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ITS Applications in Developing Countries: A Case Study of Bus Rapid Transit and Mobility Management Strategies in Dar es Salaam – Tanzania

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1. Introduction

Mobility problem and planning technique suffered a revolution in the 1980s. We still encounter many of the same transport problems of the 1960s and 1970s: congestions, technology, pollution, accidents, financial deficits and so on. However, it was possible to learn a good deal from a long period of weak transport planning, limited investment, emphasis on the short term and mistrust in strategic transport modeling and decision making. A new contemporary dimension is the fact that most developing countries are suffering serious transport problems as well. These are no longer just the lack of roads to connect distant rural areas with markets. Indeed, the new transport problems bear some similarities with those prevalent in the industrialized world: congestion, pollution, technology, and so on. Fortunately, transportation technologies and mobility management strategies are emerging that can help to meet the transportation challenge; these include ITS technology that provide and foster more reliable operation guidance, information, fare technology, automotive, fuel technologies and so on. For the purpose of this chapter we assume that intelligent transport system (ITS) should be taken to include all those systems that use information technology. The impact of information system and other ITS innovation on travel demand and transport system performance can be modeled in many different ways, but the key ways of the modeler is to determine the appropriate level of aggregation. This will be determined primarily by the purpose of the exercise. At one extreme strategy planner might welcome an aggregate model which uses information theory to predict the consequences that ITS innovation should have for the efficiency of the transport system. Implementation of Bus Rapid Transit - BRT and mobility management strategies can enhance the mobility in the city and reduce the demand for private vehicles. It can be concluded from this chapter that the introduction of a BRT system in Dar es Salaam has numerous evident gains in terms of improving the current public transport supply. Nevertheless, some shortcomings have been identified that limit the contribution of the system in its endeavor towards creating a sustainable urban mobility system in the city. These shortcomings are the inequitable distribution of services across population groups; the need to limit the growth in the number of cars; the lack of involvement of the current

public transport operators in the planning process and the heedless handling of their fates. Mobility and transportation are also the leading indicators of economic growth of a society. Unfortunately, if left unchecked, these indicators show a declining trend with the passage of time (i.e., traffic congestion) because transportation systems are often designed to overcome the present crisis without considering the increasing nature of the population of a country. Under Dar es Salaam city in Tanzania the conditions of accessibility of existing public transport and mobility is deeply creates great hardship for the citizen they have bad seat arrangements, overload passengers, not follow allocated routes, speed and drive recklessly, emit large amount of large amount of pollutants and Carbon Dioxide (CO₂), and so on. Hence you can find that in developing countries can quickly reveal the source of customer dissatisfaction with public transport and non-motorized options poor transit services and these push consumers to private vehicle options. The splendid transit system called Bus Rapid Transit System with more mobility when compare to heavy rail/ light rail transit. It is an integrated, well defined system with design features similar to light rail rapid transit systems. BRT represents a way to improve mobility at a relatively low cost through incremental investment in a combination of bus infrastructure, operational movements and technology. BRT will utilize intelligent transportation system technology, modern land use planning and transportation policies to support new concept for rapid transit system.

2. Over view of population and urbanization

2.1 Population growth and urbanization

Although travel has been part of a human experience for many centuries, the 20th century seems to have depicted a quite distinct experience (OECD, 2000). The century happens to be characterized by remarkable rates of growth in population, mobility and urbanization such that, globally, motorized transport increased by more than one hundred fold while population increased by fourfold (OECD, 2000). Along with these changes, urban land has been rapidly expanding due to the modern patterns of city growth that are land intensive as well as the improvements in transportation services that made commuting easier (UNFPA, 2007). The sum total of these phenomena has thus been a continuing movement of people resulting in tremendous growth of urban areas (UNFPA, 2004). Accordingly, at present, for the first time in history, more than half of the world's population dwells in cities and it is estimated that all regions of the world will have urban majorities by 2030 (Habitat, 1996a). This gives urban areas, and the issues related to them, an increasing importance in contemporary socio - economic and environmental discussions.

2.2 Population trends in Tanzania

The country has experienced continued, steady population growth over the past three decades. According to the data from National Population and Housing Census, which has been conducted four times by the National Bureau of Statistic (NBS), the population of Tanzania mainland has increased nearly triple since 1967; the population extended from 11.9 million persons in 1967 to 17.0 million persons in 1978, 22.4 million persons in 1988 and to 33.4 million persons in 2002 (Table 2.1). The average annual population growth rate was 3.3 percent between 1967 and 1978, 2.8 percent between 1978 and 1988 and 2.9 percent between 1988 and 2002. Tanzania represents one of the larger African countries on a population basis. According to the World Bank population index of year 2004, Tanzania had fifth largest population size

following Nigeria, Egypt, Ethiopia and South Africa. Population size is roughly comparable to Sudan and Kenya (Table 2.2). Population density is relatively modest at approximately 43 persons per square kilometer of land area. The share of urban populations was 36.4 percent in Tanzania, which was lower than South Africa (57.4 percent), Kenya (40.5 percent) and Sudan (39.9 percent) and much higher than Ethiopia (15.9 percent) and Uganda (12.3 percent).

Year	Tanzania Mainland	Average Annual Growth Rate (percent per annum)
1967	11,958,654	
1978	17,036,499	3.27 (1 967-1 978)
1988	22,455,207	2.80 (1 978-1 988)
2002	33,461,849	2.89 (1988-2002)

Source: The United Republic Tanzania Population and Housing Census, NBS.

Table 2.1. Population Trends in Tanzania Mainland.

2.3 Population growth and urbanization in Dar es Salaam City

The increasingly trend of urbanization worldwide can be demonstrated using the rapid increase over the past decades in urban population in almost all regions of the world (UNFPA, 2004). According to the United Nations World Urbanization Prospects (WUP, 2005), urban population has grown from 29% in 1950 and 37.2% in 1975 to 48.7% in 2005. That represented an annual rate of change of 2.65% which was more than double the rate for rural population, 1.12% (Habitat, 1996a). Following this increasing trend, it is estimated that the global urban population will reach as much as 5 billion by 2030, which would represent 60% of the world’s population (UNFPA, 2004). Although both developed and developing countries have been experiencing an increase in urban population, the rates of change in these regions vary greatly. According to (WUP, 2005), the urban population in developing countries increased annually at 3.61% between 1950 and 2005 while developed countries had the increase at only 1.37% per year. Likewise, these rates are estimated to be 2.20% and 0.47% for developing and developed countries, respectively, over the years between 2005 and 2030 (Habitat, 1996a). This is quite plausible as internal migration (i.e. the movement of people within a country) from rural areas to urban areas is high in the developing world for several reasons (UNFPA, 2004). The most important ones appear to be the so called demand pull and supply push factors that denote productivity and monetary reward prospects in urban areas and rural poverty due to traditional agriculture. (Borris. S.L Bertinell & E. Strobl 2006) While social changes induced by need for higher education, rising incomes, and emerging life styles are other reasons (Button, K & P. Nijkamp 1997) Being an African city, Dar es Salaam has for decades been experiencing rapid population growth (Olvera, L.D Plat & Pochet 2003). States, for example that the population of the city grew at an annual growth rate of 9.4% between 1968 and 1978 and at 4.7% between 1978 and 1988. The past decades showed similar patterns such that the population of the city reached 2.5 million by 2002, doubling the population since 1988 (Lupala J 2002). Currently, the population growth rate of the city is estimated to be 4.1% (JICA, 2008). This denotes a pressure directly exerted on the transport demand in the city, be it in terms of the need for more vehicles or the need to commute longer due to a geographical growth of the city. Figure 2.1 below shows the map of Dar es Salaam city.

Country	Year 2004 Population	Land Area (sq km)	Population Density (Persons/sq km)	Percent Urban Population
Nigeria	128,710,000	910,770	141.3	47.5
Egypt	72,642,000	995,450	73.0	42.2
Ethiopia	69,961,000	1,000,000	70.0	15.9
South Africa	45,509,000	1,214,500	37.5	57.4
Tanzania	37,627,000	883,590	42.6	36.4
Sudan	35,523,000	2,376,000	15.0	39.9
Kenya	33,467,000	569,140	58.8	40.5
Algeria	32,358,000	2,381,700	13.6	59.4
Morocco	29,824,000	446,300	66.8	58.1
Uganda	27,821,000	197,100	141.2	12.3
Ghana	21,664,000	227,540	95.2	45.8
Mozambique	19,424,000	784,090	24.8	36.8
Madagascar	18,113,000	581,540	31.1	26.8
Ivory Coast	17,872,000	318,000	56.2	45.4
Cameroon	16,038,000	465,400	34.5	52.1
Angola	15,490,000	1,246,700	12.4	36.4
Niger	13,499,000	1,266,700	10.7	22.7
Mali	13,124,000	1,220,200	10.8	33.0
Zimbabwe	12,936,000	386,850	33.4	35.4
Burkina Faso	12,822,000	273,600	46.9	18.2
Malawi	12,608,000	94,080	134.0	16.7
Zambia	11,479,000	743,390	15.4	36.2
Senegal	11,386,000	192,530	59.1	50.3
Tunisia	9,932,400	155,360	63.9	64.1
Chad	9,447,900	1,259,200	7.5	25.4
Guinea	9,201,800	245,720	37.4	35.7
Rwanda	8,882,400	24,670	360.0	20.1
Benin	8,177,200	110,620	73.9	45.3
Somalia	7,964,400	627,340	12.7	35.4
Burundi	7,281,800	25,680	283.6	10.3
Togo	5,988,400	54,390	110.1	35.7
Libya	5,740,100	1,759,500	3.3	86.6
Sierra Leone	5,336,400	71,620	74.5	39.5
Eritrea	4,231,500	101,000	41.9	20.4
Central African Rep.	3,986,000	622,980	6.4	43.2
Congo, Rep.	3,882,900	341,500	11.4	53.9
Liberia	3,240,600	96,320	33.6	47.3
Mauritania	2,980,400	1,025,200	2.9	63.0
Namibia	2,009,300	823,290	2.4	33.0
Lesotho	1,798,000	30,350	59.2	18.1
Botswana	1,769,100	566,730	3.1	52.0
G. Bissau	1,539,700	28,120	54.8	34.8
The Gambia	1,477,700	10,000	147.8	26.1
Gabon	1,362,300	257,670	5.3	84.4
Mauritius	1,234,200	2,030	608.0	43.6
Swaziland	1,119,800	17,200	65.1	23.7
Djibouti	779,100	23,180	33.6	84.1
Comoros	587,940	2,230	263.7	35.6
Cape Verde	495,170	4,030	122.9	56.7
Eq. Guinea	492,230	28,050	17.5	49.0
Sao Tome & Principe	152,960	960	159.3	37.9
Seychelles	83,643	460	181.8	50.1

Source: Study Team based on World Bank data. Ranking in descending population size

Table 2.2. African Population Patterns in Year 2004.

2.4 Urban sprawl

In accordance with the observed population growth in urban centers, almost all cities throughout the world experience expansion in their geographical space (UNFPA, 2007). This assumes different reasons in different parts of the world. In the developed world, and particularly in North America, urban sprawl results largely as people move into suburb areas in search of a higher quality of living (White hand J. & J. Larkham, 1992). While in the developing world, and typically in African countries, urban sprawl occurs as people build illegal houses in the peripheries of cities and render cheap rental conditions thereby attracting more and more settlers (Habitat, 19996a). Driven largely by many factors, the surface area of Dar es Salaam has increased rapidly over the past decades. (Olvera, L. D. Plat & P. Pochet, 2003) State, for example, that the land coverage of the city increased by many factors between 1968 and 1982. Likewise (Lupala. J 2002) records the geographic growth of the city during the period between 1963 and 2001 to be an increase by more than 18 times (from 3,081 ha to 57, 211 ha). Presenting this differently, (Olvera, L. D. Plat & P. Pochet, 2003) shows that the distance from the city center to the edge has increased from 15 km in 1978 to 30 km by the mid 1990s. Currently Dar es Salaam has a size of about 1800 km/sq (Hall. F, 2004 & JICA 2008)

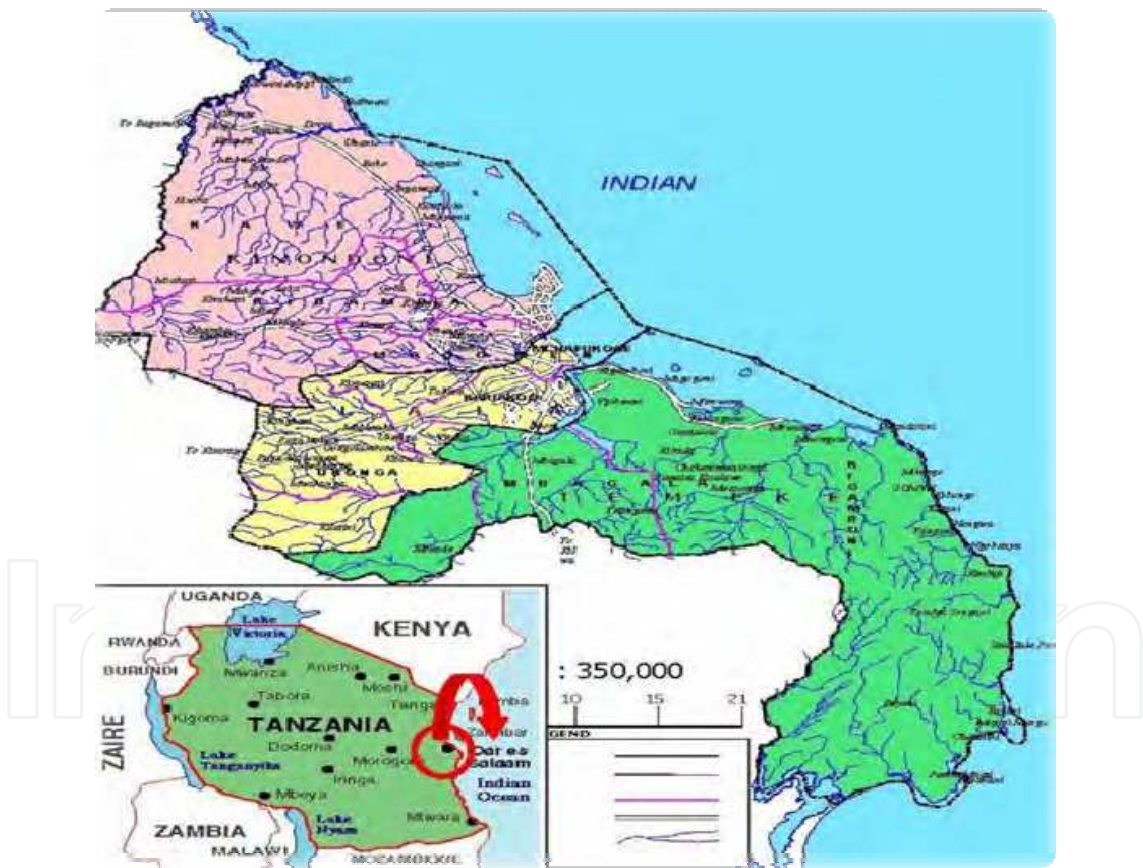


Fig. 2.1. Map of Dar es Salaam.

2.5 Designing model approach for the bus networks to grow with cities

This simple model looks at the rapid growth of a hypothetical city. The city is divided into zones of 1km square, each with a density of 200 inhabitants per ha, where bus passengers

can reach a route by walking a maximum of about 500m. For the first stage, of 80,000, one simple “square” bus route, as marked in blue, can connect all the zones. If a new zone is added, this route can simply be extended from A to allow access to the entire city. Figure 2.2 below express the effect of city grow on bus routes (80,000 to 180,000)

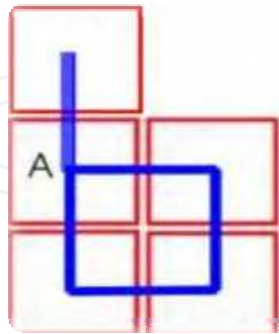


Fig. 2.2. The effects of city grow on bus routes (80,000 to 180,000).

When the city grows to 180,000, four (4) basic routes are needed: ABD; ACD; AD; and BC. Again, for a new zone, an extension of the three (3) routes AD and ABD and ACD give full accessibility. Figure 2.3 below express the effect of city grow on bus routes (180,000)

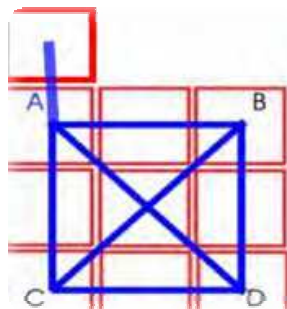


Fig. 2.3. The effect of city growth on bus routes 180,000.

In figure 2. 4: The city reaches a population of 320,000 by expanding in area, adding an extra 25% on each side. The route network needed to link the different zones starts to adopt the zigzag pattern typical of larger towns, and the routes have become longer 5 to 6 km instead of 2 to 4 km. eight routes are now needed for all zones to be connected: AMP; ADP; AP; MD; BFGL; CGFJI; EFJKO; HGKJN. There are also several routes superimposed, with excess capacity although this still leaves no direct connection between B and J; C and K; H and F; L and J; O and G; N and F; I and K; and E and G. Passengers between these zones must change buses and pay an extra fare. A new zone added to this structure will require six (6) extended routes, causing these routes to share the available demand and become 1km longer. This expansion is doomed to be unprofitable. Other typical problems of this “organic growth” are also shown: the purple route develops an irrational pathway; the black route has two (2) variations (say “Black a” and “Black b”), which means that the frequencies at the end points are unsatisfactory; and there is an oversupply of capacity at the route endings. If the city plans to develop new districts, with five (5) new zones at specific locations, each zone will

need several new routes to reach the existing city areas, including a route that offers a direct link between the zones themselves. Figure 2.4 routes on grid for a city of 320,000

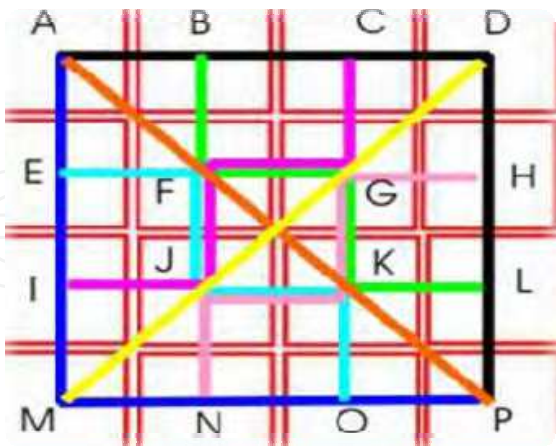


Fig. 2.4. Routes on a grid for a city of 320,000.

In the larger city an expanded system for a city of 320,000; needed each new development zone full accessibility to the main destinations (see Figure 2. 5). If this is not available, the passenger either has to use another mode to reach a satisfactory route, take more than one route, or simply not use public transport. At this stage in a city’s development, there is a need to follow the integrated approach. This allows the system to expand in order to meet the demands of planned city growth. Figure 2.6 shows how expansion in two (2) main corridors, north - west and south - east, can be included into the existing system by adding two (2) new interchange terminals at C and D. The main trunk route becomes C to D, using high capacity vehicles and some form of bus priority. The extra ten (10) zones at the same density would have an additional population of 200,000, taking the city to 520,000 inhabitants. Once the basic infrastructure is in place, access to the entire transport network is simplified and thus can become an essential factor in promoting the desired urban development. Figure 2.5 and 2.6 below express system for a city of 320,000 and expanded integrated system on a grid for a city of 520,000 respectively.

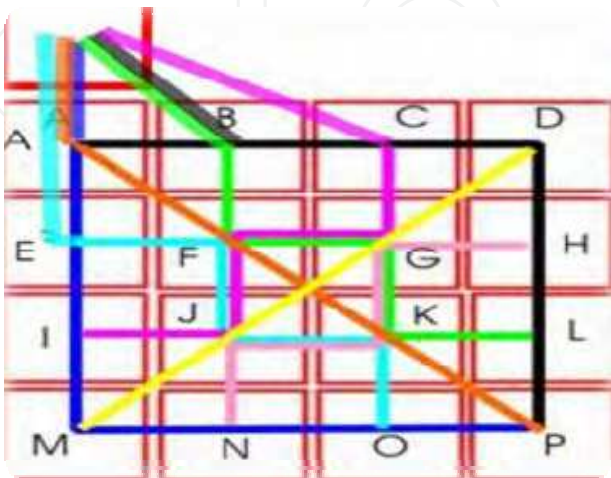


Fig. 2.5. An expanded system for a city of 320,000.

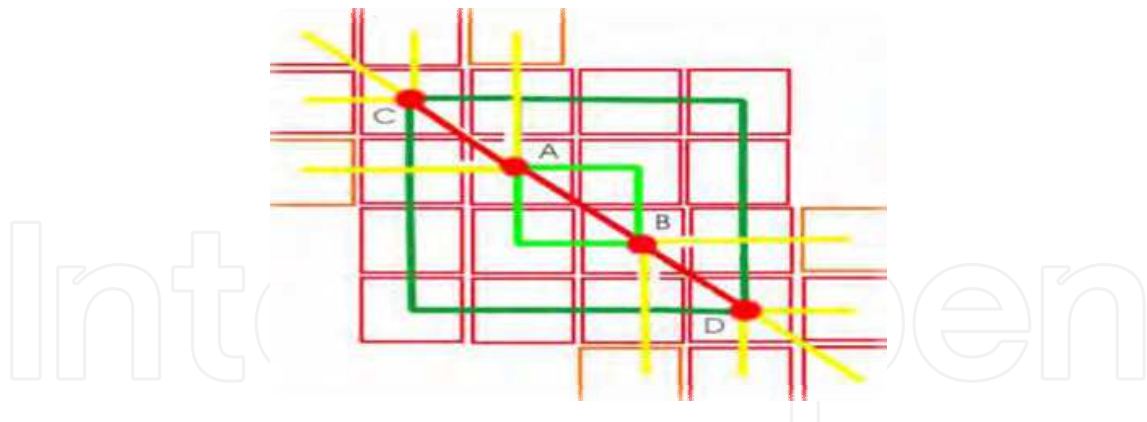


Fig. 2.6. Integrated system on a grid for a city of 520,000.

3. Mobility management and strategies in developing countries

3.1 Structural principles for sustainability

To achieve viability and sustainability of the transport systems in the developing countries, a set of structural principles are prepared:

- i. A strategic policy must be set which integrates and coordinates all aspects of urban development and planning;
- ii. The system needs to define single responsibility and accountability;
- iii. Risk and responsibility must be appropriately assigned between parties (government and agency); No party should carry risk it cannot manage;
- iv. The responsible agency needs adequate resources (self generating revenue mechanisms or allocated budgets) to perform its task;
- v. The institution needs to be involved in setting its own internal business strategy in accordance with strategic policy guidelines;
- vi. The necessity of a sound business model that delivers efficiency, sustainability, value for money (and integrated value added benefits), prioritization, economic, social and environmental benefits;
- vii. Use of performance/outcomes - based contract to specify and document the undertakings of both parties and establish the working relationship between them. Normal contractual conditions will specify general terms and conditions while the specifications of service outlines the quantity of service, payments as well as performance indicators, and the monitoring and enforcement conditions
- viii. The contract is commercially oriented in that it is fully funded to provide its services. No public service obligations or implications cloud its task and responsibilities;
- ix. Key Performance indicators must relate clearly to outputs and outcomes (deliverables, measurable data) as evidenced in service delivery, or outcomes (quality of life indicators) showing policy objectives are being met.

For the case of Dar es Salaam city in Tanzania, the establishment of Dar es Salaam Rapid Transit Agency - (DART Agency) addressed in detail many of above principles and outlines in considerable detail the objectives and methodologies of implementation and administration of the agency. At a higher level, Dar es Salaam Urban Transport Authority

(DUTA) will provide direction and coherence across all sectors so they operate harmoniously. The Institutional Development in Dar es Salaam Transport Authority has proposed to establish the Dar es Salaam Urban Transport Authority (DUTA) as an accountable and transparent authority responsible for the transport system development of Dar es Salaam. The management of urban transport as a function is almost nonexistent in Dar es Salaam specifically due to the lack of guidance attention for responsible agencies and the number of responsible entities involved, with municipalities and also national authorities cross-cutting into urban transport affairs. This has resulted in a fragmented planning process and lack of coordination, vertically and horizontally between levels of government and departmental disciplines. As one of the strategic policies to meeting these challenges DUTA has been proposed and its conceptual design has to be presented.

3.2 Transport demand

Transport problems have become more widespread and severe than ever that in both industrialized and developing countries alike. Fuel shortage are (temporarily) not a problem but general increase in road traffic and transport demand has resulted in congestion, delay, accidents and environmental problems well beyond what has been considered acceptable so far. These problems have not been restricted to road and car traffic alone. Economic growth seems to have generated levels of demand exceeding the capacity of most transport facilities. The demand for transport service is highly qualitative and differentiated. There is a whole range of specific demands for transport which are differentiated by time of day, day of week, journey purpose, type of cargo, importance of speed and frequency, and so on. A transport service without the attribute matching this differentiated demand may well be useless. The demand for transport is derived; it is not an end in itself. With the possible exception of sightseeing, people travel in order to satisfy a need (work, leisure, education, health) at their destination. This is even more true of goods movement. In order to understand the demand for transport, we must understand the way in which facilities to satisfy these human or industrial needs are distributed over space, in both urban and regional content. A good transport system widens the opportunity to satisfy these needs; a heavily or poorly connected system restricts options and limits economic and social development.

3.3 Transportation demand in Dar es Salaam City

Burdened with a rapid population growth and city expansion, Dar es Salaam's transport sector depicts a situation where the gap between public transportation needs and provision is continuously widening (Olvera *et al.*, 2003). This situation has been worsened as public transport is the only alternative for the poor. Two World Bank surveys done in 1994 and 1996 show, for example, that about 43% of all the trips done in Dar es Salaam were done using public transport, whereas only 7% of these trips were done with cars and motorbikes and 3% by bicycles (SSATP, 2005). A recent study by (Kombe *et al.* 2003) & (Kanyama *et al.*, 2004) also shows that as much as 60% of all trips made in the city are done on buses. Furthermore, the city's transport sector is burdened with high travel demand soaring from the uneven distribution of public and private facilities within the city (SSATP, 2005). This denotes, firstly, a concentration of employment and market opportunities in the city center. According to (Olvera *et al.* 2003), for example, Dar es Salaam's main urban facilities; its port,

the main hospital, the largest market and the commercial district Kariakoo are all located in the center of the city which obliges the inhabitants to commute to access the opportunities there. And secondly, it denotes lack of services, as schools and health units, within or close to residential areas that makes commuting unavoidable. (Olvera *et al.* 2003) demonstrates this by analyzing a 1993 Dar es Salaam Human Resources and Development Survey that the closest public secondary school and the closest public hospital are located on average at 4.8 km and 3.9 km, respectively, away from any home in the city, with higher figures for poor neighborhoods. The private alternatives are on average 3.9 km and 5.4 km away (Ibid). Although the figures given above duly portray the level of stress on the public transport in the city, accurate information can be gained by looking at the overall travel demand. A 2007 survey done by the Japan International Cooperation Agency - JICA has established that 2.87 million trips per day are made in total in the city using all modes of transport and that 2.13 million (74%) of those trips are made by motorized modes (JICA, 2008).

3.4 Transport delivery

Over view of the characteristic of transport supply is that it is a service and not a good. Therefore, it is not possible to stock it, for example, to use it in times of higher demand. A transport service must be consumed when and where it is produced, otherwise its benefit is lost. For this reason it is very important to estimate demand with as much accuracy as possible in order to save resources by tailoring the supply of transport service to it. Many of the characteristics of transport system derive from their nature as a service. In very broad terms a transport system requires a number of fixed assets, the infrastructure, and a number of mobile units, the vehicles. It is the combination of these, together with a set of rules for their operation. That makes possible the movement of people and goods. It is often the case that infrastructure and vehicles are not owned nor operated by the same group or company. This is certainly the case of most transport modes, with the notable exception of many rail systems. This separation between supplier of infrastructure and provider of the final transport service generates a rather complex set of interaction between government authorities (central or local), construction companies, developers, transport operators, travelers and shippers and the general public. The latter plays several roles in the supply of transport service: it is usually the resident affected by a new scheme, or the unemployed in an area seeking improved accessibility to foster economic growth.

3.4.1 Interactive fuzzy multi-objective linear programming to transportation planning decision

In real-world transportation planning decision (TPD) problems, input data or related parameters are frequently imprecise / fuzzy owing to incomplete or unobtainable information, a novel interactive fuzzy multi objective linear programming (*i*-FMOLP) model for solving TPD problems with multiple fuzzy objectives. The proposed *i*-FMOLP model attempts to minimize simultaneously the total production and transportation costs and the total delivery time with reference to available capacities at each source and forecast demand at each destination. The transportation planning decision (TPD) problem involves the distribution of goods and services from a set of sources (e.g. factories) to a set of destinations (e.g. warehouses). With a variety of transporting routes and differing transportation costs for the routes, the aim is to determine how many units should be shipped from each source

to each destination so that all demands are satisfied with the minimum total transportation costs. Basically, the TPD problem is a special type of a linear programming (LP) problem that can be solved using the standard simplex method. Some special solution algorithms, such as the stepping stone method and the modified distribution method, allow TPD problems to be solved much more easily than the general LP method. However, when any of the LP method or the existing effective algorithms is used to solve the TPD problems, the goal and related inputs are generally assumed to be deterministic/crisp (L. Li & K. Lai, 2000). In most practical TPD problems, input data or related parameters are often imprecise/ fuzzy owing to incomplete or unobtainable information. Obviously, conventional LP method and solution algorithms cannot solve all fuzzy TPD problems. In 1976, (Zimmermann, 1997) first introduced fuzzy set theory into an ordinary LP problem with fuzzy goal and constraints. Following the fuzzy decision-making method proposed by (Bellman & Zadeh, 1970), that the chapter confirmed the existence of an equivalent LP problem. Since then, fuzzy linear programming (FLP) has developed into several fuzzy optimization methods for solving TPD problems. (Chanas et al. 1984) presented an FLP model for solving the TPD problem with crisp cost coefficients and fuzzy supply and demand values. Moreover, (Chanas & Kuchta, 1998) proposed the concept of the optimal solution of the TPD problem with fuzzy coefficients expressed as L-L fuzzy numbers, and developed an algorithm for obtaining the solution. Related works on the use of FLP to solve TPD problems included (Bit et al. 2001, Chanas et al. 1984, and Chanas and Kuchta 1998). However, in real-world TPD problems, the decision maker (DM) must simultaneously handle conflicting aims that govern the use of the resources within organizations. These aims are minimizing total production costs, total transportation costs and total delivery time/distance, and maximizing total profits, total relative safety, customer service level and utilization of equipment and facilities (Bit et al. 2001, Chanas et al. 1984, and Chanas and Kuchta 1998). Particularly, the DM must simultaneously optimize these conflicting objectives in a framework of fuzzy aspiration levels. In 1978, (Zimmermann 1997) first extended his FLP approach to a conventional multi-objective linear programming (MOLP) problem. For each of the objective functions in this problem, the DM was assumed to have a fuzzy objective, such as “the objective function should be substantially less than or equal to some value”. Subsequent works on fuzzy goals programming (FGP) included (Luhandjula 1982, Sakawa 1988, Chen and Tsai 2001). Subsequently, researchers have developed several FOP methods to solve multi-objective TPD problems. Bit et al. proposed an additive fuzzy programming model that considered weights and priorities for all non equivalent objectives for the multi objective TPD problem. (Li and Lai 2000) designed a fuzzy compromise programming method to obtain a non-dominated compromise solution for multi-objective TPD problems in which various objectives were synthetically considered with the marginal evaluation for individual objectives and the global evaluation for all objectives. (El-Wahed, 2001) developed a fuzzy programming approach to determine the optimal compromise solution of a multi objective TPD problem by measuring the degree of closeness of the compromise solution to the ideal solution using a family of distance functions. Related works on fuzzy multi objective TPD programming problems included (Bit et al. 2001). This thesis develops a novel interactive fuzzy multi objective linear programming (*i*-FMOLP) model for solving TPD problems with multiple fuzzy objectives. The proposed *i*-FMOLP model attempts to simultaneously minimize the total production and transportation costs and the total delivery time with reference to available capacities at each source and forecast demand at each destination.

3.4.2 Problem description, assumptions and notation

The TPD problem examined herein can be described as follows. Assume that a distribution center seeks to determine the transportation plan of a homogeneous commodity from m sources to n destinations. Each source has an available supply of the commodity to distribute to various destinations, and each destination has a forecast demand of the commodity to be received from the sources. The TPD proposed herein attempts to determine the optimal volumes to be transported from each source to each destination to simultaneously minimize the total production and transportation costs and the total delivery time. The TPD problem proposed in this work focuses on developing an interactive i-FMOLP model for optimizing the transportation plan in fuzzy environments. The mathematical model developed herein is based on the following assumptions.

- i. All of the objective functions are fuzzy with imprecise aspiration levels.
- ii. All of the objective functions and constraints are linear equations.
- iii. The values of all model parameters are certain over the planning horizon.
- iv. The transportation costs and delivery time on a given route is directly proportional to the units shipped.
- v. The total supply available at all sources just equals the total demand required at all destinations.
- vi. The linear membership functions are assigned to represent the fuzzy sets involved, and the minimum operator is used to aggregate all fuzzy sets.

Assumption (i) concerns the fuzziness of the objective functions in practical TPD problems, and incorporates the variations in the DM's judgments for the solutions of fuzzy multi objective optimization problems in a framework of fuzzy aspiration levels. Assumptions (ii) to (iv) indicate that the linearity, certainty and proportionality properties must be technically satisfied as a standard LP problem. Assumption (v) is the 'necessary and sufficient' condition for a feasible solution to the TPD problem. Assumption (vi) is made to convert the original fuzzy MOLP problem into an equivalent LP problem that can be solved efficiently by the standard simplex method (H. J. Zimmermann 1997).

3.4.3 Problem formulation

This chapter chose the multi-objective functions for solving the TPD problem by reviewing the literature and considering practical situations. (Diaz, S.S Chanas et al, 1984) specified three objective functions to minimize the total transportation costs, total delivery time, and total relative time for a TPD problem with fuzzy multiple objectives. Practical TPD problems typically minimized the total production costs, total transportation costs and total delivery time (Li and K. K. Lai et al. 2000) accordingly, two objective functions were simultaneously considered in developing the proposed MOLP model, as follows.

- Minimize total production and transportation costs

$$M_{in}Z_1 \cong \sum_{i=1}^m \sum_{j=1}^n (P_{ij} + C_{ij}) Q_{ij} \quad (1)$$

- Minimize total delivery time

$$M_{in}Z_2 \cong \sum_{i=1}^n \sum_{j=1}^m t_{ij} Q_{ij} \quad (2)$$

Where:

Z_1 total production and transportation costs (\$)

Z_2 total delivery time (hours)

Q_{ij} units transported from source i to destination j (units)

P_{ij} production cost per unit from source i to destination j (\$/unit)

C_{ij} transportation cost per unit from source i to destination j (\$/unit)

t_{ij} transportation time per unit from source i to destination j (\$/unit)

The symbol ' \cong ' is the fuzzified version of '=' and refers to the fuzzification of the aspiration levels. In real world TPD problems, the environmental coefficients and operation parameters are usually uncertain because some information is incomplete or unobtainable over the planning horizon. Accordingly, Equations. (1) & (2) are fuzzy with imprecise aspiration levels, and incorporate the variations in the DM's judgments regarding the solutions of fuzzy multi objective optimization problems. For each of the objective functions of the proposed MOLP model, this work assumes that the DM has such imprecise objective as, "the objective functions should be essentially equal to some value". These conflictin objectives are required to be simultaneously optimized by the DM in the framework of fuzzy aspiration levels.

3.4.4 Constraints

Constraints on total supply available for each source i

$$\sum_{j=1}^n Q_{ij} = S_i, i = 1, 2, \dots, m \quad (3)$$

- Constraints on total demand for each destination j

$$\sum_{i=1}^n Q_{ij} = D_j, j = 1, 2, \dots, n \quad (4)$$

- Non – negativity on total constraints on decision variables

$$Q_{ij} \geq 0, i = 1, 2, \dots, m, j = 1, 2, \dots, n \quad (5)$$

Where S_i denotes the total supply available of source i (units), and D_j denotes the total demand of destination j (units). This work addresses a practical application of a FGP model for solving the TPD problem with fuzzy multiple objectives. Therefore, the constraints (3) and (4) in the proposed MOLP model are assumed to be crisp. Notably, the MOLP model described above has a feasible solution only if the total supply available at all sources just equals the total demand required at all destinations

3.5 Transport delivery in Dar es Salaam City

The present public passenger transport system is composed of about 7000 buses, about 4000 taxis and a certain number of rickshaws (SUMATRA, Dar es Salaam City, 2009). All of these vehicles are owned and operated by private entrepreneurs (Ibid). The existing public transport buses, so called daladalas, dominate the public transport delivery in the city (SSATP, 2005). The service provided by daladalas is rather hideous. A comprehensive report by (Kanyama *et al.* 2004), for example, evaluates their service poor and chaotic. The article elaborates that daladalas are unscheduled and thus incur long travel times; they have bad seat arrangements, overload passengers, not follow allocated routes, speed and drive recklessly, etc. The report argues also that most daladalas are “not only second hand but third hand or fourth hand or more” that they emit large amount of pollutants and Carbon Dioxide (CO₂). A visit to any number of developing cities can quickly reveal the source of customer dissatisfaction with public transport and non-motorized options. Poor transit services in the developing world push consumers to private vehicle options. Public transport customers typically give the following reasons for switching to private vehicles:

- i. Inconvenience in terms of location of stations and frequency of service;
- ii. Failure to service key origins and destinations;
- iii. Fear of crime at stations and within buses;
- iv. Lack of safety in terms of driver ability and the road worthiness of buses;
- v. Service is much slower than private vehicles, especially when buses make frequent stops;
- vi. Overloading of vehicles makes ride uncomfortable;
- vii. Public transport can be relatively expensive for some developing nation households;
- viii. . Poor quality or nonexistent infrastructure (e.g., lack of shelters, unclean vehicles, etc.)
- ix. Lack of an organized system structure and accompanying maps and information make the systems difficult to use; and
- x. Low status of public transit services.

However, all of these problems can be rectified within the modest budgets of developing nation municipalities. Cities such as Bogotá (Colombia), Curitiba (Brazil), and Quito (Ecuador) have dramatically improved transit services with simple solutions. In each case, the city relied upon low cost improvements in public transit and non motorized infrastructure rather than expensive tailpipe technologies. Figures below illustrates the poor quality of public transport in developing cities creates great hardship for the citizen. Figure 3.1 indicate effects of pollution and noise from traffic combustion of fossil fuels produces a number of substances that directly impact upon human health. In the ideal situation, the only result of such combustion is water vapor and carbon dioxide, neither damaging to human health, although carbon dioxide is the main greenhouse gas with impacts on the global climate. However, in reality, combustion is most often not complete and results in the production of substances such as carbon monoxide (CO) and particles (a basic component of particulate matter). Other pollutants due to incomplete combustion processes include volatile organic compounds (VOCs), oxides of nitrogen (NO_x) and sulphur dioxide (SO₂). If lead has been added to the fuel, lead aerosols are also produced. These by products from combustion, apart from damaging human health, also react in the environment, producing

secondary transport pollutants such as sulphuric acid, sulphates and ozone. Atmosphere and climate, together with urban form, population and street density, influence the extent to which populations are exposed to primary and secondary pollutants.



Fig. 3.1. Emission is a threat to peoples' health.

Figure 3.2 indicate overloading in the buses was a problem for people as it often led to incidents of pick - pocketing, impaired air circulation, and bad smells due to warm weather and sweat. The respondents were also worried that overcrowding in the buses could lead to the spread of communicable diseases such as Tuberculosis (TB). Furthermore, overcrowding and squeezing in the buses led to incidents of women being sexually abused by men. When scrambling to enter in the buses become extreme, it is possible to see commuters entering in the buses through the windows. In general, overloading of the buses creates hard travelling conditions for parents with children, women, disabled people and the elderly



Fig. 3.2. Survival of the fittest: Commuters board a bus through the windows during rush hour.

Figure 3.3 indicates that small buses (daladalas) are the most common mode of motorized public transport for households, irrespective of income, in Dar es Salaam. The most dominant types of buses with a capacity of transporting 15 passengers



Fig. 3.3. A series of small buses with capacity of 15 passengers and uncomfortable sitting arrangement.

3.6 Transport balance in the life of the city

There is a high dependence on public transport and also walking is a major mobility function across communities in Dar es Salaam. It follows accordingly that, in order to improve the quality of life of its citizens, the city's development must cater in a large way for these two modes of transport. A major risk or a challenge to the city is the explosion in private car ownership and use generated by incomes increases. A large scale rise in car use demands heavily on public resources to cater for the necessary infrastructure such as roads, but a demand frequently proven to be beyond the capacity. Furthermore, increased pollution, congestion, wide traffic thorough fares and the imposition of cars on walking and living spaces will develop an undesirable living environment. Dar es Salaam has the opportunity to avoid many pitfalls encountered by other developed cities and the initiative already taken to prioritize public transport through the BRT system, which is a major positive step in defining a balanced city. This balance involves applying the right priorities between personal mobility (walking, NMT, cars); the essential movement of goods and freight (port and service vehicles); and an orderly planned public transport system (BRT and associated bus networks). Ultimately, the city is best served if it can create livable communities through a sustainable transport system that enhances and empowers its communities.

3.6.1 Dar es Salaam City towards the world city concept

World cities emerged from the globalization of trade, commerce, and leisure are driven by on line communication and computing technologies and are undoubtedly a "new" breed of cities of which the characteristics surpass these of the well know "mega - city". According to this service based approach, there are three (3) groups of World Cities, complemented by three (3) groups of cities evolving towards becoming a world city (Table 3.1). In the service based classification for world class status, consideration is given to the global capacity of cities in terms of selected services they provide. Global capacity is defined empirically (calculated) in terms of aggregate scores and interpreted theoretically as concentrations of expertise and knowledge. The focus for this classification was on four key services: accounting, advertising, banking and law although other economic activities can also be considered. Cities are evaluated as global service centres in each of these sectors and aggregation of these results to other "supporting" domains provides a measure of a city's global capacity.

Established World Cities				
Classification		ALPHA CITY (α city)	BETA CITY (β city)	GAMMA CITY (Γ city)
Description		Full service world cities	Major world cities	Minor world cities
Examples	First level	London; New York; Paris; Tokyo	San Francisco, Sydney, Toronto, Zurich	Amsterdam, Boston, Caracas, Dallas, Düsseldorf, Geneva, Houston Jakarta, Johannesburg , Melbourne, Osaka, Prague, Santiago, Taipei, Washington
	Second level	Chicago, Frankfurt, Hong Kong, Los Angeles, Milan, Singapore	Brussels, Madrid, Mexico City, Sao Paulo	Bangkok, Beijing, Montreal, Rome, Stockholm, Warsaw
	Third level		Moscow, Seoul	Atlanta, Barcelona, Berlin, Budapest, Buenos Aires, Copenhagen, Hamburg, Istanbul, Kuala Lumpur, Manila, Miami, Minneapolis, Munich, Shanghai
Emerging World Cities				
Relative strong evidence		Athens, Auckland, Dublin, Helsinki, Luxembourg, Lyon, Mumbai, New Delhi, Philadelphia, Rio de Janeiro, Tel Aviv, Vienna.		
Some evidence		Abu Dhabi, Almaty, Birmingham, Bogota, Bratislava, Brisbane, Bucharest, Cairo, Cleveland, Cologne, Detroit, Dubai, Kiev, Lima, Lisbon, Manchester, Montevideo, Oslo, Riyadh, Rotterdam, Seattle, Stuttgart, The Hague, Vancouver, Ho Chi Minh City.		
Minor evidence		Adelaide, Antwerp, Arhus, Baltimore, Bangalore, Bologna, Brasilia, Calgary, Cape Town, Colombo, Columbus, Dresden, Edinburgh, Genoa, Glasgow, Gothenburg, Guangzhou, Hanoi, Kansas City, Leeds, Lille, Marseille, Richmond, St Petersburg, Tashkent, Tehran, Tijuana, Turin, Utrecht, Wellington.		

Source: J.V. Beaverstock, R.G. Smith and P.J. Taylor. *A Roster of World Cities*, in *Cities*, 16 (6), (1999), pp 445-458

Table 3.1. Classification of principal World Cities.

The advantage of the “producer service approach” is, according to (Sassen, 1994) that the ranking firmly associates the cities with their tendency to engage with the internationalization, concentration, and intensity of producer services in the world economy. According to the classification methods above, London, New York, Paris, and Tokyo are prime examples of world cities and are also mega cities. However, it is possible and even common for cities that are not mega cities to be world cities and vice versa, overall a world city, also known as a “world class city” can be defined by ten

characteristics and the level to which the city incorporates these characteristics determines its status as world city:

- i. Name familiarity where the city name is sufficient and there is no need to add the country name.
- ii. Active influence and participation in international events and world affairs, with the city housing international headquarters such as the UN (New York), the EU Commission (Brussels) or the European Central Bank (Frankfort).
- iii. A fairly large population with at least one million inhabitants but typically several 16 million.
- iv. A major international airport acting as high profile hub for several international airlines.
- v. An advanced transportation system offering multiple modes of (public) transportation and a highly developed road network.
- vi. Home to international cultures and communities or a city which attracts large foreign businesses and related expatriate communities.
- vii. Home to international business and stock exchanges that influence the world economy.
- viii. Advanced communications infrastructure with WIFI and high-speed broadband.
- ix. World renowned cultural institutions and events and a lively cultural scene, including festivals, premieres, music, opera, and theatre scene.
- x. Several powerful and influential media outlets with an international reach

3.7 Development frame work, integrated approach and economic growth in Dar es Salaam City

The vision for Dar es Salaam city presents the long term perspective and framework for the Dar es Salaam Transport Policy and System Development Master Plan. It discusses both the general development vision for Dar es Salaam with the year 2030 perspective and the more specific and directly inters - related vision for the future transport system in Dar es Salaam. The year 2003 National Transport Policy underwrites the principle of achieving "... efficient and cost effective domestic and international transport services to all segments of the population and sectors of the national economy with maximum safety and minimum environmental degradation." Realizing the principle requires substantial efforts oriented to creating "...safe, reliable, effective, efficient and fully integrated transport infrastructure and operations which will best meet the needs of travel and transport at improving levels of service at lower costs in a manner, which supports government strategies for, socio - economic development whilst being economically and environmentally sustainable." The transport policy thus proclaims that initiatives taken in its policy, economy, society and environment will define the city's long - term development. Figure 3.4 below is the development frame work of Dar es Salaam city. The "National Transport Policy and System Development Master Plan" argues that the fundamental requirement for improvement is the establishment of an adequate institutional framework. Creating the appropriate institutional framework cannot be realized successfully without a balanced and integrated approach where vision, strategy, and action are intertwined and part of a wider vision for sustainable economic development (Figure 3.5).



Fig. 3.4. Developing frame work.

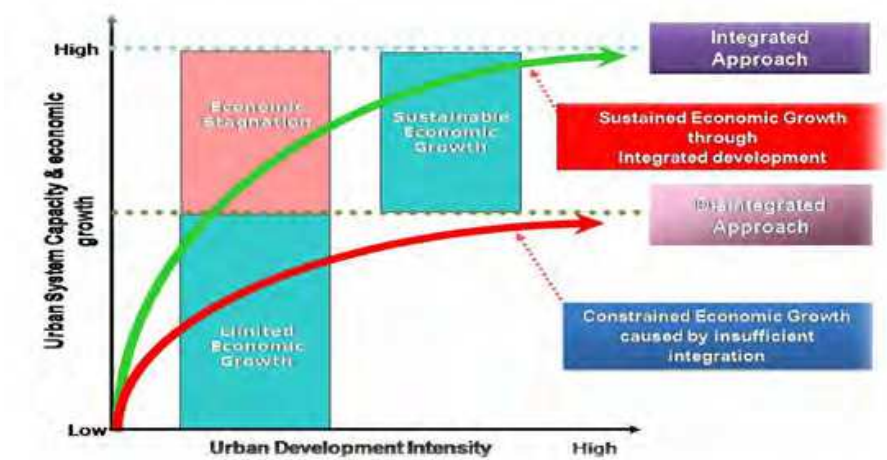


Fig. 3.5. Integrated approach and economic growth.

The National Transport Policy acknowledges the need for an integrated approach when it links the efforts in the field of transport with the long term development goal of the country as expressed in other national guidelines such as the National Poverty Reduction Strategy Paper (PRSP), the Rural Development Strategy (RDS), the Civil Service Reform Program, and reform programs aiming at private sector involvement in economic development, strategic environmental sustainability, gender issues, eradication of diseases and literacy campaigns. The National Transport Policy therewith recognizes the pivoting role of transport and acknowledges that the realization of objectives in “...priority sectors such as education, health, water, agriculture, manufacturing, tourism, mining, energy, land and good governance hinges on the availability of adequate and reliable transport to reach inputs to production points and also to distribute outputs from production points to consumption points/markets. The integrated approach is thus imperative and finds justification in the scale and scope of the urban transport problem including: “... high cost, low quality services due to various reasons including the existence of high backlog of infrastructure maintenance and rehabilitation, inadequate institutional arrangements, laws, regulations and procedures which are not consistent or compatible with each other to create conducive climate for investment and hence growth of the sector, inadequate capacity caused by low level of investment in resources, and low level of enforcement of safety, environmental sustainability and gender issues. The “Transport Policy and System

Development Master Plan” therefore entrenches the future transport system for Dar es Salaam into a wider vision related to the long term social and economic development of the City. The Dar es Salaam Development Vision follows a sequential logic where the *Vision* leads to a *Strategy*, itself defined by a number of concrete *Actions* of which the development of an integrated urban transport system is one, albeit critical, component (Figure 3.6). The approach for the transport policy and system development master plan follows a structured and hierarchical (sequential) approach:

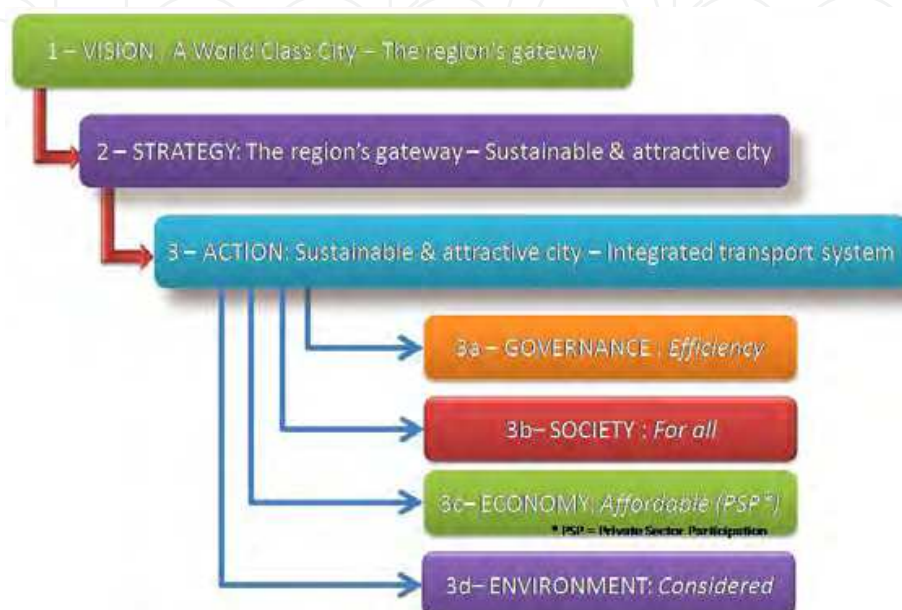


Fig. 3.6. Integrated approaches for the new urban transportation system.

- i. The vision is a long term and final objective according to which all initiatives need to be targeted. Achieving this vision might take several decades but it provides a general framework along which strategies can be / are developed that contribute to proceeding towards the realization of the vision
- ii. The strategy for Dar es Salaam is the translation of the vision into concrete initiatives in different areas that contribute to the realization of the vision (the growth and development of Dar es Salaam towards becoming a world class city). The key of the strategy is that all actions (sub strategies) need to work towards the transformation of the city into a sustainable and attractive city.
- iii. The Actions necessary to create a sustainable and attractive city: Actions are needed in different areas, such as urban planning, land use planning, environmental protection, etc. One of the critical areas for concrete action is the (long - term) urban transport strategy for which the “Transport Policy and System Development Master Plan” will formulate the “Dar es Salaam Transport Vision - 2030” which provides the four (4) building blocks essential to achieving attractiveness and sustainability of the city, namely:
 - a. *Governance*: considering the most efficient structure to develop and manage an integrated transport system, now and in the future;
 - b. *Society*: ensuring that the transport system is accessible to all, including (and in particular) to the less fortunate and the poor members of the community as well as

- the physically challenged persons. At the same time, it should be of a quality that is attractive and acceptable for visitors, in particular tourists and business persons.
- c. *Economy*: where realism on the affordability of the transport system should be the guiding principle which means that infrastructure planning and transport services should consider budgetary constraints, not only focusing capital investments but equally and maybe even more importantly considering long term maintenance and operating costs. To increase the possibilities of capital expenditure for major infrastructure developments, a gradual reduction of the present dependence up on international donors and IFI's should be pursued by inviting the private sector to participate in the efforts.
 - d. *Environment*: where the (long term) impact on the environment, in particular on fauna and flora and on the quality of air should be considered important elements of sustainability and attractiveness of the city. Lack of fauna and flora is unattractive and creates "unsafe" population concentrations while a poor quality of air impacts the health of its inhabitants (e.g., respiratory problems). All these problems will increase the cost of social well being and will put pressure on the city's public budget and spending capacity.

The "Transport Policy and System Development Master Plan for Dar es Salaam" thus should recommend concrete actions for the creation of an integrated transport system in the city. The action plan will be embedded in the comprehensive strategy to create a sustainable and attractive city, based upon a clear vision about that future development of Dar es Salaam. The figures 3.7 and 3.8 below illustrate the dual dimension of the city plan and integrated transportation system respectively.



Fig. 3.7. The dual dimension of the Transport Plan.

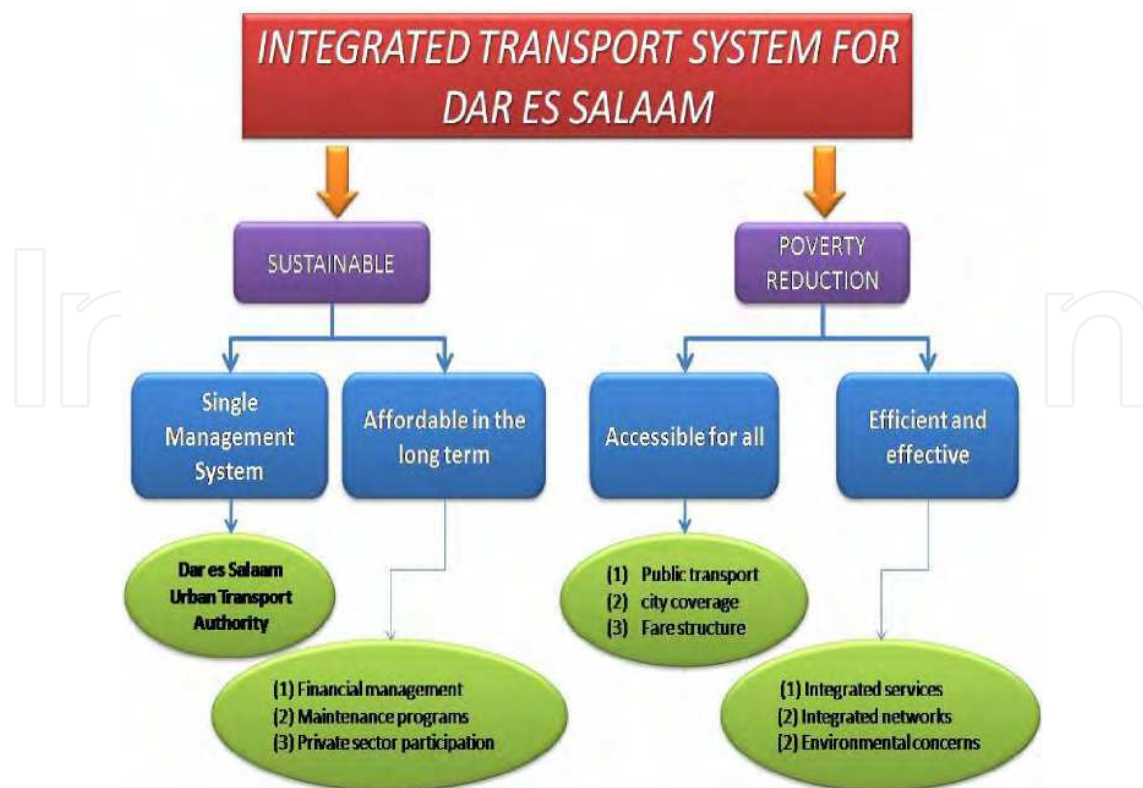


Fig. 3.8. Integrated transportation system.

3.8 General urban transport enhancement strategy

Transport is an entitlement to the citizens of Dar es Salaam, and good transport networks have multiplicity of benefits; *socially, economically, environmentally and culturally*. Equity is also important as transport should be affordable to all so that there is equal and affordable access to opportunities of employment, education and social inclusion. Furthermore the paybacks in both direct and indirect terms are substantial and will contribute directly to improved economic performance, productivity and greatly reduce the negative stresses that citizens endure on a daily basis. The increasingly difficult urban transport situation in the city, characterized by a high degree of traffic congestion, constrained resources for urban transport and deteriorating air quality, lies in the forefront of concerns. Urban transport problems are borne out of a set of complex and diverse environmental and economic factors and profound institutional failures. In Dar es Salaam, due to a low level of car ownership and high dependence on public transport, the problems of public transport are synonymous with the problems of urban transport because public transport vehicles (Dala Dala) serve such a large proportion of total trip demand. The present public transport system in Dar es Salaam is highly unsatisfactory from the perspectives of all stakeholders: the public, the city, the operators and the users. Government is now addressing its growing transport problems with the introduction of the Bus Rapid Transit (BRT) with the essential associated administrative and institutional reforms. A key consideration in this regard is that, most certainly within the near term planning horizon, the need to move people must take precedence over the need to move vehicles. However, in the medium to longer term, other transport pressure will arise. If history holds any lessons, it is that future growth in income will inevitably catalyze an increase in trip making, as well as changes in the modes used to

accomplish such trips. It is likely that private modes of transport, such as passenger cars, will continue to become increasingly popular with the citizens of Dar es Salaam. It is expected that the current 74,000 private vehicles located within the metropolitan area will increase to about 180,000 by year 2015, and near 515,000 by year 2030 (JICA 2008). This means that vehicle ownership will more than triple from 25 cars per 1,000 persons in year 2007, to 89 cars per 1,000 persons by year 2030. Pronounced impacts on Dar es Salaam congestion, and the need for additional road infrastructure, are consequently expected. The construction of BRT will certainly be a key mitigating factor in defining the modal choice relationship in terms of inducing mode switching and providing increased mobility for transit dependent elements of the population. However, demand on the road network is nevertheless expected to dramatically increase in future in line with rising socio economic well being of the populace. No single remedy can be expected to comprehensively address such phenomena, instead, a more holistic approach is needed which relies on intermodality and a harmonious combination of the various modes that compromise a multi faceted and integrated urban transport system. Herein lies the challenge; solutions are needed whose practicality can be viewed through the prism of existing realities, and whose validity will remain intact over the Master Plan planning horizon extending to year 2030. In defining transport systems for the future, the chapter has fully considered a number of key features which will dictate the nature of transport evolution from a strategic viewpoint; namely

- i. The physical characteristics (space for road expansion, increasing traffic etc) and urban structure (type and extent of land use) of the city;
- ii. A developing city with constrained financial resources;
- iii. The social characteristics of its people (high dependency on public transport, need for mobility to increase opportunity and reduce poverty; increasing well being in future); and
- iv. The policy and regulatory frameworks as key to developing sustainable transport.

One of the key recommendations in this chapter is that, in order to improve what is at present an overlapping and (often) ineffective organizational approach to developing road systems, executing traffic control and management, as well as operating public transport, the formation of a multi disciplinary and multi modal Dar es Salaam Urban Transport Authority (DUTA). At the same time capacity development is very necessary in the field of transport planning and administration. Also an organization named National Center for Transport Studies (NCTS), whose responsibility is placed on education, research and development is proposed.

4. Intelligent transportation system innovations

Overview of the widespread application of ITS has been anticipated for some years and since the early 1990s, there have been numerous model based attempts to predict their impact. ITS is not just about the provision of information to travelers. It can affect the nature of the travel experience (e.g., by simplifying the process of paying fare or road toll, by enabling the driver to pre book his parking space or conduct business by phone while en route to the office, or by taking control of the vehicle in hazardous situations). It can also extend the range of levers available to the system manager (e.g., by making it possible to charge motorist that reflect the current level of congestion or pollution, or to detect and prosecute a wide range of traffic violations). All of these could influence traveler behavior in various ways, for example, recognize that mode choices might be affected by the provision of simplified ticketing or

tolling system or by the ability to work end route, and that the choice of car park might be strongly influenced by the possibility of pre booking space in some location and so on.

4.1 Intelligent transportation system technologies applied to BRT system in developing countries

ITS technologies are being implemented more commonly in European, North American countries, and Australia than in developing countries. BRT systems in developing countries are still limited in ITS applications because of the capital and operating costs (Wright 2004). ITS technologies mainly contribute to the image, safety, and operating speed (Kittelson & Associates et al. 2003, Darido et al. 2006, Currie 2006 and Sakamoto et al. 2007) but are not essential features for a successful BRT system. The BRT systems in Bogotá, Quito, Beijing, Mexico City, and all Brazilian systems are successful examples that have not implemented or have very limited ITS technologies. Transit Signal Priority (TSP), real time passenger information systems, and Automatic Fare Collection (AFC) are examples of typical ITS applications in BRT systems. Implementation of TSP has grown rapidly among the U.S. transit systems. Real time passenger information systems increase productivity of passengers while waiting for buses, avoid crowding at stations, and enhance the image of the shelters (Kittelson & Associates et al 2003). Automatic Vehicle Location (AVL) systems help track the locations of vehicles, which can be used for real time fleet management and future planning purposes. The global positioning system based AVL system is perhaps the most popular among the available location technologies (Gillen and Johnson 2002). One of the new ITS technologies for BRT are lane assist systems being implemented in the BRT systems in Orlando and Minneapolis. Lane assist permits BRT vehicles to operate at higher operating speeds with improved safety (Kulyk and Hardy 2007). Precision docking technology (implemented in Las Vegas, but more popular in European cities) helps reduce dwell time. Some features below applied in several BRT systems.

- i. *Fare Collection Methods* - Automatic fare collection (AFC), although originating in other transit systems, has become a regular feature of BRT systems worldwide. Advanced AFC with a common smart card allows integration of several modes in one single system, which offers customer convenience (GTZ 2006). In surveys carried out among transit users in Hong Kong, Taipei, New Delhi, London, Oslo, Copenhagen, Washington D.C., San Francisco, Chicago, Rome, Bangkok, Seoul, and Istanbul, smart cards were noted as being effective in promoting ridership, increasing customer satisfaction, improving boarding time, and increasing ease of access (Boushka 2006). AFC usually generates important data for demand forecasting and operational planning (Hidalgo et al. 2007). However, three recent examples demonstrate that AFC may not be as beneficial as it appears. The first example is AFC on the Silver Line in Boston. AFC equipment initially was implemented with the purpose of saving running time. However, contrary to expectations, the travel time increased after AFC implementation. Such experience illustrates the importance of dwelling time control (Darido et al. 2006). The second and third examples are the Quito and Jakarta BRT systems, where the implementation time for user adaptation to AFC technology has been considerably short, causing “insufficient testing and quality assurance.” In addition, their fare collection systems are not compatible with other public transportation modes or even among different BRT corridors in the same city (Hidalgo et al. 2007).
- ii. *Operating Speed* - Operating speed depends on many factors such as guide ways, number of stops, dwell time, etc. When Bogotá’s TransMilenio was first implemented,

the operating speed went from approximately 15 km/h to 26.7 km/h (Cain 2007). In Seoul, the operating speed of buses has improved after the implementation of BRT in 2004 (by 2.7 km/h to 11 km/h, depending on the corridor), and the speed has increased as users become more familiar with the system (GTZ 2006). Operating speed has a direct impact on ridership attraction. As the name implies, BRT service should be “rapid.” The travel time and ridership attraction of the BRT features reviewed above, all are aimed at reducing travel time or increasing ridership. Therefore, travel time savings (for users) and ridership attraction (for agencies and operators) are the most important design goals. In fact, the most distinctive features of BRT systems are the ones that contribute most to reduction in travel time (such as guide ways, high capacity vehicles, high service frequency, TSP, AFC) and ridership attraction (such as enhanced stations and shelters, transit oriented development, real time passenger information systems, route coverage).

4.2 Bus rapid transit system creating better mobility

BRT is an enhanced bus system that operates on bus lanes or other transit ways in order to combine the flexibility of buses with the efficiency of rail. By doing so, BRT operates at faster speeds, provides greater service reliability and increased customer convenience. It also utilizes a combination of advanced technologies, infrastructure and operational investments that provide significantly better service than traditional bus service. Bus systems provide a versatile form of public transportation with the flexibility to serve a variety of access needs and an unlimited range of locations throughout a metropolitan area. Because buses travel on urban roadways, infrastructure investments needed to support bus service can be substantially lower than the capital costs required for rail systems. As a result, bus service can be implemented cost effectively on routes where ridership may not be sufficient or where the capital investment may not be available to implement rail systems. Traffic congestion, urban sprawl, central city decline, and air pollution are all problems associated with excessive dependence on automobiles. Increasing recognition of the need for high quality transit service to alleviate these conditions has fueled growing demand for new public transportation service. Despite the inherent advantages of bus service in terms of flexibility and low capital cost, the traveling public frequently finds the quality of bus service provided in urban centers to be wanting. Conventional urban bus operations often are characterized by sluggish vehicles inching their way through congested streets, delayed not only by other vehicles and traffic signals, but also by frequent and time consuming stops to pick up and discharge passengers. Buses travel on average at only around 60 percent of the speeds of automobiles and other private vehicles using the same streets due to the cumulative effects of traffic congestion, traffic signals, and passenger boarding. Moreover, compared to rail systems, the advantageous flexibility and decentralization of bus operations also result in a lack of system visibility and permanence that contributes to public perceptions of unreliability and disorganization.

4.2.1 What is bus rapid transit?

Low cost investments in infrastructure, equipment, operational improvements, and technology can provide the foundation for *Bus Rapid Transit* systems that substantially

upgrade bus system performance. Conceived as an integrated, well defined system, Bus Rapid Transit would provide for significantly faster operating speeds, greater service reliability, and increased convenience, matching the quality of rail transit when implemented in appropriate settings. Improved bus service would give priority treatment to buses on urban roadways.

4.2.2 Why bus rapid transit?

Transportation and community planning officials all over the world are examining improved public transportation solutions to mobility issues. This renewed interest in transit reflects concerns ranging from environmental consciousness to the desire for alternatives to clogged highways and urban sprawl. These concerns have led to a re - examination of existing transit technologies and the embrace of new, creative ways of providing transit service and performance. BRT can be an extremely cost effective way of providing high quality, high performance transit. Advancements in technology such as clean air vehicles, low floor vehicles, and electronic and mechanical guidance

4.2.3 Overview of bus rapid transit system

With population increase, increasing transportation demand has lead to debilitating traffic in most major cities. Figure 4.1 indicate population increases of some major cities.



Bogota – Colombia

California – USA

Fig. 4.1. Population increase of some major cities.

In order to address this situation, a high pax capacity transport alternative must be chosen
system pax/hour/direction capacity ('000 pax

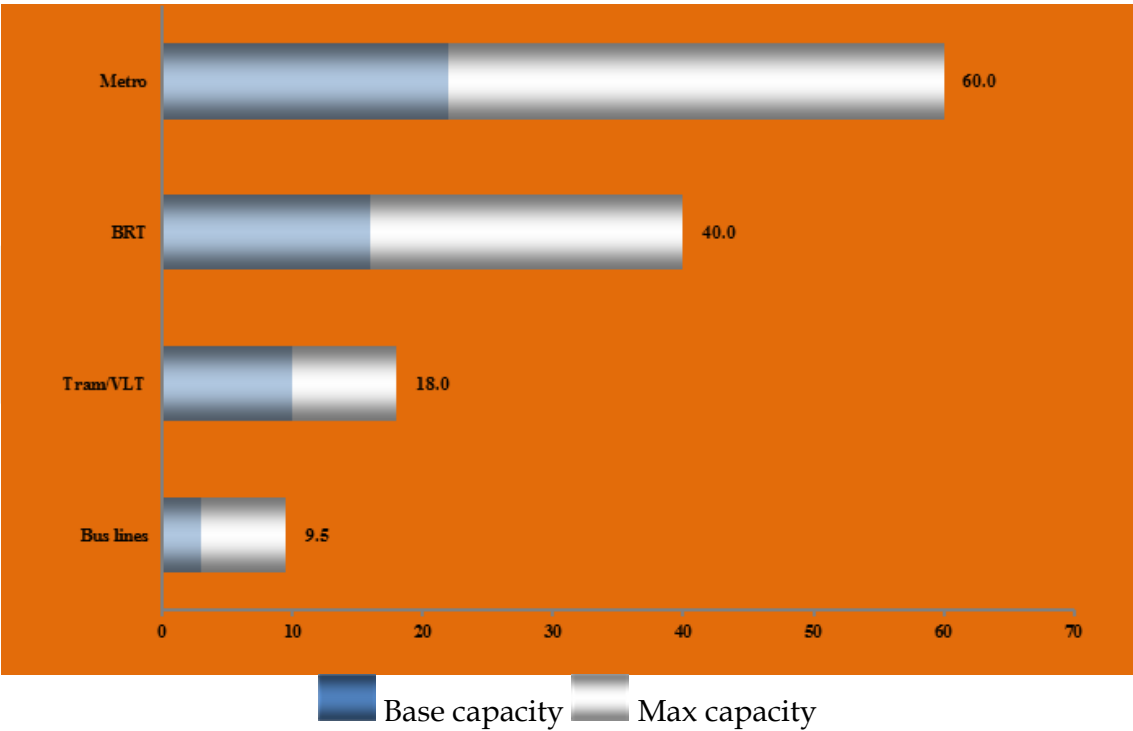


Fig. 4.2. Different mode of public transportation capacity.

In comparison to rail based systems, a BRT system provides a high pax system with a significantly lower implementation cost and time. Figure 4.3 and 4.4 indicates the different mode of transportation implementation cost (US\$MM/KM) and time (Mths) respectively.

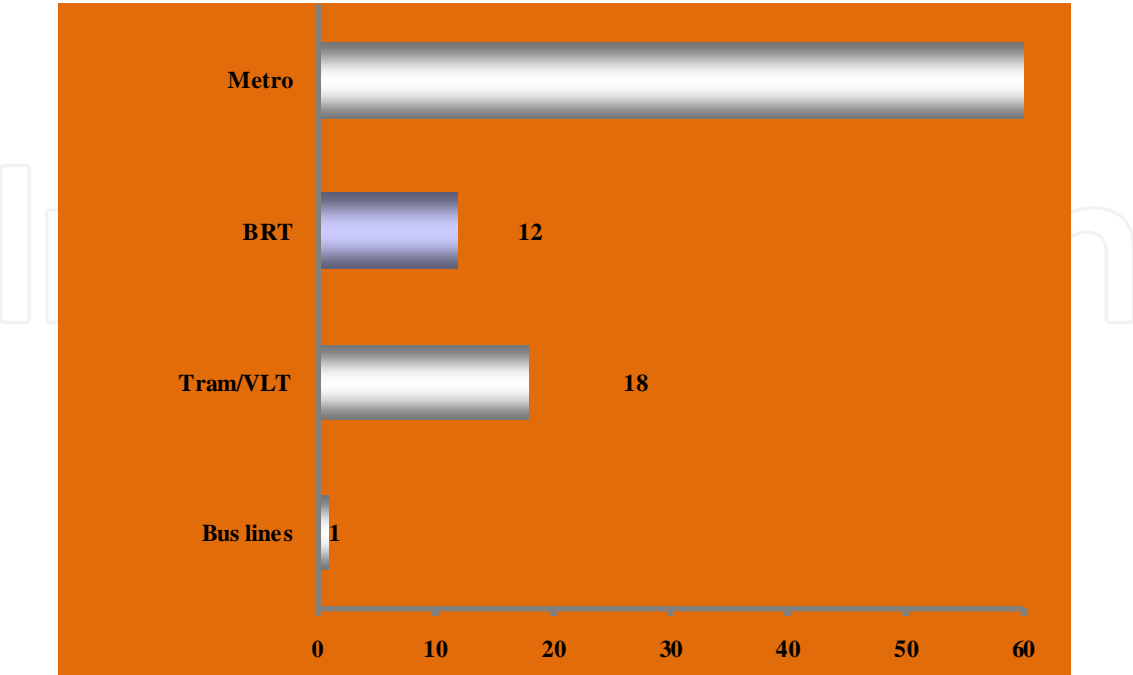


Fig. 4.3. Implementation cost (US\$ MM/).

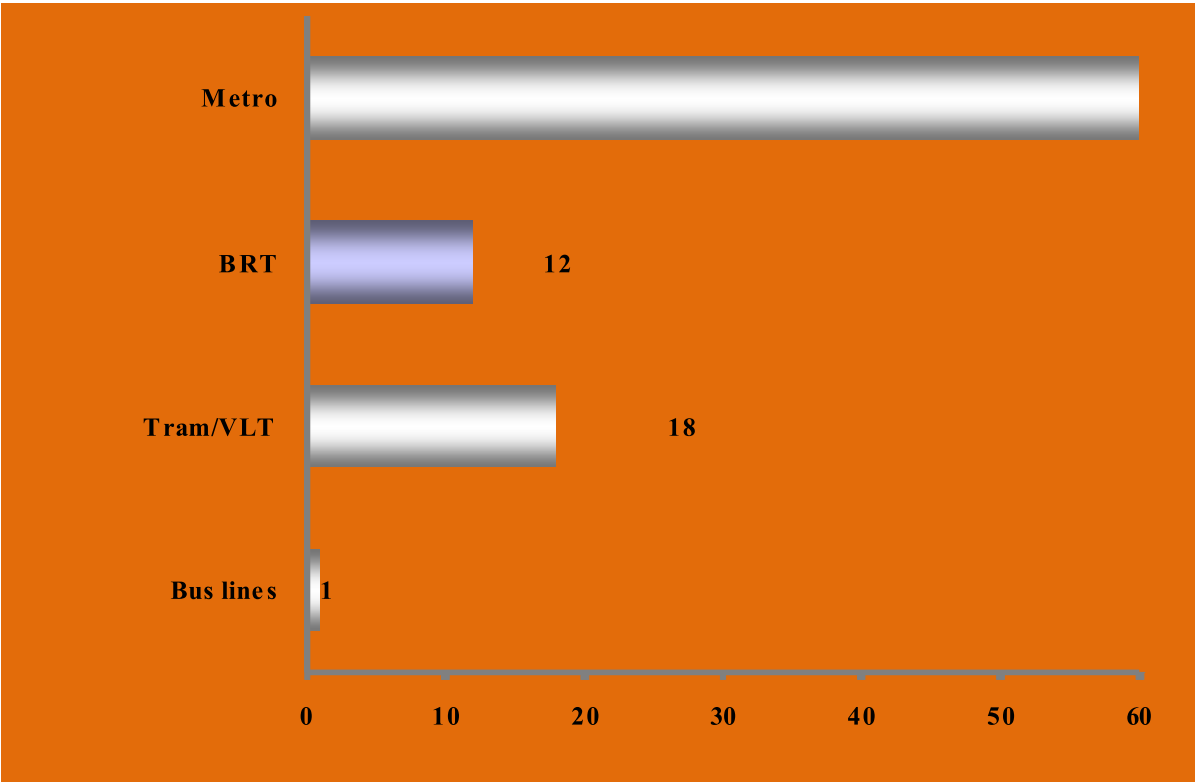


Fig. 4.4. Implementation time (Mths).

Bus Rapid Transit combines the benefits of light rail transit with the flexibility and efficiency of bus transit. The goal of BRT development is to enhance ridership and reduce operating costs with increased service levels and quality. A BRT system combines the technology of intelligent transportation systems, traffic signal priority, cleaner and quieter vehicles, rapid and convenient fare collection, and integration with land use policy. BRT has demonstrated improvements in public transportation service and enabled improvements that can be implemented at relatively low cost. The mission of Bus Rapid Transit (BRT) is to combine the flexibility and low implementation cost of bus service with the comfort, efficiency, cost effectiveness, land use influence and versatility of light rail transit (LRT). Various projects around the world have indicated that BRT is an effective alternative for congested cities at a relatively low construction and operation cost. Cities in developing countries have struggled with the problem of how to upgrade and improve existing transit services at a low cost. Developing countries with high transit dependent populations and limited financial resources have increasingly attempted the use of BRT systems because of their low costs and relatively fast implementation times. The cost of a BRT project is considered to be approximately one third of a LRT project, which is a cost that developing countries can afford. After construction the system is practically self

financing with fares of about \$US0.50 per trip. BRT has proved that it allows low fares and reduced travel times for low income users. BRT systems such as Curitiba in Brazil and Transmilenio in Colombia are great examples of the success that the BRT system has had in Latin American countries.

4.2.4 BRT – Concepts and evolution

There is a broad range of perspectives as to what constitutes BRT. At one end of the spectrum, BRT has been defined as a corridor in which buses operate on a dedicated right of way such as a bus way or a bus lane reserved for buses on a major arterial road or freeway. Although this definition describes many existing BRT systems, it does not capture the other features that have made rail rapid transit modes so attractive around the world. BRT has also been defined as a bus based rapid transit service with a completely dedicated right of way and on line stops or stations, much like LRT. This is consistent with the FTA definition of BRT as “a rapid mode of transportation that can combine the quality of rail transit and the flexibility of buses”. For the purpose of this chapter, BRT has been defined more comprehensively as a flexible, rubber tired form of rapid transit that combines stations, vehicles, services, running ways, and ITS elements into a fully integrated system with a strong image and identity. BRT applications are designed to be appropriate to the market they serve and their physical surroundings, and they can be incrementally implemented in a variety of environments (from rights of way totally dedicated to transit to streets and highways where transit is mixed with traffic). In brief, BRT is a fully integrated system of facilities, services, and amenities that are designed to improve the speed, reliability, and identity of bus transit. In many respects, it is rubber tired LRT, but with greater operating flexibility and potentially lower capital and operating costs. Often, a relatively small investment in dedicated guide ways can provide regional rapid transit. This definition has the following implications:

- Where BRT vehicles (buses) operate totally on exclusive or protected rights of way (surface, elevated, and/or tunnel) with on-line stops, the level of service provided is similar to that of heavy rail rapid transit (metros).
- Where buses operate in combinations of exclusive rights of way, median reservations, bus lanes, and street running with on line stops, the level of service provided is similar to that of LRT.
- Where BRT operates almost entirely on exclusive bus or HOV lanes on highways (freeways and expressways) to and from transit centers with significant parking and where it offers frequent peak service focused on a traditional CBD, it provides a level of service very similar to that of commuter rail.
- Where buses operate mainly on city streets with little or no special signal priority or dedicated lanes, the level of service provided is similar to that of an upgraded limited stop bus or tram system.

Figure 4.5 describes the seven major components of BRT running ways, stations, vehicles, service, route structure, fare collection, and ITS. Collectively, these components form a complete rapid transit system that can improve customer convenience and system performance.

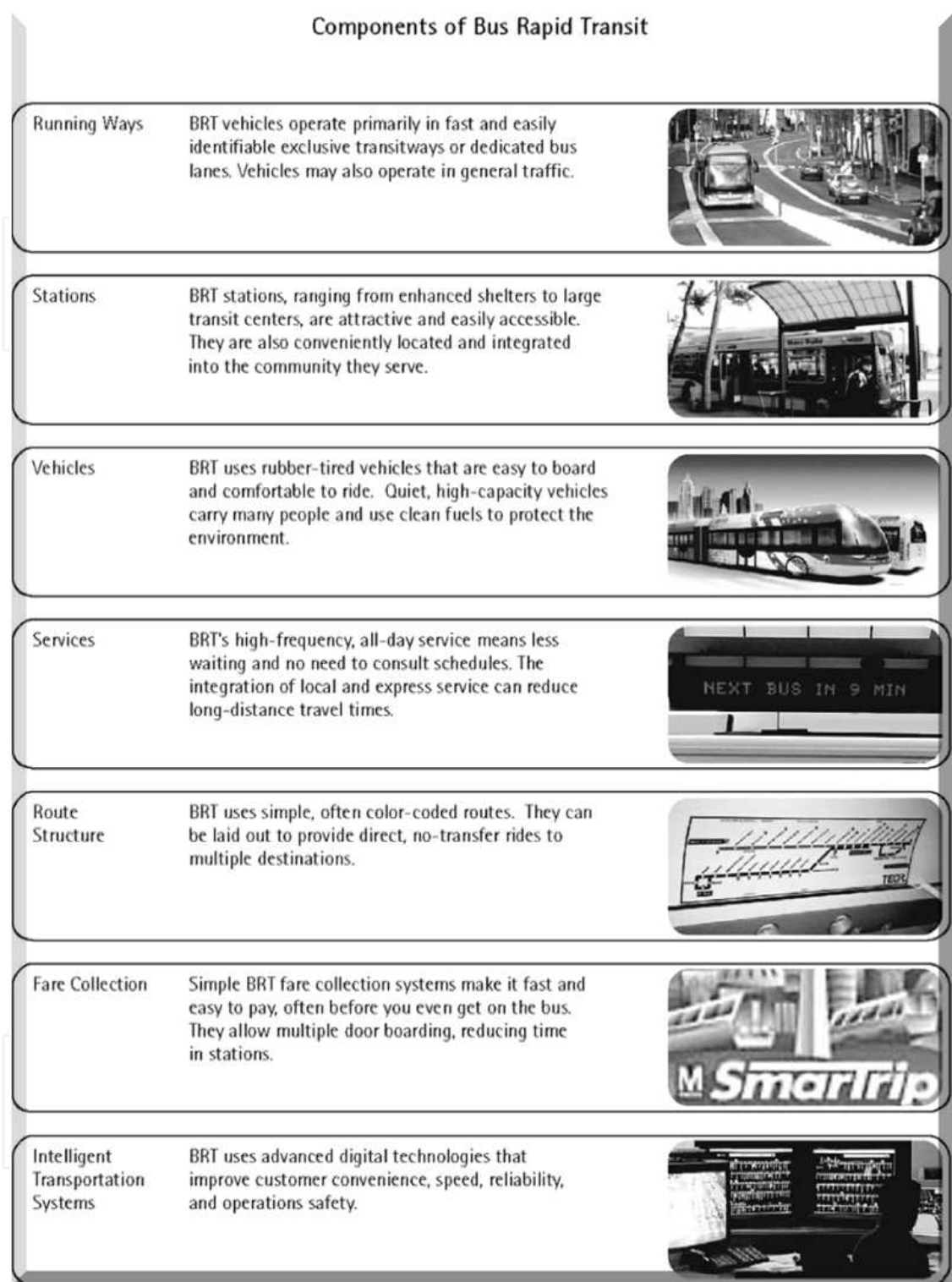


Fig. 4.5. Major components of BRT.

4.2.5 Limitation of BRT

However, effectiveness of BRT is not always permanent. (Vuchic, 2005) pointed out that BRTs cannot succeed if police enforcement is not strict due to security system, citing the examples of Philadelphia and Mexico. Experiences from the U.S. cities such as Shirley Bus

way in Washington and El Monte Bus way in Los Angeles show that pressures by automobile interests are threat to the existence of BRT. Relationship of BRT to other modes is a crucial factor for the success of BRT: BRT cannot bring success as a standalone policy and effectiveness depends on the presence of complementary transport options, such as promotion of non motorized transport and integrated feeder services (Wright, 2001). Another important factor for success understanding of planning and design elements, based on experiences in real world conditions (Vuchic, 2005).

4.3 Experience of BRT System as a mode of public transport from other cities

4.3.1 The BRT system in Curitiba – Brazil

The bus system of Curitiba, Brazil, exemplifies a model Bus Rapid Transit system, and plays a large part in making this a livable city. The buses run frequently some as often as every 90 seconds and reliably, commuters ride them in great numbers, and the stations are convenient, well designed, comfortable, and attractive. Curitiba has one of the most heavily used, yet low cost, transit systems in the world. It offers many of the features of a subway system vehicle movements unimpeded by traffic signals and congestion, fare collection prior to boarding, quick passenger loading and unloading but it is above ground and visible. Even with one automobile for every three people, one of the highest automobile ownership rates in Brazil, and with a significantly higher per capita income than the national average, around 70 percent of Curitiba's commuters use transit daily to travel to work. Greater Curitiba with its 2.2 million inhabitants enjoys congestion free streets and pollution free air.

4.3.1.1 Evolution of the bus system in Curitiba

The bus system did not develop overnight, nor was it the result of transit development isolated from other aspects of city planning. It exists because thirty years ago Curitiba's forward thinking and cost conscious planners developed a Master Plan integrating public transportation with all elements of the urban system. They initiated a transportation system that focused on meeting the transportation needs of the population rather than focusing on those using private automobiles and then consistently followed through over the years with staged implementation of their plan. They avoided large scale and expensive projects in favor of hundreds of modest initiatives. A previous comprehensive plan for Curitiba, developed in 1943, had envisioned exponential growth of automobile traffic and wide boulevards radiating from the central core of the city to accommodate the traffic. Rights of way for the boulevards were acquired, but many other parts of the plan never materialized. With the adoption of the new Master Plan in 1965, the projected layout of the city changed dramatically. The Master Plan sprang from a competition among urban planners prompted by fears of city officials that Curitiba's rapid growth, if unchannelled, would lead to the congested, pedestrian unfriendly streets and unchecked development that characterized their neighbor city, São Paulo, and many other Brazilian cities to the north. As a result of the Master Plan, Curitiba would no longer grow in all directions from the core, but would grow along designated corridors in a linear form, spurred by zoning and land use policies promoting high density industrial and residential development along the corridors. Downtown Curitiba would no longer be the primary destination of travel, but a hub and terminus. Mass transit would replace the car as the primary means of transport within the

city, and the high density development along the corridors would produce a high volume of transit ridership. The wide boulevards established in the earlier plan would provide the cross section required for exclusive bus lanes in which express bus service would operate.

4.3.1.2 The Curitiba's bus system

Curitiba's bus system evolved in stages over the years as phases of the Master Plan were implemented to arrive at its current form. It is composed of a hierarchical system of services. Small minibuses routed through residential neighborhoods feed passengers to conventional buses on circumferential routes around the central city and on interdistrict routes. The backbone of the bus system is composed of the express buses operating on five main arteries leading into the center of the city much as spokes on a wheel lead to its hub. This backbone service, aptly described as *Bus Rapid Transit*, is characterized by several features that enable Curitiba's bus service to approach the speed, efficiency, and reliability of a subway system: integrated planning ; exclusive bus lanes ; signal priority for buses ; Pre - boarding fare collection ; level bus boarding from raised platforms in tube stations ; free transfers between lines (single entry) ; large capacity articulated and bi-articulated wide door buses ; and overlapping system of bus services.

Each artery is composed of a "trinary" road system, consisting of three parallel routes, a block apart. The middle route is a wide avenue with "Express" bus service running down dedicated high capacity express bus ways in the center two lanes, offering frequent stop service using standard, articulated and bi - articulated buses carrying up to 270 passengers a piece. The outer lanes are for local access and parking. Back in the 1960s the building of a light rail system in these avenues had been considered, but proved to be too expensive. The two outer routes are one way streets with mixed vehicle traffic lanes next to exclusive bus lanes running "direct" high speed bus service with limited stops. Both the express and direct services use signal priority at intersections.

Buses running in the dedicated and exclusive lanes stop at tube stations. These are modern design cylindrical shaped, clear walled stations with turnstiles, steps, and wheelchair lifts. Passengers pay their bus fares as they enter the stations, and wait for buses on raised station platforms. Instead of steps, buses are designed with extra wide doors and ramps which extend when the doors open to fill the gap between the bus and the station platform. The tube stations serve the dual purpose of providing passengers with shelter from the elements, and facilitating the efficient simultaneous loading and unloading of passengers, including wheelchairs. A typical dwell time of only 15 to 19 seconds is the result of fare payment prior to boarding the bus and same level boarding from the platform to the bus. Passengers pay a single fare equivalent to about 40 cents (U.S.) for travel throughout the system, with unlimited transfers between buses. Transfers are accomplished at terminals where the different services intersect. Transfers occur within the prepaid portions of the terminals so transfer tickets are not needed. In these areas are located public telephones, post offices, newspaper stands, and small retail facilities to serve customers changing buses. Ten private bus companies provide all public transportation services in Curitiba, with guidance and parameters established by the city administration. The bus companies are paid by the distances they travel rather than by the passengers they carry, allowing a balanced distribution of bus routes and eliminating the former destructive competition that clogged the main roads and left other parts of the city unserved. All ten bus companies earn an

operating profit. The city pays the companies for the buses, about 1 percent of the bus value per month. After ten years, the city takes control of the buses and uses them for transportation to parks or as mobile schools. The average bus is only three years old, largely because of the recent infusion of newly designed buses, including the articulated buses, into the system.

4.3.1.3 Integration of transit with land use planning

Curitiba's Master Plan integrated transportation with land use planning, with the latter as the driving force, and called for a cultural, social and economic transformation of the city. It limited central area growth, while encouraging commercial growth along the transport arteries radiating out from the city center. The city's central area was partly closed to vehicular traffic, and pedestrian streets were created. The linear development along the arteries reduced the traditional importance of the downtown area as the primary focus of day to day transport activity, thereby minimizing congestion and the typical morning flow of traffic into the central city and the afternoon outflow. As a result, during any rush hour in Curitiba, there are heavy commuter movements in both directions along the public transportation arteries. The Master Plan also provided economic support for urban development along the arteries through the establishment of industrial and commercial zones and mixed use zoning, and encouraged local community self sufficiency by providing each city district with its own adequate education, health care, recreation, and park areas. By 1992, almost 40 percent of Curitiba's population resided within three blocks of the major transit arteries. Other policies have contributed to the success of the transit system, in the areas of zoning, housing development, parking and employer paid transit subsidies. Land within two blocks of the transit arteries has been zoned for mixed commercial and residential uses. Higher densities are permitted for office space, since it traditionally generates more transit ridership per square foot than residential space. Beyond these two blocks, zoned residential densities taper with distance from transit ways. Land near transit arteries is encouraged to be developed with community assisted housing. The Institute of Urban Research and Planning of Curitiba (IPPUC), established in the 1960s to oversee implementation of the Master Plan, must approve locations of new shopping centers. They discourage American style auto oriented shopping centers by channeling new retail growth to transit corridors. Very limited and time restricted public parking is available in the downtown area, and private parking is very expensive. Finally, most employers offer transportation subsidies to workers, especially low skilled and low paid employees, making them the primary purchasers of tokens.

4.3.1.4 Staged development of the bus system

As the population increased during the period from 1970 through the present, Curitiba's bus system evolved incrementally. It required expansion of service routes, frequencies, and capacities, and improvements in fare payment, scheduling, and facility design to facilitate the passenger transferring process. Innovative low cost and low tech options for new services and features were chosen over more expensive alternatives at each stage. Planners did not hesitate to abandon choices that did not work in favor of more effective solutions. At several points throughout the bus system development, the option of constructing a rail network was considered. Initially, buses were chosen over rail because they were far more adaptable and cheaper for a developing city such as Curitiba. In the mid 1980s the ridership

had grown enough to support a rail network, but capital costs were prohibitive. Instead, the high capacity, high speed service known as "direct" service was eventually introduced on the one way exclusive bus lanes that parallel the main corridors one block away. This service, including the tube stations, cost about \$200,000 per kilometer to build, and was far cheaper, faster and less disruptive than the estimated \$20 million per kilometer for a light rail system. Not to be underestimated in the evolution of the transit system is the influence of the current governor of the State of Parana, Jaime Lerner. Lerner left his position as president of the IPPUC to become a three--time Mayor of Curitiba, and then governor. With a stake in the development of the Master Plan, he was its champion throughout the years, providing guidance, a firm governmental commitment to transit, and leadership. His steady promotion of the plan enabled it to withstand any tendencies for local politics to alter its course.

4.3.1.5 Results of bus rapid transit

The popularity of Curitiba's Bus Rapid Transit system has affected a modal shift from automobile travel to bus travel, in spite of Curitiba's high income and high rate of car ownership relative to the rest of Brazil. Based on 1991 traveler survey results, it was estimated that service improvements resulting from the introduction of Bus Rapid Transit had attracted enough automobile users to public transportation to cause a reduction of about 27 million auto trips per year, saving about 27 million liters of fuel annually. In particular, 28 percent of direct bus service users previously traveled by car. Compared to eight other Brazilian cities its size, Curitiba uses about 30 percent less fuel per capita, because of its heavy transit usage. The low rate of ambient air pollution in Curitiba, one of the lowest in Brazil, is attributed to the public transportation system's accounting for around percent of private trips in the city. Residential patterns changed to afford bus access on the major arteries to a larger proportion of the population. Between 1970 and 1978, when the three main arteries were built, the population of Curitiba as a whole grew by 73 percent, while the population along the arteries grew by 120 percent. Today about 1,100 buses make 12,500 trips per day, serving more than 1.3 million passengers per day, 50 times more than 20 years ago. Eighty percent of the travelers use either the express or direct bus service, while only 20 percent use the conventional feeder services. Plans for extending the rapid bus network will reduce the need for conventional services. In addition to enjoying speedy and reliable service, Curitiba's spend only about 10 percent of their income on travel, which is low relative to the rest of Brazil.

4.3.2 The case of Transmilenio the BRT system in Bogota – Colombia

4.3.2.1 Before the BRT implementation

This section describes the transportation conditions in Bogotá in 1998, (before Transmilenio) in order to understand the positive transportation changes made in the city. Ninety five percent of the road network was used by 850,000 private vehicles, which transported about 19% of the population. Close to 70% of trips shorter than 3 km were made by car. Buses occupied a low percentage of the roadway network. Seventy two percent of trips were made by public transit on about 21,000 buses. The average trip by bus was about 1 hour 10 minutes in duration with an average speed of 10 km/hr. The majority of the buses were more than 14 years old with an average of 50% occupancy. A total of 48% of public transit

vehicles were medium sized buses (40 - 80 passengers), 37% small buses (20 - 40 passengers), and 15% were minibuses. The fares ranged between US\$0.30 and US\$0.40 depending of the type and age of the buses (Transmilenio S.A., 2000). In general buses did not have comfortable seats, ventilation or security. There were no defined bus stops, therefore, buses picked up and dropped off passenger at any location along the route. There was no motivation for car owners to switch to public transportation because of the low quality of the system. Figure 4.6 shows some of the buses previously used in the public transportation system in Bogotá.



Fig. 4.6. Bogotá, Before the BRT Implementation.

The transportation system was operated by multiple private operators, which perceived their income as a function of the number of buses in their fleet. The bus system growth was very fast and disorganized. Between 1993 and 1997 the demand for bus service increased 27%. On the other hand, the bus supply increased 72%, which shows the lack of control and planning of the system supply (Transmilenio S.A., 2000). This unbalanced growth brought a phenomenon known as “la guerra del centavo,” which can be translated as “the war of the cent.” The war of the cent refers to the aggressive war of the drivers for picking up the maximum number of potential passengers. This aggressive competition between buses was permitted in the streets. Since the revenue earned by the operators depended on the number of passengers served, the war for passengers was very competitive. Because of the excessive number of buses, these private operators had excessive consumption, tires, and other operational requirements. In addition, the lack of maintenance and renovation of vehicles brought excessive operational costs and increased contaminants and noise. Fare collection was performed by the driver, which produced distractions that in many cases ended in accidents. In addition, this increased the travel time making the service less attractive to the public. Other problems included high pollution levels of 750,000 tons of atmospheric pollutants per year generated by traffic and noise levels above 90dB on major streets. Air pollution was a serious issue due to the higher altitude (27% less available oxygen than at sea level) and the lack of pollution control. In addition, a high number of accidents (52,764) and 1,174 fatalities were recorded in 1998 (Transmilenio S.A., 2001).

4.3.2.2 After the BRT implementation

Transmilenio was created in order to reduce accidents, shorten travel times, reduce pollution, and provide accessibility for young, elderly, and people with disabilities and to provide affordable, high quality and advanced transportation technology. The infrastructure, management, controls and planning are supplied by a new transit authority. The fare collection and operation systems are controlled by the private sector. The new transit authority, Transmilenio S.A. was created in October 1999 in order to manage, control and plan the system. Transmilenio S.A. is supported by 3% of the fare revenues and other activities, such as commercial advertising (Hidalgo and Sandoval, 2001). Financial resources for the implementation of the BRT system came from a fuel tax, local revenues, a credit from the World Bank and grants by the national government. Resources were planned to fund the BRT infrastructure until 2006 with a possible extension to 2018. The project was planned, designed and constructed by local and international firms. It took about eighteen months to finish the studies and develop detailed plans for the system. Examples of BRT systems in other Latin Countries, such as Quito (Ecuador), Curitiba, Sao Paulo, and Goiania (Brazil), and Santiago (Chile) helped to identify important elements for the planning and design of the system.

From the beginning of the BRT implementation the private transportation operators that provided transit service in Bogotá were involved in the planning process. Operators of the old system were offered the opportunity to be the operators of the new system. This strategy was implemented by showing them the opportunities and advantages of their participation. The operators' experience was recognized and valued as a key aspect for the success of the new BRT system. Having the operators of the system as part of Transmilenio, protests and work stoppage possibilities for the service were avoided. Every time that a new Transmilenio bus was put in service, some old buses had to leave the system. The newer buses are used as feeder buses to take passenger from remote locations to the Transmilenio system.

In April 2000, four different firms created by local transportation operators associated with international investors received the contract concession to provide and operate 470 new articulated buses. Ninety-six percent of the private operators that provided transit service acquired stock in the four firms that were awarded the contracts. This shows the success of the program to include former transit operators in the Transmilenio operation. The fare collection was awarded to a local firm supported by an experienced fare collection system provider. The control system was awarded to a Spanish firm. Feeder service and renovation of existing buses contracts were awarded to traditional transit operators (Hidalgo and Sandoval, 2001). The new system infrastructure was constructed by local contractors under the supervision of the Institute of Urban Development (Instituto de Desarrollo Urbano, IDU). Their duties were to develop: 35 km of bus ways and complementary lanes, 4 terminals, 4 parking and maintenance yards, 58 stations, 17 pedestrian overpasses, plazas, sidewalks, built or rehabilitated 126 km of roads for feeder services, in a 24 month construction period. About 17,000 people are estimated to have participated in the project. On December 18, 2000, Transmilenio started operation (Transmilenio).

4.3.2.3 Transmilenio infrastructure characteristics

The Transmilenio infrastructure consists of dedicated bus ways, streets for feeder buses pedestrian access facilities, stations, points for bus parking and maintenance, and an advanced control system. Bus ways are located in the center lanes of the main avenues of the city. These bus ways are physically isolated from the mixed traffic lanes, private vehicles, trucks, and taxis. There are two lanes dedicated for Transmilenio in each direction (See Figure 4. 7). The two lanes in each direction were included to allow buses to pass one another, which improves the speed of the system and allows for express or skip stop service. In a 15 year period, 22 bus ways or main lines covering 388 km are expected to be in operation. Table 4.1 shows the year and the number of km of bus ways that are expected until 2018 (International Seminar on Human Mobility, 2003). Figure 4.8 shows a map of Bogotá with the 22 bus ways expected through 2018.

Year	Km of bus ways
2005	130.4
2010	252.6
2015	384.3
2018	388.9

Table 4.1. Km of Bus ways expected.



Fig. 4.7. Infrastructure Characteristics.

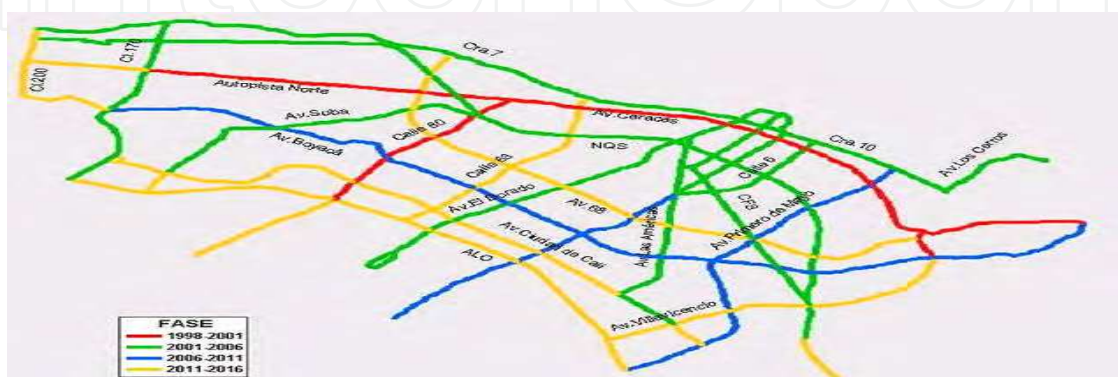


Fig. 4.8. Twenty two Bus ways Through the City.

There are three types of stations;

- Simple Stations: They are located every 500 meters. At these stations passengers can purchase tickets and enter the system.
- Intermediate Stations: These stations are the contact points between the feeder buses and the main lines. Their objective is to provide smooth, fast and effective interaction between the Transmilenio and feeder buses.
- Portals or Main Line Stations: They are located at the beginning and end points of the main line routes. In these stations transfers are accomplished among Transmilenio buses, feeder and transportation routes. The fee is integrated with the feeders, so that when a transfer takes place double payment is not required. These stations are provided with bicycle parking facilities.



OUT SIDE



INSIDE

Fig. 4.9. Stations.

Walkways, plazas and sidewalks were constructed to provide adequate pedestrian and bicycle access. Parking and maintenance areas for the buses near terminal stations were also constructed. Each station is provided with maps and route information to facilitate the use of the system.

4.3.2.4 Operational system

The overall system includes main lines and feeder buses. The buses are an important element for the image of the system. The buses are operated by private contractors, but controlled by Transmilenio. S.A. The main line circulates through exclusive corridors, starting and ending the routes at the Portals and Front End Stations (See Figure 4.9). On the main lines, Transmilenio is the only system operator. Feeder buses do not use the main lines. There are two types of service on the main lines: normal and express service. Normal service stops at every station along the routes; they are identified with the number 1. Express service does not stop at all the stations along the route, which reduces travel time and the size of the fleet because buses can complete more cycles. Express service is identified with the numbers 10, 20, 30, 40, and 50. The combination of the normal and express services allows the system to carry more passengers per hour per direction and divide the passengers according to their destination, which is more appropriate for the size of the buses. Normal buses run every five (5) minutes and express buses every four (4) minutes. Passengers that use the express service can stop and take buses in the other directions as needed. Table 4.2 shows the year and the number of passengers that are expected through 2018 (International Seminar on Human Mobility, 2003).

Year	Passengers/day
2005	2,681,000.00
2010	4,136,000.00
2015	5,004,000.00
2018	5,295,000.00

Table 4.2. Number of passengers expected.

The main line is served by articulated buses with a capacity of 160 passengers. They are 18 meters long, 2.60 meters wide, and have four doors of 1.20 meters each on the left side of the bus. The design of the buses was focused on customers, with inside comfort, easy entrance of passengers, clean air and noise emissions. They have pneumatic suspension, automatic transmission, and the engines use diesel and natural gas. Feeder buses have capacities of 80 passengers (Transmilenio). A total of 6,000 articulated buses are expected by 2015. Figure 4.10 shows a photograph of the buses that serve the feeder system. Feeder buses have lower capacity than the main line buses. New or recent model buses are used as feeder buses with a capacity of 80 passengers. They serve areas that do not have access to the main lines. Passengers transfer from/to the feeder buses to/from Transmilenio through the stations. Each driver works 6-hour shifts. Drivers are paid as a function of the kilometers served by their buses, and they are not involved in fare collection. The system operates from 5:00 AM to 11:00 PM. The system is designed to serve 5,000 trips per day with a total investment of US\$2.3 billion. This value does not include the fare collection system implementation costs and the cost of the buses



Articulated Buses



Feeder Buses

Fig. 4.10. Articulated buses and Feeder buses.

4.3.2.5 Fare collection system

Transmilenio uses a prepaid method of payment (off board fare collection). The passenger pays the fare upon entry to the system in the stations. The passenger purchases a smart card at the ticket office located at the entrance of each station. The smart card can be yellow for one trip, red for two trips, or the capital card that permits several trips. It permits multiple boarding reducing dwell times, bus operating cost, and travel times for passengers. Access turnstiles are located at the entrances and exits of the stations to validate and register the number of passengers using the system.

4.3.2.6 Advanced control system

An advanced control system is a very important part of the BRT system. A satellite control center allows continue supervision of the operation of the buses. Each bus has a Global Positioning System (GPS) receiver to report the bus location, a computer that contains the schedule, a tracking communication system that shares information with a control center located in Transmilenio, S.A. and the police, and a transponder that sends the information to receivers at the entrances and exits of every station. This communication system provides

real time information and is the basis for the control of the system. This makes it possible to adjust the schedule and identify possible new routes into the system.

4.3.2.7 Infrastructure result

Phase 1 was implemented between 1999 and 2002. The system began with 21 stations and was 15.5 km in length. In November 1999 there were 35 km of bus ways, 100 km of feeder routes, 401 articulated buses and 103 feeder buses (Hidalgo and Sandoval, 2001). Three main lines were constructed within the city: Calle 80, Troncal Caracas, and Autopista Norte. Forty-one kilometers of new bus ways were built through the three corridors (See Figure 4.11- This figure also includes phase II). Seven feeder zones with 309 kilometers of feeder routes within 74 neighborhoods were installed to move passengers from remote areas to the main BRT system. Along the main lines four terminal stations, four intermediate integration stations, and 53 simple stations were constructed. In addition, 30 pedestrian overpasses, plazas and sidewalks were constructed. In this phase there were US\$240 million of investment (International Seminar on Human Mobility, 2003).

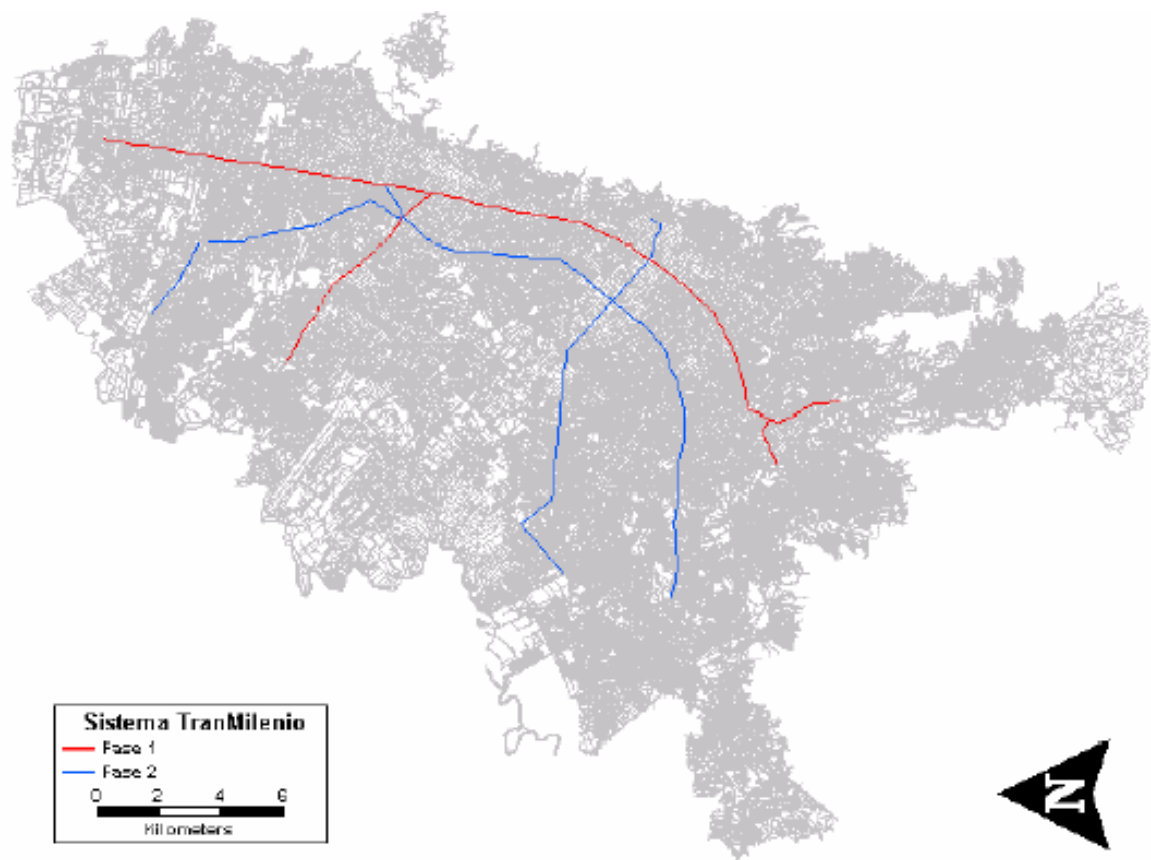


Fig. 4.11. Phase I and Phase II Main Lines.

4.3.2.8 Operational result

In December 18, 2001, the mayor of Bogotá, Enrique Peñalosa, along with Transmilenio S.A. Company, inaugurated the new BRT service in the city. Until January 2001 the service was free. In November, 2000, the system demand grew by 550,000 passengers per week (Hidalgo and Sandoval, 2001). During phase 1 the system moved an average of 770,000 passengers/day with 34,000 passengers per hour per direction on the busy sections of the system, averaging 5.3 passengers per kilometer. A total of 344,162,256 people were transported, and buses covered 66,035,715 kilometers through the main lines (International Seminar on Human Mobility, 2003). There are 470 articulated and 235 feeder buses in use. They have an average speed of 26 km/hour in the main lines. The speed increased from 10 km/hour to 26 km/hour with the implementation of the system (International Seminar on Human Mobility, 2003).

Ticketing and fare collection: In phase I, 90 ticket booths were installed, 359 barriers and 1.3 million smart cards have been used. The fare began at 800 Colombian pesos and ended at 900 Colombian pesos, which is about US\$0.40. This low fare makes the system affordable for low income users. This phase had daily revenue of about US\$270,000 from about 770,000 passengers (International Seminar on Human Mobility, 2003).

Advanced control system: Six control stations were implemented. Each station is able to monitor and control 80 articulated buses. Each articulated bus has a GPS system to track its location at six-second intervals and with +/-2 meter accuracy. Schedule adherence can be verified and adjusted accordingly. A total of 94 supervisors controlled the buses by the end of phase 1. Continuous communication between operators and the control center supervisors was achieved by the end of this phase (International Seminar on Human Mobility, 2003).

Accident, pollution and safety: The reductions in pollution and accidents as well as safety improvements were some of the most important impacts observed at the end of phase 1. There was observed a reduction of about 92% in fatalities, about 75% in injuries and about 79% in collisions. Robberies at transit stops were reduced by 47% (Hidalgo and Sandoval, 2001). A monitoring study at the one of the main lines (Troncal Caracas) in 2000 and 2001 showed a reduction of about 43% of sulfur dioxide (SO₂), 18% of Nitrogen Dioxide (NO₂), and 12% of particulate matter of less than 10 microns (PM-10) (Hidalgo and Sandoval, 2001).

Travel time: A reduction of 32% in the travel time for public transportation users was measured. The speed along the Calle 80 and Caracas main lines increased from 10 km/Hour and 18 km/hour to an average of 27 km/hour. Surveys show that 83% of the users perceive the increase in speed as the main reason to use Transmilenio. Thirty seven percent of the users perceive that they spend more time with their families because of a faster commute (Hidalgo and Sandoval, 2001).

Hence we can conclude that the various projects in Latin American countries indicate that obstacles have surfaced, but the BRT system is a good alternative to improve and upgrade the transportation system at a cost that developing countries can afford. Examples such as the BRT system in Bogotá, Colombia, demonstrate that the BRT system can be as efficient, cost effective, comfortable and versatile as the LRT. During the first phase of operation the transportation system in Bogotá became more organized and effective and with higher

quality. There has been observed a reduction in travel time, pollution, and accidents as well as increases in safety and speed through the network when influenced by the BRT system. People are leaving their cars at home and users seem to accept and like the system. Surveys in Colombia show that the 49% of the users find the system very good and another 49% find the system good during the first phase of operation. The BRT system in Colombia can be taken as an example for other developing countries to follow in the future.

4.3.3 Lesson from Curitiba and Bogota

The example of Curitiba - Brazil and the experience of the Transmilenio BRT system in Bogota - Colombia illustrate the potential of improved bus services to address mobility needs in metropolitan areas. Buses provide flexible and cost effective public transportation. Metropolitan areas throughout the city can build on the experience of Curitiba and other developing cities to develop Bus Rapid Transit systems that provide fast, reliable, and convenient service in cities and suburbs.

Upgrading the performance of bus services to meet the objectives of Bus Rapid Transit will require policies that give priority to bus operations and provide for investment in crucial system components: infrastructure that separates bus operations from general purpose traffic; facilities that provide for increased comfort and system visibility; and technology that provides for faster and more reliable operations. New guidance, information, and fare technologies offer an expanded range of possibilities for operating bus systems that have the potential to produce marked improvements in performance, surpassing previous standards and changing public perceptions of bus service. High quality bus operations have the potential to create new, improved land use options that provide for compact, pedestrian-friendly and environmentally sensitive development patterns that preserve neighborhoods and open space. Bus Rapid Transit thus will have maximum benefit when developed in close coordination with land use policies and community development plans.

Implementation of Bus Rapid Transit poses a number of challenges, ranging from the need for adequate cross sections on city streets to provide separate rights of way for buses, to maintaining the quality of general purpose traffic flow and minimizing local noise and air quality impacts. These challenges require detailed analysis in the context of specific local applications to identify appropriate solutions and to determine where Bus Rapid Transit can have the greatest benefit. Bus Rapid Transit is a concept that merits widespread evaluation and consideration as an adaptable, effective public transportation alternative to automobiles

4.3.4 The bus rapid transit system in Dar es Salaam City – DART system

To mitigate the aforementioned public transport challenges, a Bus Rapid Transit system - so called DART, for Dar Rapid Transit has been proposed since 2003 and succeeded in gaining sufficient funding and political will to be fully implemented by 2030 (JICA, 2008). It is a citywide 137 km system designed to completely replace the existing public transport called daladalas (Dar es Salaam City Council, 2007) Figure 4.12 and 4.13 below is phase 1 and complete route map respectively. It is therefore expected to provide reliable and comfortable

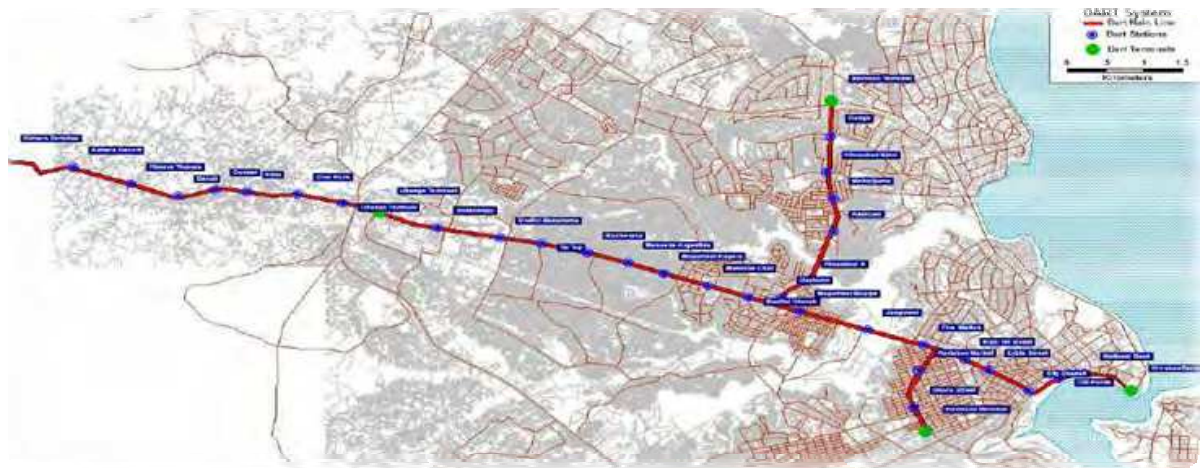


Fig. 4.12. DART Phase 1.

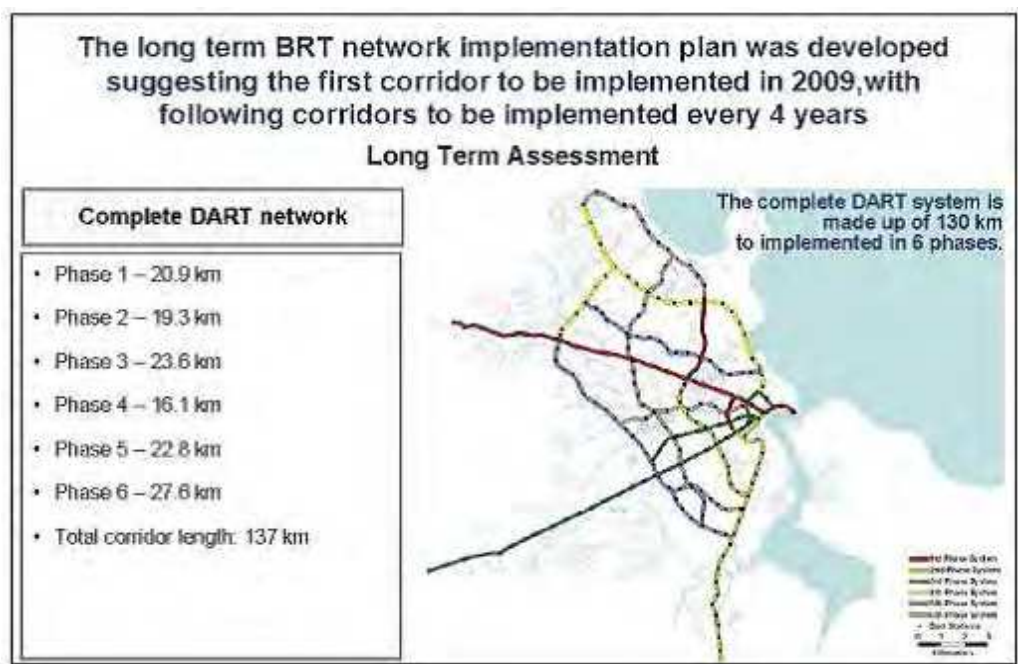


Fig. 4.13. Completed Route Map of DART.

trips with short travel times as its buses run on exclusive and segregated lanes. It is also expected to be more environmentally friendly (and sustainable) as its buses will be EURO 3 standard and thus less polluting than the existing public transport (daladalas). Although the following specific questions have been developed: Would the BRT buses ensure equitable access to all population groups in the city? Does the new system accommodate the current public transport operators? How does vehicular emissions of CO₂ and CO in the city before and after Dart implementation.

4.4 Evolution of road network and BRT coverage in Dar es Salaam City

A total of 1,091 km roads including the proposed expressway are expected at the year of 2030 (Figure 4.14 and 4.15) respectively. Most of the roads in Kigamboni side are new roads

that are expected to attract future urban development in the south of Dar es Salaam. An expressway system is proposed, which runs through the entire Urban Growth Boundary (UGB) area as a spine road system for the region. The transport policy suggests that the priority should be given to people’s mobility, but at the same time mobility of cars is important in order to improve the attractiveness of Dar es Salaam as a Gamma World City in future. The expressway runs in parallel with the Morogoro road in the future urban business/commercial axis, hence which provides direct access with motorists to go to their destinations along the BRT Phase 1 corridor. This expressway alignment will contribute to the urban regeneration of the BRT Phase 1 corridor as well

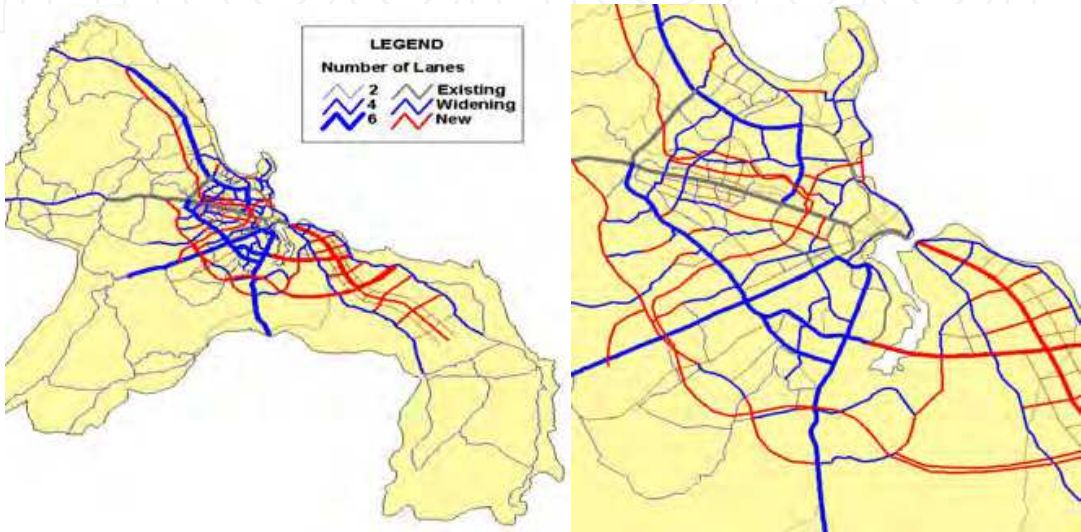


Fig. 4.14. Year 2030 Network by the number of lane.

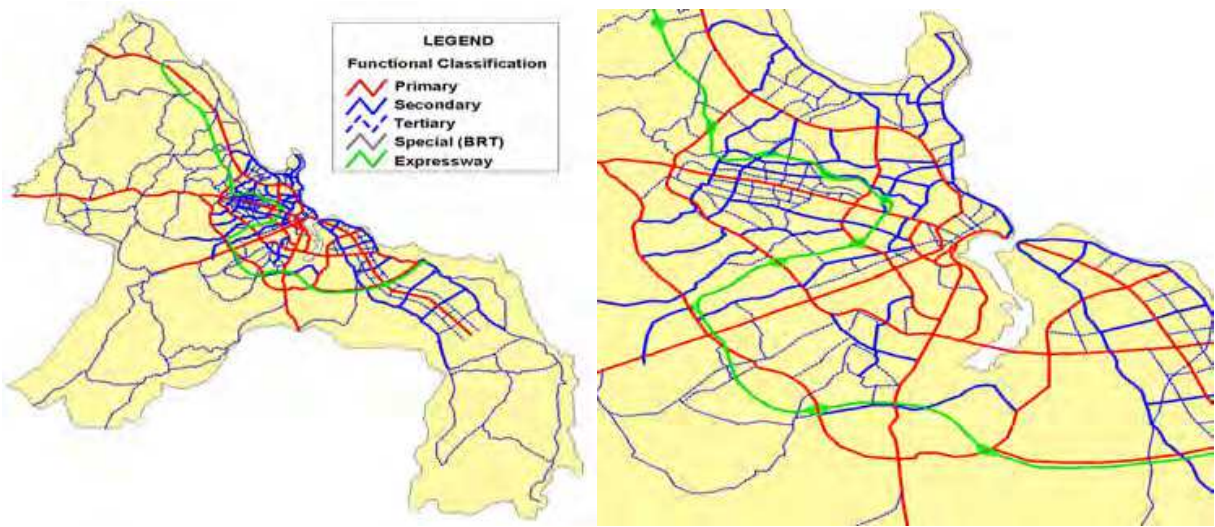


Fig. 4.15. Year 2030 Network by road class.

4.4.1 Network planning and efficiency

Dar es Salaam is well progressed to developing a ‘state of the art’ BRT system but it is necessary to place this into a proper and objective planning context. BRT is not a ‘cure all’ and its success is dependent on where it sits in the overall public transport of Dar es Salaam

and whether it meets the essential criterion necessary for success. All successful public transport systems need to include the demand oriented services; Bus priority (including BRT where appropriate) giving; increased bus speeds; reduced travel time; access and integration; efficient network design.

4.4.2 Demand oriented services

Under traditional public ownership, buses were mostly 'supply oriented' building the system on technical or regulatory premises on the assumption that patronage will follow. More recently, transport planners have understood that consumers have greater choice, so for public transport to survive demands a 'demand responsive' approach. For the transit user, the transit experience is more than just a bus trip; it is a total journey (from door to door) and judged in terms of access, convenience, travel time and comfort. Network design should take this into account and involve all aspects of route planning, passenger waiting facilities, ticketing, bus quality, service frequency, comfort and convenience in the planning process. For a 'demand oriented system', passenger convenience is the main issue, being that the system can be used with ease and ultimately saves the user time. This concept needs to be embedded into policy objectives and the design and management of the system. The figure: 4.16 and figure: 4.17 below show the bus priority and the role of DART manager respectively. Each city must develop its own strategic approach for Bus Priority and BRT as 24 part of the total system network. BRT is not an 'off the shelf' bus solution; it needs to be carefully adapted to the prevailing conditions, but in Dar es Salaam, high public transport dependency creates a natural opportunity for a BRT system and hence to insure the role of Dart manager in the implementation and running the system management model.

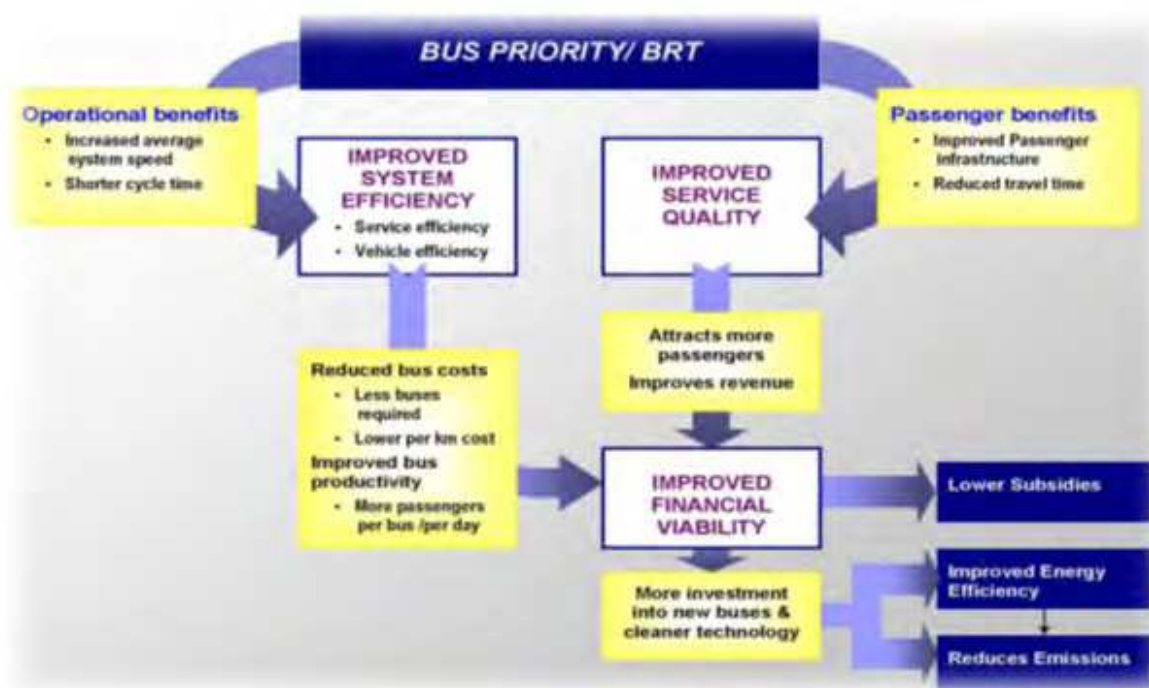


Fig. 4.16. Bus priority.

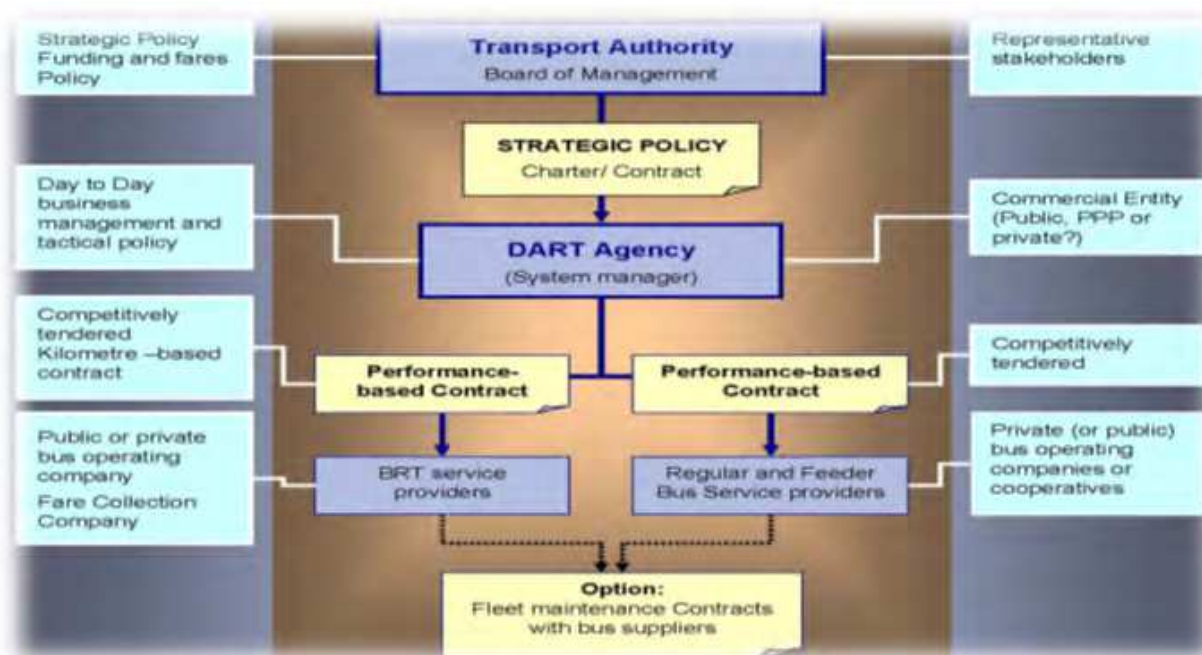


Fig. 4.17. System Management Mode.

4.4.3 DART system

Dar Rapid Transit - DART will be a high quality mass transport system in Dar es Salaam - Tanzanian operating on specialized infrastructure and offering affordable mobility, environment improvements, and a better quality of life of the residents of Dar es Salaam. The DART mission is to provide quality and affordable mass transport system for the residents of Dar es Salaam which will reduce emissions, enable poverty reduction, lead to sustainable economic growth, improve the standard of living and act as a pioneer of private and public investment partnership in the City. DART will achieve this by using: Modern, privately managed buses with low emissions; segregated bus lanes; Scheduled bus services; High capacity bus stations with a central platform; on level boarding; Privately-managed fare collection system; and Average bus speeds over 22 km/hr.

The system has five system actors. The DART Agency, a public agency, will regulate and manage the system and the service. Two private sector bus companies and one private sector fare Collector Company will provide the system services, which will be publicly bid. The winners of the bid will be awarded 20 year concessions. Finally, one fund manager will ensure fiscal accountability and transparency of the fare revenue.

- DART Agency* - a government agency responsible for overall management of the system, policy-setting, regulation, planning and controlling of operations and marketing.
- DART Fare Collector* - one private sector company responsible for daily fare collection, maintenance of the physical infrastructure at the bus stations, acquisition and maintenance of equipment used at the station, as well as cleanliness and security at stations.

- iii. *DART Bus Operator(s)* - two private sector companies responsible for acquisition, operation and maintenance of buses along specified trunk and feeder routes.
- iv. *DART Fund Manager* - one institution responsible for financial management and reporting, liquidity control and payments to the system actors (bus operators, fare collector, DART agency and the fund manager).

All system actors will adhere to the DART system values of: Customer Driven and User Friendly, Innovative, Cost Effective and Affordable, Timely and Reliable, Team Work, Safe, Financially Sustainable and Profitable, Environmentally Friendly, Poverty Reduction through Economic Development. Dar Rapid Transit will provide several direct benefits to the City, including:

Category	Description
Economic	Cheaper means of mass transportation Reduce travel times Less congestion Segregated lanes for buses Fast boarding and disembarkation Centrally controlled communications system Increase economic productivity fair return on investment building of Public Private Partnerships Less cost for customers and Government in general Better working conditions for drivers and conductors Create employment
Social	Reliable and comfortable Reduce accidents and air pollution-related illnesses Increase civic pride and sense of community
Environmental	Less vehicle pollutants emissions Reduce noise levels Prioritizes and integrates Non Motorized Transport
Political	Delivery of mass transit system within one political term Delivery of high-quality resource that will produce positive results for virtually all voting groups
Urban form	More sustainable urban form City Beautification

Table 4.3. Dar Rapid Transit benefits.

4.4.4 DART will be the first full BRT system in Africa

DART is a high capacity bus rapid transit system with closed stations and physically segregated lanes. Phase 1 of the system consists of 21 km of segregated median bus ways, 29 stations, 6 feeder stations, 5 terminals, and a network of feeder routes operating in mixed traffic. It will offer seven trunk line services, using (136) air conditioned, 18 meter articulated buses with a 140 passenger capacity and 15 feeder bus services, using (111) air conditioned, 8.5 meter micro - buses with a 50 passenger capacity. The baseline proposed fare to the public will be: Table 4.4 below highlight the proposed fare.

Trunk and Feeder	500Tshs
Trunk Only	400Tshs.
Feeder Only	400Tshs.

Table 4.4. Proposed fare highlights.

Customers will enter stations and feeder buses with contactless smart cards. There will be an option to pay cash both on the feeder buses and in the stations. The DART Agency has set baseline fares at Tsh 400 for trunk service and Tsh 400 for feeder service. A customer transferring from a trunk bus to a feeder or vice versa will pay a combined fare of Tsh 500 if using a contactless SMART card. Those using cash must pay Tsh 400 to use the trunk bus services and Tsh 400 to use the feeder services. There will be 392,217 passengers per day on the system for a total annual ridership of 117.7 millions of trips. The projected total fare income is estimated to be TZS 46 billion in the project’s first year of operation, rising to TZS 73.6 billion in 2028. Table 4.3 below highlights the system’s revenue stream for the first 20 years of operations.

Revenue Allocation ('000 TZS)	2009	2010	2011	2012	2013
Tariff revenue	46,162,583	47,752,845	49,397,890	51,099,605	52,166,113

Table 4.5. System’s revenue highlights.

The goal of DART is to transform Dar es Salaam’s informal system of “daladala” minibuses into a customer--oriented public transportation service. To this end, the DART Agency will prohibit 43 of the daladala routes that utilize Morogoro and Kawawa North Roads. The Agency plans to cancel all of the daladala routes on Morogoro Road. On Kawawa North Road, daladalas continuing south, away from the BRT corridors, will be permitted to operate, but those turning onto the Morogoro corridor will be cancelled. Table 4.4 below is the operation highlights of the DART system.

	Trunk	Feeder
Peak headway (min.)	1.5	1.1 to 7.5
Off--peak headway (min.)	6	15
Average commercial speed (km/hr)	23	17
Hours of operation	5:00 to 23:00	5:00 to 23:00
Daily service kilometers	45,000	26,000

Table 4.6. Operational highlights.

4.4.5 System scheduling and control

There are two parts to the system control. The first is scheduling the services - every week, every day, and every hour for each service (all initial 7 trunk services and 15 feeder route services) for each operator. The second is controlling the system to ensure quality of the service, including if the buses are running on time and know if the drivers are going too slow or too fast. Control also involves addressing contingencies if there are problems in

operations (i.e. a bus breaking down, strikes) and the ability to speak directly with drivers to let them know about all these conditions. In order to ensure system cohesion and technical integration, as well as achieve economies of scale, the FCS operator is responsible for providing:

The scheduling software and the control software to the DART Agency, training on the respective software's to the DART Agency; the communications and physical equipment for the control functions of the system, including data transmission, on board logic units and GPS on the buses, and radio services; terminals at the bus depots with software for receiving the scheduling from the DART Agency; WLAN points at the depots to facilitate data transmittal; and Specifications to the bus operators for the Logic Units that are on-board the buses to do the control so that they can plan for them in the bus layout.

- i. *Scheduling* - The DART Agency schedules the bus service. The two main inputs are the number of buses (which is a fixed number) and the number of total passengers and number per station (which is dynamic and comes from the Fare Collection System information). While the bus operators are responsible for providing the scheduled service, the FCS operator is responsible for providing the number of passengers. Since it is the FCS operator's responsibility to provide the passenger number information, it is also responsible for providing the software for scheduling to the DART Agency to ensure coherence between the information from the FCS and the software used to do hourly, daily, weekly, monthly scheduling per service. The DART Agency will create monthly, weekly, and daily schedules for the bus operators. They produce the longer term schedules in order to help the bus operators schedule maintenance for the buses.

The DART Agency sends to the depot of each operator the daily schedule (routes and services) at least one day in advance for all services, including truck and feeder. There will be one terminal (with appropriate software) in each depot provided by the fare collector that will receive that information. The bus operator then takes that information and assigns specific buses and specific drivers to the service. The software the bus operator uses to do that bus allocation and crew scheduling is their own responsibility. The bus operator sends the scheduling with the specified bus and driver back to the scheduler in the DART Agency control center. The control center then must verify that it matches the schedule that was sent originally and do their first control looking at what buses are running to ensure buses are being rotated for maintenance and how long the drivers are scheduled to work to ensure that safety and legal standards are met. The control center then must approve the schedule. Once the bus operator gets the approval, they then must save the information of the service of each bus on the Logic Unit (on board computer) of each bus, both trunk and feeder. The Logic Unit is bought by the Fare Collector. However the technical specifications must be given by the Fare Collector to the bus operators before they procure the buses in order for the manufacturers to know the cable specifications, as well as support required for and the dimensions of the Logic Unit. When the bus operators send information of detailed scheduling back to the control center, they also save it on the on board computer to help the driver be on time. Station stops and times appear on the logic unit's display for the driver. Only the driver assigned to a particular bus may operate that vehicle. This can be ensured by giving each driver a specific code that unlocks the bus. For a particular bus, both the service and the driver will change

daily. The important consideration is to save the correct service and driver information to the bus specified for that day's service. For feeder buses, the driver is joined by a conductor working for the Fare Collection Company. The bus operator and the Fare Collection Company will have to work together to coordinate the schedules of personnel (conductors on the buses) and coordinate the timing issues with depositing the money collected each round trip. Finally, the card readers on the feeder buses are the responsibility of the Fare Collection Company to maintain, but there will be fines to the bus operator for negligence if equipment is damaged. The bus operator is not paid for dead kilometers meaning the kilometers from the bus depot to the start of the service and the kilometers from the end of the service to the depot. They are only paid for the kilometers of service provided. Once the bus is in service, the driver only talks to and follows directions from the DART control center.

- ii. *Controlling* - The main form of control will be using GPS tracking and sending that information to the control centre via GPRS data packets. The buses will be equipped with Global Positioning System (GPS) transponders that are procured by the Fare Collector in the Logic Unit. These transponders will record arrival times and location of the bus and periodically during the day this information will be sent to the control center for verification. The distance traveled will be determined by the control center computer and checked against odometer readings, beginning with the place where service was started and ending where the service finished. With GPS, the central computer system will record arrival times at stations and terminals and then check them against the assigned schedule. The bus driver proceeds to drive the scheduled service that is on the Logic Unit. The bus driver is charged with maintaining the service and the frequency on the schedule and adjusting his driving to match those specifications.

However, this will also be monitored by the control center that can then request that the driver to slow down or speed up to meet the assigned schedule. While on the road, bus drivers have direct contact with the control center. This communication can be through radios or using cell phone technology / GSM chips in the logic unit with pre configured panel activation buttons. As soon as the driver is on the corridor, he should only take direction from one source and that source should be the DART Agency control center never from the bus operator office or depot. The logic unit will also record the number of kilometers driven and the times the driver arrived at the station or predefined Feeder Bus Stops, as determined by the GPS locator and recorded by the Logic Unit. This information will be sent to the control center via GPRS technology at pre determined intervals. There will be a mechanism on the bus that the driver activates in order to open the sliding doors at the station. When the bus returns to the depot, all that information from the Logic Unit, including the odometer reading, will be sent to the control center by the Depot Terminal. For manual control, when the bus reaches the first terminal, the DART Agency controller visually verifies the time of arrival and the condition of the bus. If there are any problems, the controller can contact the control center to remedy via radios or GSM chip / cell phones. If there is a problem in the system (bus early, bus late, bus in poor condition), the people in the terminals must transmit immediately to the control center for them to fix directly with the driver or with the depot, in order to send a reserve bus, for example. The timing information will also be transmitted via GPRS from the bus directly. The control center is

responsible for comparing scheduling versus actual, both the time scheduling and the kilometers. Those numbers get shared with the financial planning team. The onboard computer and software is provided by the FC as a bundled unit to the bus operators and the FC is responsible for ensuring / guaranteeing data transmission. Figure 4.18 below illustrates the control system.

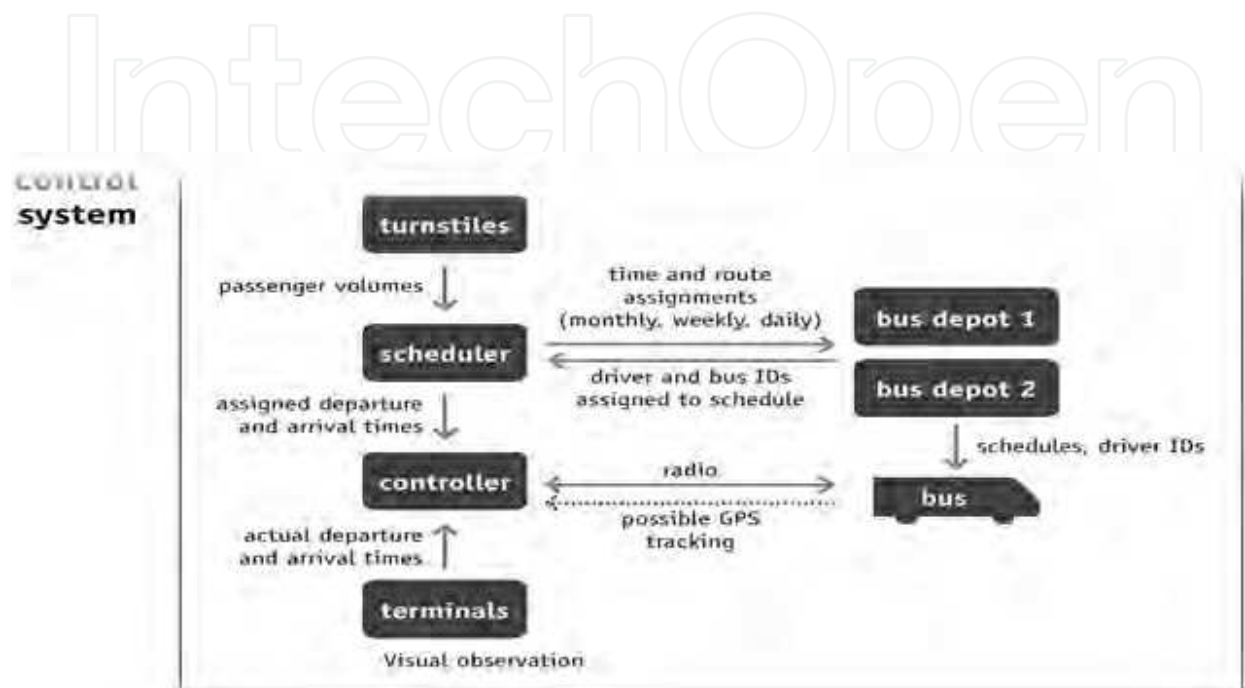


Fig. 4.18. Control system.

4.4.6 Fund manager

The transparent and fair distribution of revenues is fundamental to the DART System and in operating a network of integrated transit providers. (Figure 4.19 the passenger revenues). To ensure confidence in the distribution of revenues in the private sector, as well as the DART Agency, an independent trust fund manager acts as a custodian of the revenues and pays out according to fixed rules and regulations as stipulated in the contracts. This fund manager will be paid a fixed fee for maintaining this fund and paying the appropriate operators. This fund manger receives the money every day from operations (from the fares) and then pays all the system operators based upon the contracts and the information given to them by the DART Agency. The fund manager will be responsible to the DART Agency and will carry out the following functions:

- i. Put systems in place for the management of the DART resources;
- ii. Makes payments to the various actors within the DART system upon instruction from the DA. This will be on the basis of pre agreed terms;
- iii. Prepare regular financial reports for submission to the DA.

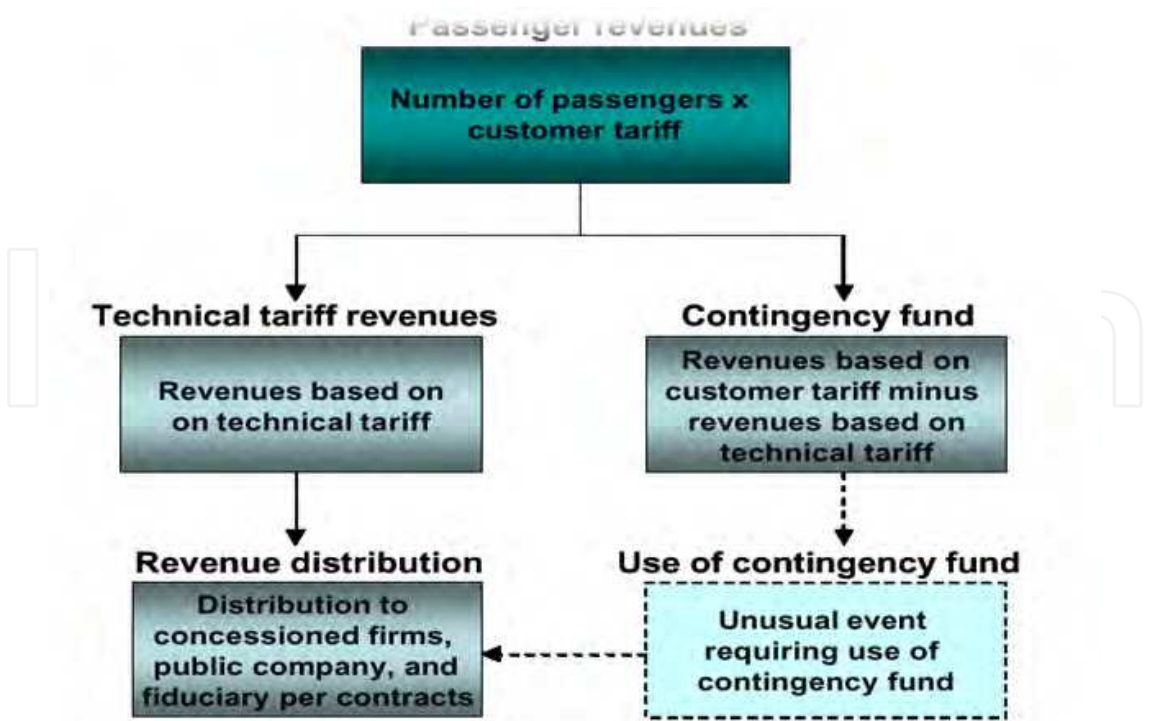


Fig. 4.19. Passenger revenues.

The fare collection system is managed by a separate private company that successfully bid for the fare handling concession. The fare handling company has no involvement with any of the bus operating companies on the BRT system. Since the fare collection company itself is due part of the proceeds, it would be a source of potential suspicion if the fare collection company was to fulfill the function of fund manager. This ticketing system operator collects the fare revenue and deposits it into the account of the trust fund manager. Finally, to ensure transparency of the system, the entire process will be independently audited by another professional firm. This auditing process provides a check on the handling of revenues by the fare collection company and the fiduciary company. The auditing process in conjunction with the electronic verification of fares collected, as well as the presence of the fiduciary company, all help contribute to an environment of confidence in the system. The figure 4.20 below shows how the revenue will be managed in the DART System.

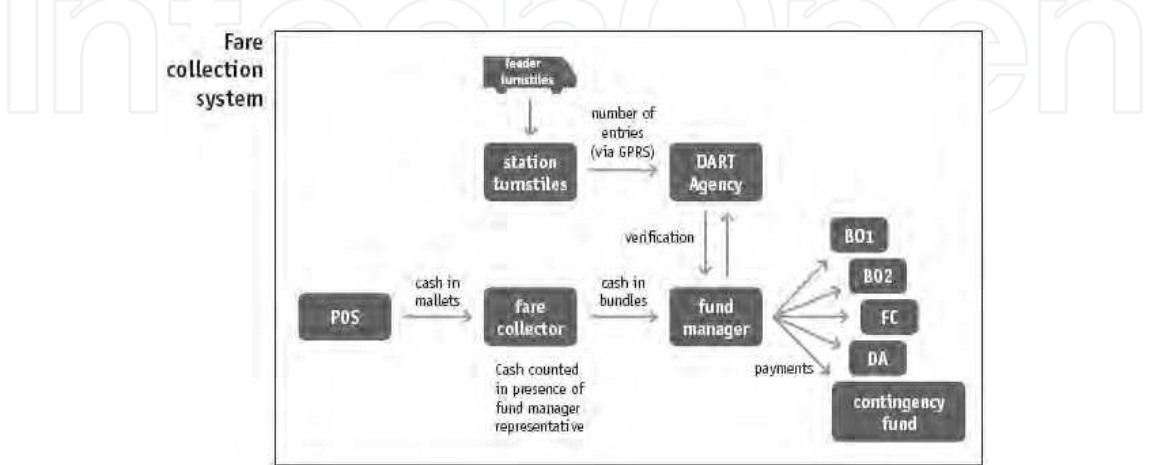


Fig. 4.20. Dart system revenue management.

4.4.7 Dart project risks and mitigating actions

The success of the DART Project is challenged by the following key factors:

- i. Price sensitive market. The majority of commuters in Dar es Salaam fall in the low income bracket that is sensitive to price changes. A contingency fund will therefore be established to cushion against sudden or unusual fare increases.
- ii. Unstable fuel prices. The operators will strive to form strategic alliances with oil companies and possibly enter into forward contracts that will shield against unforeseen fuel price increases.
- iii. High borrowing costs. The project requires specific buses, equipment, computers and technology that are of modern standards. Acquisition of most of the project assets requires external financing. In Tanzania interest rates are high and this can only be minimized by the DART system operators obtaining a syndicate loan(s).
- iv. Unreliable power supply. Power fluctuations and interruptions are common in the city and this can disrupt DART services. Power generators have been considered as an alternative power source at bus stations and terminals.
- v. General resistance from the public (commuters) and other stakeholders. An aggressive marketing strategy is in place to enable the DART Agency to sensitize the public and create awareness or acceptance.
- vi. Security of cash in transit. The risk of theft or robbery of DART collections during transit points i.e. to and from stations/terminals and the bank can be mitigated by enlisting the services of a reputable and experienced bank offering secure cash-in transit services.

Hence in order to achieve the above revenues targets, the Project will consider the following critical success factors: Tax waivers on bus importation; banning of dala dalas (and enforcement of ban) from Phase One Corridor; obtaining financing for the project at an affordable rate; close collaboration of the public and private sectors.

5. Intelligent transportation system technology in bus rapid transit

The use of new Intelligent Transportation Systems (ITS) or Advanced Public Transportation Systems (APTS) applications could contribute to improved bus service and increased bus operating speeds. Some ITS and APTS applications that a Bus Rapid Transit system might employ are described below, but this list is by no means exhaustive:

- i. *"Smart" card fare collection methods* - use read and write technology to store dollar value on a microprocessor chip inside a plastic card. As passengers board a bus, the card reader determines the card's value, debits the appropriate amount for the bus ride, and writes the balance back onto the card, all within a fraction of a second. There are two types of card readers, the proximity reader which can read cards held a few inches away, and the contact reader which requires physical contact with a card. Under development are systems that will be able to read cards carried in passengers' pockets, wallets and purses. Cashless systems such as "smart" cards speed up the fare collection process and eliminate expensive cash handling operations at transit agencies. "Smart" cards can also be programmed for distance - based pricing by recording where a passenger enters a transit system and debiting the appropriate amount from the card

- balance according to the point where the passenger exits the system, regardless of the number of internal transfers.
- ii. *Automatic vehicle location (AVL) systems* - enable transit agencies to track their vehicles in real time and provide them with information for making timely schedule adjustments and equipment substitutions. AVL systems are computer based vehicle tracking systems that measure the actual real time position of each vehicle, and relay the information to a central location. The measurement and relay techniques vary, but the most common are: signpost and odometer, wherein a receiver on a bus detects signals sent by signposts along the bus route and transmits the identity of the signpost and the odometer reading to the control center; and global positioning satellite (GPS) technology, wherein an onboard GPS receiver determines the bus position and transmits the information to the control center. AVL systems can be augmented by geographical information systems (GIS) on control center computers that display the location of the vehicles on route map grids.
 - iii. *Computer aided dispatching and advanced communications* - are systems that enable transit dispatchers, in combination with AVL systems, to maintain bus system efficiency by performing service restoration activities and communicating instructions to and receiving messages from drivers. Service restoration activities include such operations as adjusting dwell times at bus stops or transfer points, adjusting vehicle headways, rerouting vehicles, adding buses to routes, and dispatching new vehicles to replace disabled vehicles. Communications can be received in buses via radiotelephones, cellular telephones, or mobile display terminals.
 - iv. *Precision docking at bus stops* - uses sensors on buses and on the roadside to indicate the exact place where the bus should stop. Bus doors opening at the same location each time make it possible for passengers to be in position for immediate boarding once a bus has stopped, shortening dwell time.
 - v. *Tight terminal guidance* - uses sensors similar to those for precision docking to assist buses in maneuvering in terminals with limited space. This type of system can help minimize the amount of space needed for bus terminal operations, as well as reduce the overall amount of time a bus spends at terminals.
 - vi. *Warning systems* - are beginning to appear on the market to assist the bus driver in a number of safety areas: collision avoidance, pedestrian proximity warning, attentive driver monitoring and warning, intersection collision avoidance, and low tire friction warning. Safety improvements can help any bus system increase its reliability and efficiency by reducing the likelihood of accidents and incidents.
 - vii. *Passenger information systems* - give passengers the means to make informed decisions about their transit travel. Of the many technologies now available for passengers to access this type of information, the APTS applications most appropriate for Bus Rapid Transit are in vehicle information systems. These systems automatically announce approaching bus stops, allowing disembarking riders to position themselves near the doors prior to arriving at their stops, and speeding up the unloading and loading operation.
 - viii. *Automated enforcement systems for exclusive bus lane* - are being enhanced by new technology, including automatic video cameras and infrared sensors. These state-of-the-art systems are just now appearing on the commercial market.

6. Effect of bus rapid transit

Successful Bus Rapid Transit systems can be expected to produce improvements in bus service, operations, and ridership, and to affect traffic congestion and air quality:

- i. *Bus speeds and schedule adherence* - Perhaps the most fundamental effect of a Bus Rapid Transit system, travel times would likely improve due to the lack of impediments to bus movement along exclusive bus lanes. Bus speeds would be expected to improve not only in absolute terms, but also relative to the automobile traffic that parallels the exclusive lanes.
- ii. *Ridership* - Ridership would be expected to increase due to improved bus speeds and schedule adherence. Customers who use buses infrequently might ride more often, and some automobile users might convert to transit. A visible improvement in bus speeds might be noticeable to drivers of other vehicles, presenting a positive image of transit as an alternative to driving.
- iii. *Other traffic* - If the creation of exclusive bus lanes reduces the number of lanes available for other traffic, then in the short term the possibility of increased congestion on the roadways is raised. Traffic flow on cross streets and turning traffic may be disrupted as buses use their signal priority to travel uninterrupted through intersections. Further, mobility on alternate routes may deteriorate, as drivers seek ways to avoid roads with exclusive bus lanes. One of the challenges of implementing an exclusive bus lane would be to minimize this disruption.
- iv. *Air quality* - Long term, as ridership increases and the overall level of general purpose traffic decreases, urban areas may experience improved air quality due to reduced emissions from automobiles

7. Conclusion

The example of Curitiba - Brazil, the experience in the Bogota - Colombia, South Africa and the application of Bus Rapid Transit system in Dar es Salaam Tanzania illustrate the potential of improved bus services to address mobility needs in metropolitan areas. Buses provide flexible and cost effective public transportation. Metropolitan areas throughout the developing cities can build on the experience of Curitiba, Bogota and other developing cities to develop Bus Rapid Transit systems that provide fast, reliable, and convenient service in cities and suburbs. Upgrading the performance of bus services to meet the objectives of Bus Rapid Transit will require policies that give priority to bus operations and provide for investment in crucial system components: infrastructure that separates bus operations from general purpose traffic; facilities that provide for increased comfort and system visibility; and technology that provides for faster and more reliable operations. New guidance, information, and fare technologies offer an expanded range of possibilities for operating bus systems that have the potential to produce marked improvements in performance, surpassing previous standards and changing public perceptions of bus service. High quality bus operations have the potential to create new, improved land use options that provide for compact, pedestrian friendly and environmentally sensitive development patterns that preserve neighborhoods and open space. Bus Rapid Transit thus will have maximum benefit when developed in close coordination with land use policies and community development plans. Implementation of Bus Rapid Transit poses a number of challenges, ranging from the

need for adequate cross sections on city streets to provide separate rights of way for buses, to maintaining the quality of general purpose traffic flow and minimizing local noise and air quality impacts. These challenges require detailed analysis in the context of specific local applications to identify appropriate solutions and to determine where Bus Rapid Transit can have the greatest benefit. Bus Rapid Transit is a concept that merits widespread evaluation and consideration as an adaptable, effective public transportation alternative to automobiles that has the potential to meet a broad range of mobility needs and support an improved quality of life.

8. Acknowledgment

The author would like to express appreciation to Prof. Yan Chen for guidance and Dr. Qu Lili for providing useful contact. This work was supported by specialized research fund for the doctoral programme of Higher Education (No 200801510001) and National Natural Science foundation of China (No. 70940008).

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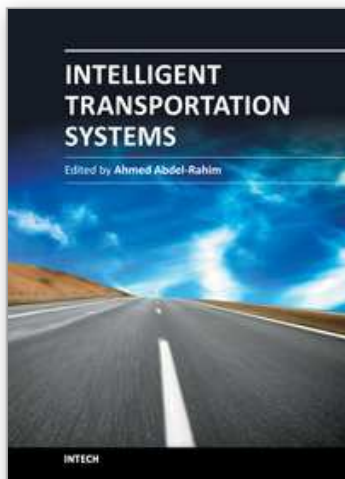
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Intelligent Transportation Systems

Edited by Dr. Ahmed Abdel-Rahim

ISBN 978-953-51-0347-9

Hard cover, 206 pages

Publisher InTech

Published online 16, March, 2012

Published in print edition March, 2012

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Philemon Kazimil Mzee and Emmanuel Demzee (2012). ITS Applications in Developing Countries: A Case Study of Bus Rapid Transit and Mobility Management Strategies in Dar es Salaam - Tanzania, Intelligent Transportation Systems, Dr. Ahmed Abdel-Rahim (Ed.), ISBN: 978-953-51-0347-9, InTech, Available from: <http://www.intechopen.com/books/intelligent-transportation-systems/its-applications-in-developing-countries-a-case-study-of-bus-rapid-transit-and-mobility-management-s>

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