public transit service quality. The fourth section concentrates on the modelling and discussion of results, followed by conclusions and some planning implications in Section 5.

2. Earlier empirical research on transit service quality

Evaluation of public transit service quality is a challenging research theme and of great importance to transit service providers and regulatory agencies (Hensher et al., 2003). From the service providers' perspective, it is essential to identify the most important attributes of service quality that are desired by current and potential users. Moreover, it is also important to allocate resources for transit improvements in directions most consistent with consumer perceptions (Prioni and Hensher, 2000). Measuring which service attributes are important to customers may be more meaningful to managers than measuring customer service expectations. For example, Landrum and Prybutok (2004) indicate that comparing service performance against what customers consider important may be just as useful to managers as comparing performance against what customers expect. However, the challenge in service provision involves gaining a realistic view on service quality delivered in the first place together with a sound understanding of public satisfaction and expectations with respect to public transport services (Mfinanga and Ochieng, 2006). Many researchers consider the customer's point of view the most relevant for evaluating transit performance, for example; Berry et al. (1990) pointed out that 'Customers are the sole judge of service quality'.

Service quality can be evaluated by considering customer perceptions and expectations, which can be used for measuring the ability of the transit agency to offer services that meet customer expectations (Morpace International Inc., 1999; Deng and Nelson, 2012; Gilbert, 2008). Passenger's perceptions are qualitative measures of transit service quality generally derived from the well-known customer satisfaction surveys, which help transit operators to identify which service quality factors are considered the most important by their customers. Customer satisfaction surveys can also be used to prioritise future quality of service improvement initiatives and to track changes in service quality over time (Eboli and Mazzulla, 2011; Currie, 2006; Cain et al., 2009). Traditional research on perceived quality provides operating companies with knowledge on the impact their decisions have on their customers, while studies on desired quality gives them in-depth information about their customers and what customers want from their service so they can develop more acceptable policies (Dell'Olio et al., 2011; Currie and Wallis, 2008).

Extensive literature is available on the attitudes towards transit services and on service quality as important determinants of travel demand. Some studies have focused on evaluation of public transit service quality from the perspective of ratings of user satisfaction.

For example, Ji and Gao (2010) identified significant factors from ratings of people's satisfaction with public transportation as well as accessibility factors and personal attributes using a multi-level logistic regression model. Dell'Olio et al. (2010) used ordered probit models to evaluate how bus users perceive the quality of their public transit service. Stradling et al. (2007) characterised the dimensions of bus service acceptability by examining what bus users disliked and liked about travelling by bus in Edinburgh using factor analysis. Tyrinopoulos and Antoniou (2008) combined factor analysis and ordered logit modelling to assess the quality implications of the variability of the user's perceived satisfaction across public transit systems. Too and Earl (2010) developed and used a SERVQUAL framework to measure public transport services. Their findings revealed a wide gap between community expectations of public transport services and the actual service quality provided.

An alternative approach for capturing customer judgments in terms of expectations and perceptions, or importance and satisfaction ratings, is based on the use of choice analysis which indirectly captures the service attributes that are important and satisfactory to customers. Choice data are collected from experiments based on stated preference techniques, in which the interviewed users make a choice among some alternative services characterised by some service quality attributes varying on two or more levels. For example, in Prioni and Hensher (2000) a stated preference experiment was proposed to the passengers of some private bus operators in New South Wales (Australia). In this experiment, the interviewed users made a choice between some alternative services characterised by some service quality attributes, varying on three levels. The choice data were used to calibrate a multinomial logit (MNL) model and by model estimation, the importance of each service attribute on the overall service quality was evaluated. In Eboli and Mazzulla (2008), a stated preference experiment was proposed to the passengers of an urban bus service in Conseza (Italy) with the main purpose of exploring the optimal design of a stated choice experiment for measuring service quality in public transport. In Marcucci and Gatta (2007) stated preference methods and choice-based conjoint analysis were used for passengers' evaluation of a transit service in some geographical areas of Marche in central Italy. The data were used to calibrate a nested logit model for considering the differences of the geographical segments and to calculate an index of service quality.

On the other hand, some studies have concentrated on the features that are supposed to reflect the appropriateness of public transit systems in view of access and accessibility to public transit (Murray et al., 1998; Murray, 2001; Rastogi and Rao, 2003a; Rastogi and Rao, 2003b; Munoz-Raskin, 2010; Jiang et al., 2012) and accessibility to key nodes of employment, housing, leisure and other social activities (Handy and Niemeier, 1997; Geurs and Ritsema, 2001; Lau and Chiu, 2004; Zhu and Liu, 2004; Delmelle and Casas, 2012). Although accessibility studies shed light on the spatial distribution of availability and reach-ability of opportunities, they do not tell us how public transit service offered has satisfied the users and to what extent is the degree of satisfaction. Other studies use the benefits-driven approach based on the maximisation of either the user's or location's benefit (Miller, 1999). Such research deals with network analysis and spatial design of a specific transit system or a single route (Matisziw et al., 2006; Hadas and Ranjitkar, 2012).

While this study draws on all of the aforementioned lines of research, it evaluates public transit service quality from an under-explored perspective, i.e. the integration of behavioural models with geo-spatial models in the evaluation of public transit service quality. Research on user perceptions of different transit service aspects has been performed before, but very few studies deal with analysis of spatial variation of people's preferences in transit service quality evaluation. It could be criticised as the subjective evaluations from the perspective of satisfaction and spatial evaluation of the physical environment are hardly integrated. The integration would be a big step forward for stipulating service quality improvement and spatial intervention strategies. Linking preferences of (potential) transit riders through stated choice modelling to spatial analysis of transit performance is important in order to allow a transit operation agency to evaluate its service provision in meeting user travel needs and expectations. The objective of this study is to integrate behavioural models derived from stated choice analysis into GIS to evaluate transit service quality with a central focus and application to the proposed BRT system (DART) in Dar-es-Salaam. The paper is aimed at finding out how potential users value the proposed DART service. In other words, how important are the proposed DART service attributes to potential customers? Where is the DART service likely to generate satisfaction and to what extent is the level of satisfaction expected?

3. Methodology and data

The evaluation of the proposed DART service quality described in this study involves two steps. The first step is to analyse commuters' preferences towards the proposed DART service in order to identify how the proposed service attributes are important to potential riders. Based on this information, the next step examines the magnitude and spatial variation of the satisfaction (or utility) levels derived from the DART service. Methodologies proposed in this study for the two steps take advantages of stated choice analysis with random utility models and the spatial analysis and visualisation capability of GIS. The integration of behavioural models with a geo-spatial model allows for spatial evaluation of the commuter preferences variation in relation to the satisfaction derived from the proposed DART service.

3.1. Survey instrument and data collection

Stated preference (SP) surveys have been widely used in transportation studies given their potential to measure how people choose not-yet-existing travel modes or how people take actions in case of introducing new policies, in this case a new bus transit system (Hensher, 1994). SP experiments examine individual responses to a series of experimentally designed choice alternatives which are described in terms of combinations of attributes with several pre-defined levels (Hensher et al., 2005). Since people in Dar-es-Salaam have not yet experienced the proposed DART system, nor experienced any BRT like system, it was necessary to use stated choice techniques to elicit commuters' preferences. This was aimed at finding out whether the proposed DART service is socially and spatially desirable from the point of view of the potential users.

Therefore, a stated preference survey was conducted in Dar-es-Salaam in September, 2007. Details of the survey development and administration have been described in (Nkurunziza et al., 2012a). In brief, survey samples were obtained from individual commuters at the age of 15 years and above who travelled on a regular basis to the central business district for main activities such as: work, school, business and recreation. The regular commuters were assumed to be a right target group with the potential of using and being able to afford the DART system service, whereas people below 15 years were assumed to not be able to respond to the survey questions independently. The results in this paper are based on a survey questionnaire that comprised three main types of questions. The first part collected information about individual travel behaviour characteristics. The second and main part of the survey contained a set of stated choice questions, i.e. a series of binary bus choices (the subject of this paper). The third part collected infor-

Table 1
Summary of the general characteristics of the respondents ($N = 684$).

Characteristics	Statistics
1. Gender	Male (53.7%), Female (46.3%)
2. Age	15–25 (30.3%), 26–64 (68.1%), >64 years (1.6%)
3. Employment Status	Full time (21.2%), Part time (12.9%), Self-employed (44.7%), Student (11.8%), Other (9.4%)
4. Education Level	No education (1.3%), Primary (32.3%), Secondary school (44.9%), Higher (21.2%), Missing data (0.3%)
5. Main travel mode	*Daladala* (public transport) (87.9%), Private car (8.9%), Walking (1.8%), Bicycle (0.3%), Other (1.1%)
6. Main travel purpose	Work (28.5%), School (9.5%), Business (49%), Other (12.9%), Missing data (0.1%)

mation related to socio-economic and demographic questions. The summary details of the raw survey data characterisation based on the first and third part of the questionnaire are reported in Table 1.

The survey samples were collected from the available pre-defined residential Traffic Analysis Zones (TAZs) of the city. TAZs are partitioned according to variables that are most pertinent to travel choices and are as homogeneous as possible within each spatial unit and heterogeneous between the units with regards to travel choice and factors (Yao, 2007; Ortúzar and Willumsen, 2001). The final selection of the residential TAZs for surveying was based on the distance of the TAZs from the Central Business District (CBD), their locational distance from the proposed DART line stops and the residential density of the TAZs. As Dar-es-Salaam is more of a mono-centric city, where the CBD is the major trip attraction zone, we adopted the concentric zonal survey approach from Goudie (2002). The CBD accommodates most of the public and private activities and it is the destination of most commuting trips in the city (JICA, 2008). The concentric zonal survey allows sampling respondents based on radial distance from the CBD. Using the zonal survey approach, the study area was divided into four buffer rings, where the CBD was taken as a reference point. The four buffer rings are residential TAZs within 5 km, 10 km, 15 km and more than 15 km radial distance from the CBD. The buffer rings were purposely constructed to detect spatial variation of commuter preferences towards the proposed DART service with respect to residential location and distance from the CBD. Fig. 1 shows the residential TAZs, where the survey samples were collected.

A total sample of 740 commuter respondents was interviewed randomly in residential TAZs within the different buffer rings, while only 684 well completed questionnaires were taken for analysis. As each respondent was presented with nine choice scenarios (see Nkurunziza et al., 2012a), the potential total number of observations (pseudo-individuals) was 6156, a reasonable sample size for choice modelling. Normally, 500–1000 sample observations are more than adequate to give good estimations (Hensher et al., 2005). For a more detailed discussion on design of stated preference surveys and stated choice analysis, see (Louviere et al., 2000; Ortúzar and Willumsen, 2001; Hensher et al., 2005; Polak and Jones, 1997).

3.2. The stated choice model structure and variable specification

The variables used in the choice experiment were based on the proposed DART service quality attributes derived from the DART design reports of Logit (2007) which were obtained from DART agency and Dar-es-Salaam City Council (DCC). Three attributes: travel time, travel fare and (in-bus) comfort were selected and considered for the study (see, Nkurunziza et al., 2012a for more details on the DART attributes). The selection of these attributes and their level values were based on work sessions held with DCC and DART agency local staff and the information collected from a pilot survey among a section of current public transport regular commuters to the Central Business District (CBD). This way we managed to increase the realism of the hypothetical choice context to a plausible maximum by bridging the gap between reality and the stated intentions.

The study uses logit modelling based on random utility theory to analyse the choice data which is by far the most used approach for processing stated preference data in transportation research (Ben-Akiva and Lerman, 1985; Louviere et al., 2000). Random utility theory assumes that individuals choose the travel alternative that maximises the individual's utility (MacFadden, 1974). A random utility model in form of binary logit was considered and estimated using maximum likelihood method. The specified random utility model estimated for this study is expressed as:

$$U_{bn} = V_{bn} + \varepsilon_{bn}, \quad V_{bn} = \sum_{k} \beta_{bk} X_{bkn} \tag{1}$$

where n is an index for individuals, b is an index for the unlabeled 'DART' type (either 1 or 2, because each scenario comprises of two alternative buses); U_{bn} is the total utility of the DART gained by an individual; V_{bn} is the systematic utility component of the DART; the random error component ε_{bn} is the non-observable utility component of the DART, which is assumed to be identically and independently standard *Gumbel* distributed across alternatives and observations. It represents individual idiosyncrasies and tastes, as well as any measurement or observational errors made by the modeller. The systematic part of utility V_{bn} depends on the bus attributes considered in the study. Parameter β_{bk} is the random utility coefficient associated with attribute X_{bkn} of the DART; X_{bkn} represents a vector of explanatory variables specific to individual n and DART type b; k is the k^{th} attribute of the DART.

The systematic utility function of the bus alternatives is defined as a linear combination of the DART service quality attribute variables and is expressed as follows:

$$V^{i}_{DART} = \beta_{TTr} TT^{i}_{DART} + \beta_{FAREr} FARE^{i}_{DART} + \beta_{CFTr} CFT^{i}_{DART} \tag{2}$$

where: V_{DART} is the systematic utility component of the DART; TT_{DART} is the one way total travel time of DART; $FARE_{DART}$ is the one-way total travel fare of DART; CFT_{DART} is the level of comfort of DART; β_{TT} is coefficient associated with travel time; β_{fare} is the coefficient associated with travel fare; β_{CFT} is the coefficient associated with comfort; i = residential TAZ; and r = the buffer ring. The systematic utility is accordingly augmented with the random error component to get the total utility of the DART service (U_{DART}) following Eq. (1).

As this was an unlabelled experiment, the intercept has not been considered when designing the models and no socio-economic variables have been introduced (Hensher et al., 2005). It was decided to work with categories of commuters (potential users) defined by radial distance from the CBD.

3.3. Spatial modelling and scenario development process

To model the commuter preferences towards transit service quality, a geo-spatial multi-modal network was constructed using ArcGIS Spatial Analyst tool. The GIS network data layers included the DART phase 1 corridor network and feeder system, the *daladala* network and the current Dar-es-Salaam city road network. These different road network data layers were built together into a spatial multi-modal network model. With the overlay of other spatial data layers such as; residential TAZs, the CBD zones and the population data, it was possible to conduct spatial analysis. However, the multi-modal network only considers the DART phase 1 corridor and its feeder network and not all the six DART phases since the

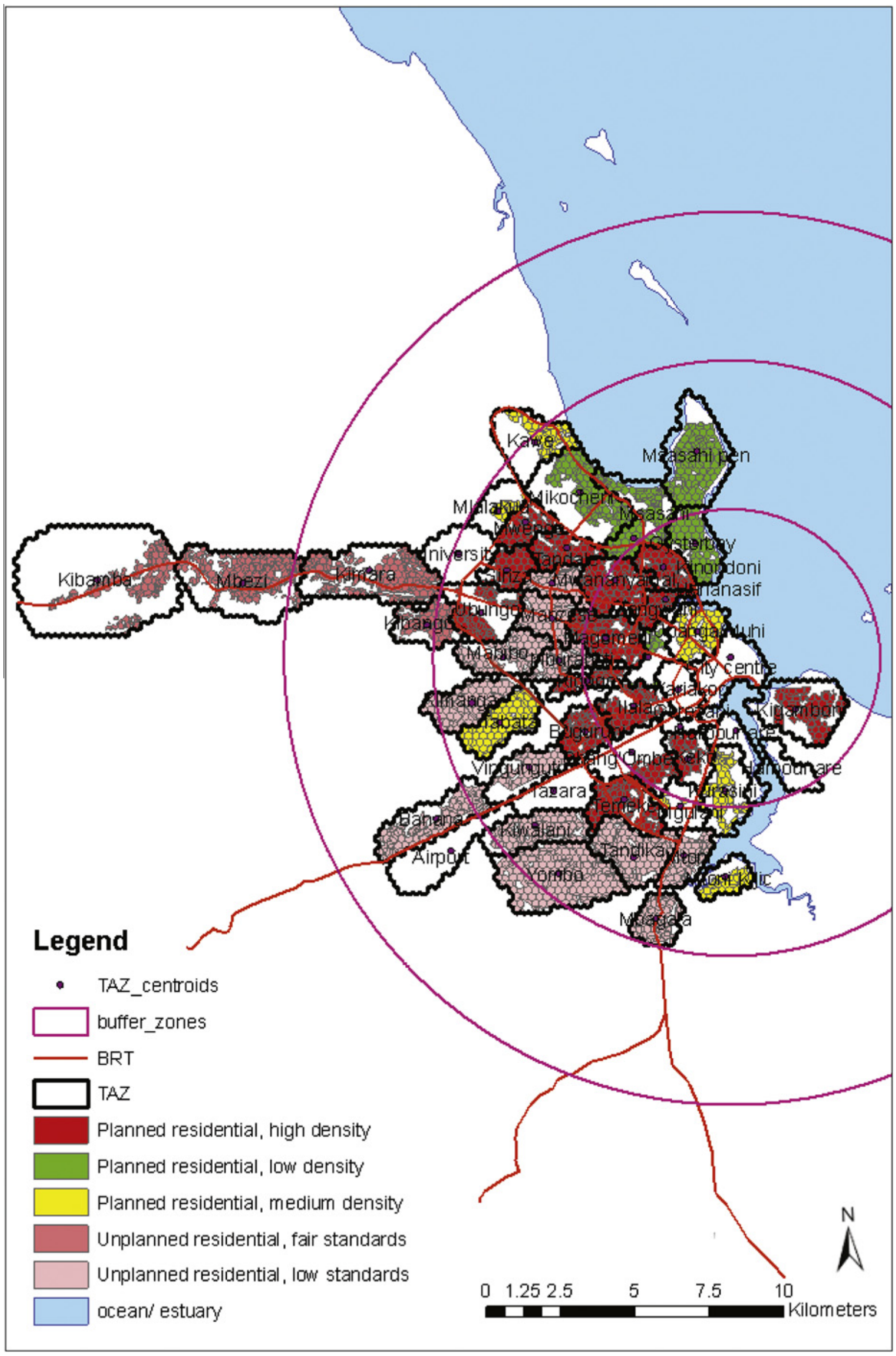

Fig. 1. A concentric zonal survey map of the study area.

required information about the other phases is not yet available. This limitation has no effect on the results since the DART system will have similar service attributes in all six phases of the DART for the entire city (Logit, 2007). Hence, the analysis and conclusions drawn in this paper are based on the DART phase 1 corridor and its feeder system. Fig. 2 shows the detailed methodology of integrating the behavioural models into GIS for spatial modelling of the proposed DART service quality.

For spatial analysis of the proposed DART service quality, it was required to develop scenarios to be able to examine the effect of the DART in reference to the existing public transport. Two scenarios: the '*DART*' and '*Without DART*' were developed. The '*Without DART*' scenario served as a base (*daladala*) scenario during analysis. When developing this scenario, the lower limits of the attribute levels used in the stated choice experiment (see Nkurunziza et al., 2012a) served as a baseline and represented the *daladala* characterised by overcrowding, longer travel times and unregulated fares among others. During analysis, the '*DART*' and '*Without DART*' scenarios were represented by the DART Phase 1 corridor and *daladala* route networks respectively. Using a scenario-based approach, behavioural models from stated choice analysis (see Table 2) were integrated into the GIS multimodal network model for spatial analysis of the proposed DART quality of service. In order to make the analysis possible, some assumptions were made. First, it was assumed that an individual commuter behaves rationally in making choices and takes the minimum cost route. Second, the DART system will have similar service attributes for all the six DART phases for the entire city. Third, for both the '*DART*' and

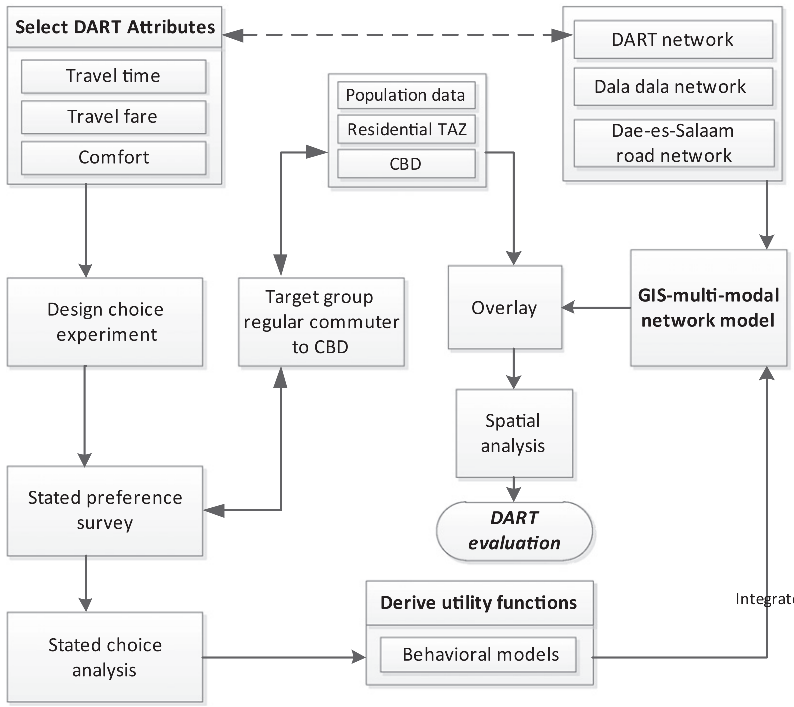

Fig. 2. Summary of detailed modelling framework.

'*Without DART*' scenarios, commuters can only get service at stops. Fourth, the DART will operate on the main trunk corridors and will not have any competition from the *daladalas*. To accommodate for this, a multi-modal network was built in such a way that the *daladala* will only operate on the DART feeder routes. Based on these assumptions, it was possible to compute the minimum cost (in terms of travel time, fare and comfort in-bus) route taken by an individual commuter from a given residential zone to the CBD and to spatially estimate the total utility derived from the trip.

4. Modelling results and discussion

The summary of descriptive statistics for the sample in Table 1 shows that males and females are almost equally distributed in the sample, although the percentage of males appears to be slightly higher. Most people in the sample are between 26 and 64 years of age as expected since this is a working age group and nearly 66% of the respondents are either full time or self-employed and 11.8% are students. Most of the sampled respondents had completed secondary education. About 88% of the sample commute by *daladala* and mainly travel to CBD for business (large-scale business, petty trading, business shopping) activities and for office work.

From the stated choice modelling, all models shown in Table 2 give significant results and all the attribute variables display the correct signs: negative for travel time and travel fare and positive for comfort. The parameter on the travel time variable is negative and highly significant, reflecting a preference for shorter travel times. The parameter on the travel fare variable is negative showing an aversion to expensive travel fares. The comfort parameter has a positive sign as expected and indicates that commuters prefer travelling in comfortable environment.

The parameter estimates shown in Table 2 show mainly the directionality of effect of the DART attributes. However, the relative effects of the attributes are not directly comparable because of the different ranges of the attributes. Stinson and Bhat (2003) propose a simple approach to assess the relative importance of each variable which is to compute the contribution to utility of each variable at its average value when the feature represented by the variable is present. For this case, we therefore computed the contribution to utility of each attribute at its average value when the proposed DART is present.

At this point it is of interest to see the information all together and graphically represent the contribution that each of the DART attribute variables makes to the utility function according to

Table 2
Models estimated for potential users based on radial distance from CBD.

Variable	<5 km Coef.	5–10 km Coef.	10–15 km Coef.	>15 km Coef.
Travel time	−0.0272***	−0.0148***	−0.0343***	−0.0347***
Travel fare	−0.0015**	−0.0035***	−0.0062***	−0.0041***
Comfort	1.11***	1.27***	1.81***	1.14***
Initial LL	−422.13	−923.27	−188.54	−349.35
Final LL	−352.82	−799.27	−153.55	−302.46
LR test	138.618	248.012	69.975	93.774
Observations	$n = 610$	$n = 1341$	$n = 272$	$n = 504$
Rho-square	0.164	0.134	0.186	0.134

*** 1% Significance level.
** 5% Significance level.

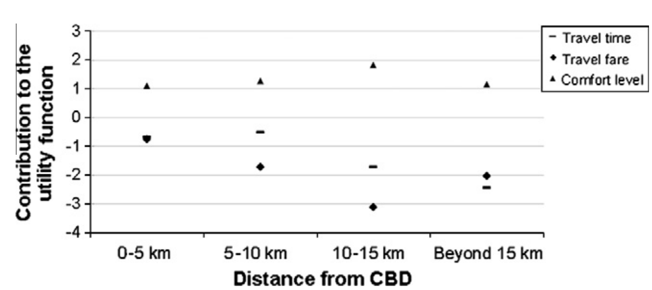

Fig. 3. Contribution of each DART attribute variable to the utility function.

Table 3
Derived utility functions from stated choice modelling.

DART attributes →	
$U_{r1}{}^{i}{}_{DART} = -0.0272TT^{i}{}_{DART} - 0.00149FARE^{i}{}_{DART} + 1.11CFT^{i}{}_{DART}$	Buffer rings r ↓
$U_{r2}{}^{i}{}_{DART} = -0.0148TT^{i}{}_{DART} - 0.00353FARE^{i}{}_{DART} + 1.27CFT^{i}{}_{DART}$	
$U_{r3}{}^{i}{}_{DART} = -0.0343TT^{i}{}_{DART} - 0.00623FARE^{i}{}_{DART} + 1.81CFT^{i}{}_{DART}$	
$U_{r4}{}^{i}{}_{DART} = -0.0347TT^{i}{}_{DART} - 0.00405FARE^{i}{}_{DART} + 1.14CFT^{i}{}_{DART}$	

Where: i = residential TAZ 1, residential TAZ 2, residential TAZ 3, …
r_1 = buffer ring 1 (residential TAZ within 0-5 km radial distance from CBD)
r_2 = buffer ring 2 (residential TAZ within 5-10 km radial distance from CBD)
r_3 = buffer ring 3 (residential TAZ within 10-15 km radial distance from CBD)
r_4 = buffer ring 4 (residential TAZ located more than 15 km radial distance from CBD)

potential user categories based on radial distance from the CBD. Having knowledge of how potential users from different spatial locations of the city value the proposed DART service makes it easier to evaluate its effectiveness and to establish lines of action in improving the quality of service. Fig. 3 shows graphically that the contribution each variable makes to the utility functions estimated for the different potential user categories follows a very different line in all cases. The comfort variable (with a positive sign) contributes greater weight to the utility function for all the defined potential user categories independent of radial distance from the CBD. The travel fare and travel time variables (with negative signs) contribute greater weight to the utility functions as one goes away from the CBD. These variables can be seen to contribute greater weight to utility functions for potential user categories from zones within (10–15) km and (>15) km radial distance from the CBD and making less contribution to the utility functions for potential users from zones within (0–5) km and (5–10) km radial distance from the CBD.

Generally, comfort is the most important attribute variable since it contributes greater weight to the utility functions for all potential user categories, followed by travel fare and travel time respectively. Similar findings have been reported in Dell'Olio et al. (2011), where comfort stood out to be an important variable

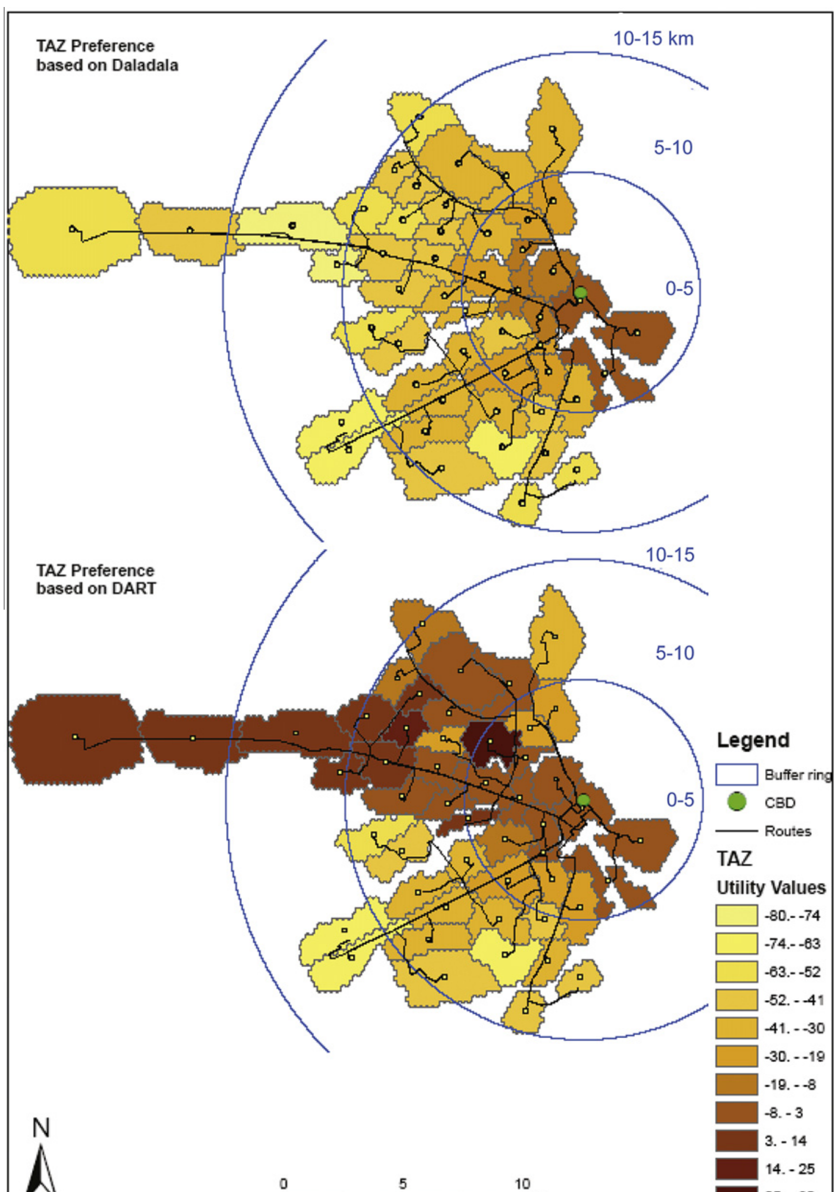

Fig. 4. Comparison of zonal preferences based on *DART* and *Without DART* '*daladala*' scenarios.

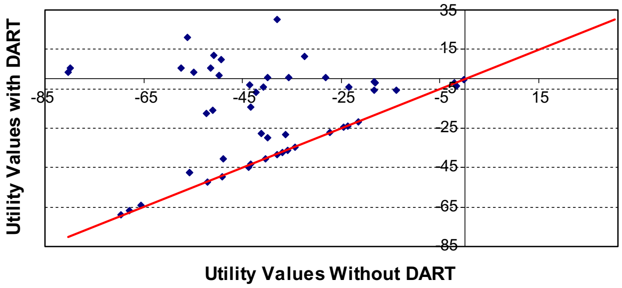

Fig. 5. Scatter plot of zonal utility differences between the *DART* and *Without DART* scenarios.

to define the quality desired from an efficient and safe public transport service. More specifically however, comfort is more important in zones within (0–5) km, travel fare is more important in zones within (5–10) km and (10–15) km while travel time is more important in zones beyond 15 km distance from the CBD. The result seems reasonable since in Dar-es-Salaam people living close to the CBD, i.e., within 5 km radial distance from the CBD are mainly the high income business people and the well-educated who would like to travel comfortably and do worry less about travel fare and travel time. People living within (5–15) km radial distance from the CBD are mainly low income people from informal settlements. For these people it sounds reasonable to place more weight on travel fare than comfort and travel time. People from outer zones of the city, i.e. beyond 15 km radial distance from the CBD place more importance on travel time than other variables since they spend more time on the way to CBD as a result of poor *daladala* service and traffic congestion.

4.1. Integrating behavioural models into the GIS multi-modal network model

At this stage, the random utility functions derived from the stated choice modelling (see Table 3) were input into the GIS multi-modal network as attributes. The integration of behavioural models into GIS was meant to spatially evaluate and visualise the utility attached to the DART attributes and to estimate the total utility of the DART service gained by an individual commuter from a given residential zone. When integrating behavioural models into the GIS multi-modal network, the travel time, travel fare and comfort attributes as well as the utility value of each of the attributes and the total utility functions were all attributed to the network.

Fig. 4 shows the preference differences between different zones by comparing the *DART* and *without DART* scenarios. For purpose of interpretation, a high positive utility value means high preference indicating that the DART is more attractive to its potential users whereas a low negative utility value indicates low preference for the DART revealing less attractiveness of the DART service. The results generally show that zones located along the DART phase1 corridor and its feeder route network have considerably high utility values in the *DART* scenario compared to the same zones in the *without DART* scenario. This simply tells us that commuters reveal high preference for the proposed DART service compared to the current *daladala* service, implying that the DART is more likely to be attractive than the *daladala*. The results further reveal that outer most zones of the city are likely to be more satisfied with the DART service than the inner zones in the *DART* scenario. In reference to the *daladala* scenario, the DART is likely to improve commuting service significantly to the city peripheral zones. Despite the general improvement in transport service, the results indicate that the DART is likely to deliver ineffective service to some zones located along the north eastern coastal line of the city especially to those within 5 km and 10 km radial distance from the CBD.

For better understanding of the proposed DART effect on people's satisfaction, a scatter plot of utility values (see Fig. 5) based on zonal preference differences from the *DART* and *Without DART* scenarios was constructed. The diagonal line serves as a reference line to assess the change in zonal preferences. Zones represented by points located above the diagonal line indicate that the DART service is most likely to increase user satisfaction in reference to the *Without DART* scenario. Zones represented by points located along the diagonal line indicate that the DART introduction is likely to have no effect on improvement of service quality implying that the DART is most likely to offer service similar to that of *daladala* in those zones. While zones located below the diagonal line show a decline in quality of service as a result of the DART introduction. The findings reveal that 68% of the zones are likely to gain more satisfaction from the DART service, 16% are neither likely to increase nor decrease their satisfaction levels from the DART and the remaining 16% of the zones are likely to decrease their satisfaction as a result of the DART introduction. The reason for this decline in satisfaction could be longer access times to the DART feeder line stops and transfer times to the BRT trunk line especially in zones along the north eastern coastline of the city. In this case, *daladala travel* times to the CBD are shorter as in reality one can easily access its service anywhere along the network routes and also one can easily reach the CBD without making a transfer.

At this point, it is also important to analyse the DART effect on the potential users from different types of residential zones. The residential zones were classified as; planned (54%), unplanned (32%) and mixed use residential (14%). The results show that planned residential zones gain relatively high utility both in the *DART* and the *without DART* scenarios (see Figs. 6 and 7 respectively) compared to the mixed use and unplanned residential zones. When comparing the utility values of the same zones in the *DART* (Fig. 6) and in *without DART* (Fig. 7) scenarios, it is shown that the utility values in the former is slightly skewed towards higher utility values while in the latter the utility values are slightly skewed towards lower utility values for all residential types, i.e. planned, unplanned and mixed use residential. This again

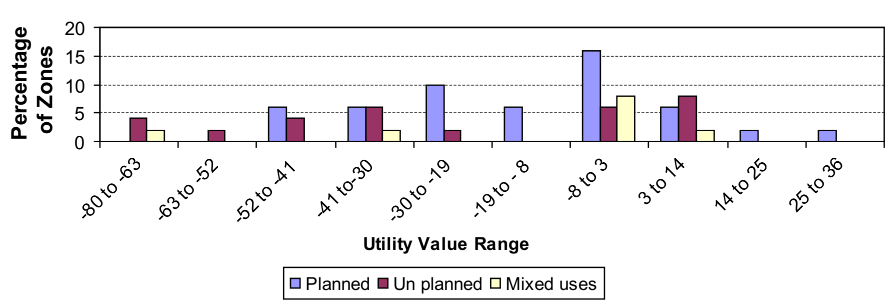

Fig. 6. Zonal utility differences for the *DART* scenario by residential type.

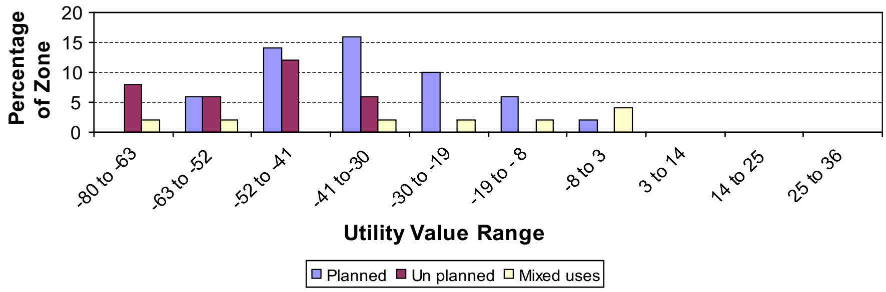

Fig. 7. Zonal utility differences for the *Without DART* scenario by residential type.

supports earlier results and confirms that the DART is likely to provide an improved and better service than *daladala*. This is revealed by the decrease in zones with lower utility values and increase in zones with high utility values in the *DART* scenario as compared to the *Without DART* scenario. Although in a different setting and context, the study findings share some similarities with studies elsewhere (Currie, 2006; Cain et al., 2009; Deng and Nelson, 2012). For example, Cain et al. (2009) conducted a study to quantify the importance of image and perception to BRT using a set of tangible and intangible factors to identify the perceived differences among BRT, LRT and Metro. The study found out that the general public had a high perception of the BRT service. Currie (2006) suggests that BRT systems show higher satisfaction than on-street bus and rail corridors based on evidence from Adelaide, Australia.

5. Conclusion

The point of view of potential passengers is fundamental for evaluating transit service quality because they are envisaged to be the real consumers of the planned services and can therefore be considered the most suitable judges. This study has provided a framework for analysing urban public transit systems and their potential for providing and improving service quality as desired by the urban population. The study applied stated choice modelling techniques to estimate the most important DART attribute variables and identified how potential users (commuters) value the proposed DART service. The study also attempted to spatially analyse the effectiveness of the DART service by answering the question: Where is the proposed DART service highly or less valued as compared to the existing public transport? The analysis was able to shed light on answers to the research question by integrating behavioural models into GIS. To our knowledge, this is a novel approach, in particular within the context of integrating random utility models into geo-spatial models. Linking the derived random utility functions from stated choice modelling to GIS made it possible to spatially analyse the potential user preferences and to identify the preference variation between zones.

The study results reveal that (in-bus) comfort is the most important variable with great contribution to the DART utility compared to travel fare and travel time variables. More specifically however, the importance of the attributes varies with respect to radial distance from CBD. Comfort is more important in zones within (0–5) km, travel fare is more important in zones within (5–10) km and (10–15) km while travel time is more important in zones beyond 15 km distance from the CBD. The results generally show that the DART is more preferred to the existing *daladala* service. Zones located along the DART main trunk corridor and in the city periphery have indicated higher preferences, suggesting high satisfaction with the DART service. Despite the general high preference for DART service, the DART is likely to have no effect on some zones and in some cases it is likely to decrease service quality. The study findings revealed that 68% of the residential zones have higher preferences in favour of the DART. 16% of the zones reported neither increase nor decrease of preferences for the DART compared to *daladala*, while the remaining 16% have reported decrease in preferences in favour of *daladala* service.

For transport planners, the study findings suggest that only through providing a commuting service characterised by better comfort, lower travel times and lower travel fares will the DART be attractive to its potential users. Planners should pay more attention and consider all the three attributes important when providing the DART service. However, in priority cases, particular attention should be given to (in-bus) comfort, which proved to be the most important variable in terms of its contribution to the DART utility. To improve the proposed DART service quality, DART feeder route networks should be planned and extended in a more cost effective manner by emphasising on zones with low satisfaction (utility) levels and those with limited access routes to DART. Residential zones with planned DART feeder route networks but indicating low satisfaction indicate a need to check on improvement of location of the DART feeder stops and transfer points. For transit operators, knowledge about the desired service quality provides operating companies with an answer to their investment questions and establishes the basis for designing future policies to encourage greater use of public transit based on the needs and expectations of their potential customers. Knowing variables that are most important to potential users is useful information for the proposed DART service planning as they provide guidelines to follow when required to improve the service. Once the operators know the variables that potential users value most they can define and direct more efficient lines of investment to those specific points.

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