IST-Africa 2020 Conference Proceedings
Miriam Cunningham and Paul Cunningham (Eds)
IST-Africa Institute and IIMC, 2020
ISBN: 978-1-905824-65-6

Transforming Paratransit in Africa's congested Cities: An ICT- enabled Integrated Demand Responsive Transport (iDRT) approach

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Abstract: Developing cities in Africa and the Global South are grappling with the problem of inadequate public transport provision. The informal privately-run paratransit system consisting of mini- and micro-buses, shared taxis (jitneys), motorcycle and bicycle taxis has seen substantial growth since the early nineties. This loosely-regulated transport system is associated with many challenges that include congestion, high crash rates, high levels of noise and air pollution. In this paper we describe the origin and current status of this structurally unique paratransit system. We then reviewed the transport master plans of four East African cities (Dar es Salaam, Kampala, Kigali, and Nairobi) and identify remaining planning gaps. We found that all the four cities reviewed lacked satisfactory plans for multi-modal public transport integration, demand responsiveness, and ICT integration which are essential to every modern and efficient public transport system. We then proposed a conceptual organised public transport system (ICT-enabled iDRT). We described how it could be adapted for a highly congested city like Kampala in order transform its existing chaotic paratransit system into an efficient public transport system that could make commuters happier and safer, reduce costs and considerably reduce pollution.

Keywords: Paratransit, demand responsive transport, minibus taxi, matatu, Informal public transport, public transport in East Africa.

1. Introduction

Cities in Africa and the Global South in general are growing rapidly - in the range of four to six per cent annually [1]. By 2030, fifty per cent of Africa's population will live in cities, and the percentage will rise to 80 per cent in 2050 due to rural-urban migration in search for social, economic and education opportunities [2]. Despite the economic and commercial importance of cities, authorities have difficulty in meeting the basic needs of the urban poor such as water, electricity and transportation [3]. The absence (or lack of enforcement) of policies on land use and economic development has led to urban sprawl, (i.e. low density, uncontrolled growth on the extremities of cities). Owing to urban sprawl, distances between settlements increased, thereby raising the cost of providing all essential services including public transport. Public transport in different cities of Africa is described by different scholars as chaotic, inefficient and dangerous.

1.1 The origin of paratransit and their challenges

The mess in Africa's public transport system started as a result of the collapse of state-owned enterprises, and the World Bank structural adjustment policies (SAPs) in the 1990s that severely limited public funds for public transport subsidies [3]. African city authorities could not provide the necessary subsidies to offset operators' deficits, replenish buses, or build critical infrastructure for public transport. Consequently, there was deterioration in service frequency, capacity, coverage, and quality, leading to a public transport crisis [4]. The public transport crisis led to the emergence of informal privately operated public transport (referred to as paratransit in some literature) as a response to growing demand and commercial opportunity. The paratransit consists of mini- and micro-buses (matatus), shared taxis (jitneys), motorcycle taxis and bicycle taxis [4], [5]. Privately-owned, the taxis have evolved from being a mere mode of transport to a way of life, spreading from urban hubs to all corners of Africa and the Global South.

Paratransit in many developing cities of the Global South is firmly entrenched, primarily due to poor planning by the authorities, which has led to urban sprawl, random distribution of public amenities (such as schools, hospitals, and shopping centres), and poor road infrastructure. Furthermore, paratransit thrives on the irregular daily mobility characteristics of people. The majority of the population in developing cities are not formally employed and as a result tend to have variable and highly irregular transport schedules and destinations. Thus, in-spite of being the only main transport service commuters have access to, it is considered flexible and affordable in addition to its near ubiquitous coverage to the remote unreachable parts of the cities.

Despite the popularity of paratransit among the urban commuters, it adversely impacts its users' health, the environmental and the economy. Paratransit in Africa substantially contributes to; (i) environmental pollution as a result of dilapidated and old vehicles often older than 20 years, slow speeds and long engine running hours), (ii) accidents especially by motorcycle taxis; (iii) traffic congestion mainly by mini and micro-bus taxis; (iv) reduced access to public transport as a result of poor synchronisation of schedules, inadequate service and route coverage, unpredictable fares, long waiting times and long walking distances to the transport route; (v) stress; and (vi) huge economic losses to the population due to inefficiencies and resulting waiting times. In Kampala, for example, we estimated (in a separate research) that a commuter loses 25.4 minutes for every hour travelled using paratransit, and a total of 1.457 million man-hours are lost by commuters every day in the Greater Kampala Metropolitan Area (GKMA). The situation is not any better in other developing cities of the Global South [5], [6].

1.2 Opportunities presented by Africa's paratransit

Within this highly unregulated, chaotic and inefficient paratransit system are several opportunities for the fundamental transformation of public transportation in Africa and the Global South without incurring exorbitant costs associated with a total overhaul to the typically used Bus Rapid Transit (BRT). By leveraging the dynamism, demand responsiveness, and self-organisation properties exhibited by paratransit systems, a hybrid ICT-enabled, seamlessly integrated multi-modal transport system could efficiently and economically solve the mobility needs of commuters in developing cities of Africa and the Global South.

The last decade has experienced disruption of the traditional transport services, especially due to the introduction of demand responsive transport (DRT). Ride-hailing services such as Uber, Lyft, Slide and Didi Chuxing have revolutionised transportation and are competing with private transport in the Global West [7]. However, this revolution in DRT has not delivered maximum value for the masses. Most ICT-enabled DRTs lack considerations for the wider public and mass transit. As such, the urban poor in the Global South have been excluded from participating in the digitally enabled DRT revolution. This exclusion has mainly been facilitated by low literacy levels, lack of access to smartphones, and internet connectivity due to poverty among the urban population.

1.3 Aims of this study

There is scholarly evidence of three main attributes that spur the quality and efficiency of a public transport system. They include integration, demand responsiveness, and application of ICT at strategic, tactical and operational levels [8], [9]. Furthermore, there is also some evidence of paratransit systems exhibiting a certain degree of demand responsiveness [10], [11], [5]. We hypothesize that enhancing the demand responsiveness using ICT and further integrating it with an adapted DRT like system can substantially improve paratransit efficiency.

The objective of this paper is twofold:

1. To perform a comparative assessment of the current and planned states of transport systems in four East African cities of Dar Es Salaam, Kampala, Kigali and Nairobi. The assessment is based on three metrics (i.e. integration, demand responsiveness and ICT application) that spur public transport quality and efficiency.
2. To present a novel conceptual ICT-enabled "integrated Demand Responsive Transport" (iDRT) system. We propose the aforementioned iDRT for Kampala City as a singular use case of a city that starts from a low baseline in our comparative assessment. This hybrid multi-modal ICT-enabled iDRT puts into consideration the digital needs of the urban poor and facilitates their inclusion in the DRT revolution. We describe how it can be applied to transform an existing congested and chaotic paratransit system to an efficient system that could leave commuters happier, safer, reduce costs and considerably reduce pollution.

2. Methodology

We carried out a comparative study of the current status with the expected future status of public transportation in four prominent developing cities in East Africa, namely Dar Es Salaam in Tanzania, Kampala in Uganda, Kigali in Rwanda, and Nairobi in Kenya. These cities have struggled with chaotic public transport systems due to the presence of unregulated privately-run paratransit services. Their public transport is dominated by the ubiquitous fourteen-seater minibus taxis and the single-passenger motorcycle taxis complemented by the larger low-frequency buses. We examined transport master plans, current status reports from various transport projects, as well as published literature on public transport in the four cities to ascertain and quantify the current and expected future statuses. From the examined documents, we assessed each city's transport system according to three key indicators, namely, the level of integration, demand responsiveness, and ICT application as described in Table 1. For each indicator, a set of metrics were identified and qualitatively scored in the range of zero to ten, where ten is the best-case score for a given city-specific metric and zero is the worst-case score as shown in Table 2.

Table 1: Description of indictors and corresponding metrics used for the comparative study.

Metrics	Description
a) Integration	*The seamless interconnection of different components of the public transport system from the first to the last mile of commute independently of transport modes, tariffs, fares, schedules, ticket system, i.e. Network and tariff integration.*
1. network	The extent of multi-modal public transport network integration, including harmonization of routes, schedules and connections.
2. tariff	The extent to which public transport tariffs and fares are integrated across several public transport operators, including one ticket for all modes of transport.
3. Transit oriented development	The extent to which transit-oriented development (TOD) is implemented, i.e. planning of physical land developments the fit into the public transportation plan.

b) Demand responsiveness		*The extent to which strategic, tactical and operational decisions are made in public transportation based on particular transport demand rather than based on fixed pre-planned and anticipated demand, e.g. flexibility in scheduling, booking, and routing vehicles based on demand.*
4.	Pre-booking	Availability of trip booking facilities for passengers prior to the time of travel.
5.	Flexible routes	Ability of vehicles to change routes according to demand.
6.	Flexible stops	Flexibility in the pickup and drop off stops along the routes.
7.	operators	Availability of multiple operators with the ability to respond to demand.
8	Flexible mvs	Flexibility in the type and size of vehicles used for a given trip depending on demand.
c) Application of ICT		*The use of ICT in various aspects of transportation. For example, planning, booking, routing, scheduling, ticketing and fare collection.*
9.	iBooking	ICT application in booking
10.	iRouting	ICT application in routing vehicles to optimise supply and meet the available demand.
11.	iDcheduling	ICT application in the scheduling of motor vehicles.
12.	eTicketing	ICT application in ticketing.
13	eFare collection	ICT application in travel fare collection e.g. cards, mobile money, ewallet.

Table 2: Our qualitative assessment of the transport systems in the four cities, done according to the indicators: extent of integration, demand responsiveness, and ICT application in the four developing cities in East Africa. We assessed the current status and the future plans of the public transport sector of each metric.

	Integration			Demand response					ICT application					
City	network	tariff	Transit oriented development	Pre-booking	Flexible routes	Flexible stops	Multiple operators	Flexible vehicles	iBooking	iRouting	iScheduling	eTicketing	eFare collection	***Average***
Dar Es Salaam	6	3	6	1	2	4	5	3	1	3	5	5	6	***3.8***
Kampala	1	1	2	1	2	2	3	1	1	1	1	1	1	***1.4***
Kigali	5	6	6	4	3	3	6	3	7	4	6	8	6	***5.2***
Nairobi	4	3	3	3	3	3	3	3	1	1	1	1	1	***2.3***
Average	***4***	***3.3***	***4.3***	***2.3***	***2.5***	***3***	***4.3***	***2.5***	***2.5***	***2.3***	***3.3***	***3.8***	***3.5***	
Average	**3.8**			**2.9**					**3.1**					

4. Results

All the current status reports and master plans reviewed highlighted the problem of urban sprawl and dynamic emergence of informal settlements for the urban poor that make urban public transport provision expensive and sometimes impossible. The aforementioned urban sprawl problem is a clear indicator of non-transit-oriented development experienced in the developing cities of East Africa as shown in Figure 1a. However, all documents mention various plans for transit-oriented development with varying degrees of emphasis as shown in Figure 1b. Table 3 (*tod* column) shows that the overall transit-oriented development score is 4.3 compared to other metrics. From the master plans, much focus is currently put on infrastructure development for roads improvement and Bus Rapid Transit (BRT) development on selected routes in the cities. Whereas early phases of BRT projects in Kigali and Dar Es Salaam are showing signs of success, similar projects in Nairobi and Kampala have stalled for over a decade. The general integration score of 3.8 (38%) for the four cities is still low and attributed to lack of seamless inter-modality (especially with paratransit), tariff and schedules integration and transit-oriented development necessary to deliver an efficient public transport system.

The demand responsiveness of transport systems in all the four cities is very low, with a score of 2.9 (29%). As shown in Table 2 and Table 3, only the quasi-flexible paratransit is responsible for the demand responsiveness in the four cities. Lack of pre-trip booking facilities; low flexibility in routes and stops; and lack of flexible scheduling of multi-capacity vehicles, make demand responsiveness a nightmare for transport systems in the East African cities. Apart from the general quasi-demand responsive nature of paratransit, the existing and future projects are based on fixed schedules, and fixed-route planning. However, a small degree of demand responsiveness can be traced in the BRT buses of Kigali and Dar Es Salaam, where the frequency of buses is increased during peak hours based on long-term projected demand.

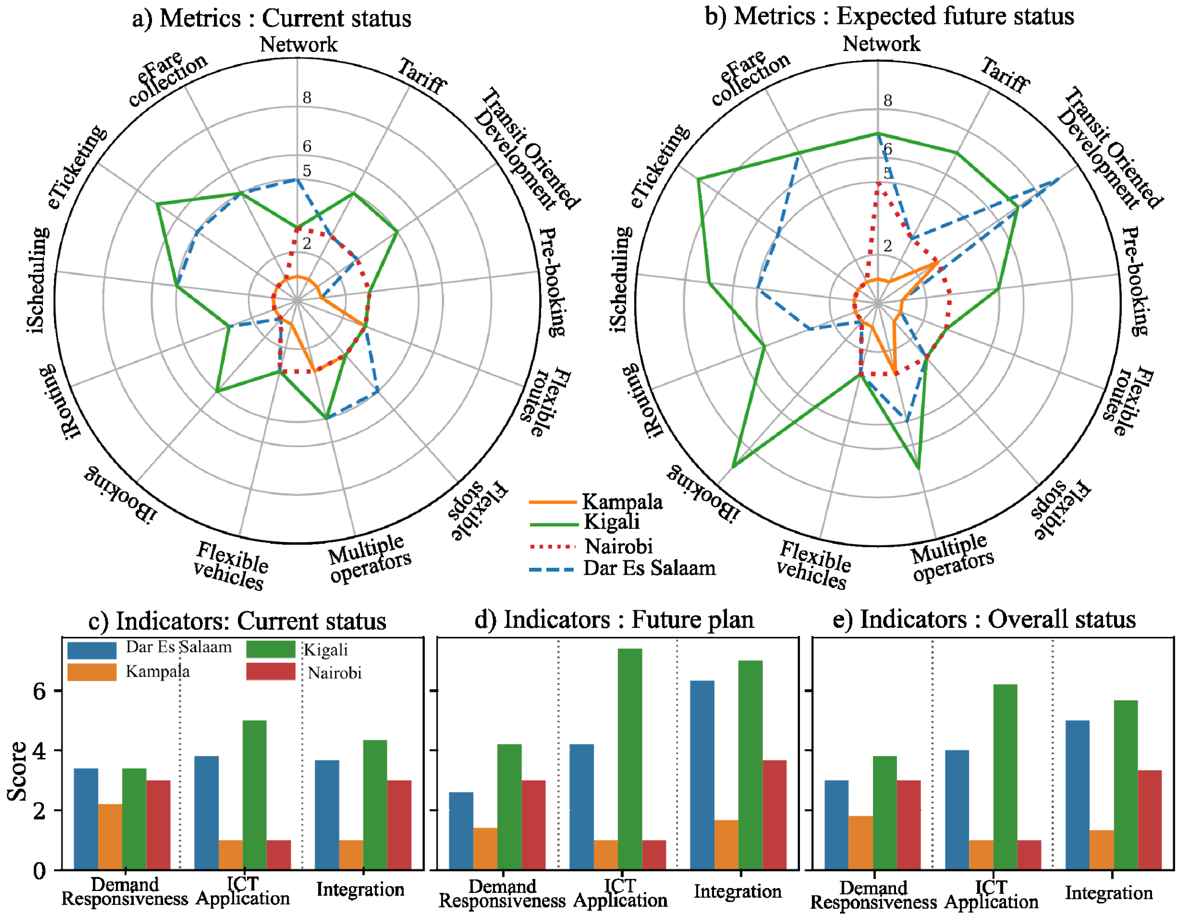

Figure 1: Comparison of metric scores of: a) the current status, b) the planned status (based on master plans). Comparison indicators of c) the current status, b) the expected future status and c) Overall average scores.

Furthermore, Kigali controls demand generated during the quarterly opening of schools by phasing the opening dates according to districts, such that more minibus taxis are rerouted to fulfil the demand in such districts. It is clear from Figures 1a and 1b, that authorities in the four cities are not doing enough, neither have they planned for demand responsiveness in public transport. Hence the need to revise transport master plans and integrate demand responsiveness in the wider ecosystem of public transportation.

Kigali and Dar es Salaam are leading the integration of ICT in public transportation, particularly in ticketing and fare collection, as shown in Table 3 and Figure 1. The cities mentioned earlier also have good strategic plans for ICT application in BRT buses. However, like their counterparts (Kampala and Nairobi), they fall short of the system-wide application of ICT in all aspects of public transportation such as booking, routing, scheduling and operations management by regulators.

Overall, according to our assessment of the three main indicators, Kigali leads with a score of 5.2 (52%) followed by Dar es Salaam, Nairobi, and Kampala with scores of 3.8

(38%), 2.3 (23%) and 1.4 (14%) respectively. Table 4 shows a summary of the analysis, whereas the bar graphs in Figure 1 show the comparison of scores of different indicators for each city. Figure 1c shows the comparison of the current status, Figure 1d shows the comparison of the planed status (according to strategic plans), and Figure 1e shows the comparison of the average overall combined status. We noted the extreme neglect of the paratransit in the overall public transport planning. Apart from Kigali's regulatory ban of matatus from the city centre, there is no comprehensive plan for paratransit to participate in the public transportation of the four cities fully.

Table 3: Summary analysis of the extent of integration, ICT application, and demand responsiveness of public transport in four cities.

City	Integration	ICT application	Demand Responsiveness	Overall score
Dar es Salaam (TANZANIA)	•BRT phased programs implemented by Dar es Salaam Rapid Transit Agency (DART) [12]. •Integrated Transit-Oriented Development along the BRT corridors to create high-density commercial and residential areas [13]. •No paratransit integration plan. *Score: 5(low)*	•Automated Fare Collection System (AFCS) in BRT buses (*planned*)[19] . •ITS upgrade for traffic management. (*planned*) [18]. *Score: 4 (low)*	•Quasi DRT for Matatus •Fixed schedule for BRT Score: 3 (low)	**3.8** *(low)*
Kampala (UGANDA)	•Planned BRT, Metro, LRT system corridors by Kampala Capital City Authority (KCCA)[14], [15]. •No paratransit integration plan. *Score:1.3 (low)*	•No ICT application Score: 1 (low)	•Quasi DRT for Matatus *Score: 1.8 (low)*	**1.4** *(low)*
Kigali (RWANDA)	•BRT System to run through the trunk routes serving all townships. (implemented) [16] •Public buses and Motor Taxis acting as feeder traffic into the primary BRT lines. (implemented) [16]. •Develop an optimized service for school-going children (planned)[16]. •Moderate paratransit integration into feeder routes. *Score: 5.7 (moderate)*	•Integrated Smart Ticketing System for Kigali Bus Service. (Tap&Go implemented) [16] *Score: 6.2 (moderate)*	•Quasi DRT for upcountry matatus •15% public (ONATRACOM) and 85% private [20]. *Score: 3.8 (low)*	**5.2** *(moderate)*
Nairobi (KENYA)	•Light Rail Transport (LRT) for three corridors (Waiyaki, Jogoo and Outer Ring Road) [17] •METRO to four corridors (NRS-Githurai, Githurai-Ruai, Juja Road, Ngong Road) [17] •BRT to Limuru, Langata and Mombasa Road corridors [17] •No paratransit integration plan. *Score: 3.3 (low)*	•epay with easy coach buses. *Score: 1 (none)*	•Quasi DRT for Matatus and buses *Score: 3 (low)*	**2.3** *(low)*

5. The proposed paratransit transformation framework (conceptual ICT-enabled iDRT)

In this section, we present a conceptual public transport system for transforming paratransit in developing cities. This system is based on three fundamental principles, i.e. seamless multi-modal integration, demand responsiveness, and use of ICT systems for all services such as scheduling, booking, ticketing and fare collection. The ICT-enabled iDRT could support the participation of the urban poor in the DRT revolution so that they can enjoy the improved mobility benefits associated with a DRT.

We used Kampala City as a case for describing the application of the conceptual ICT-enabled iDRT because of its low overall score (1.4) in all three indicators previously assessed. Kampala has a population of 1.5 million residents scattered throughout five administrative divisions: Central, Kawempe, Lubaga, Makindye and Nakawa. Commuters from the four divisions and beyond converge mainly in the Central division for work, shopping, leisure and school. It is estimated that 4.5 million trips are made by passengers daily to and from the city. Currently, the most common mode of transport is the minibus taxi accounting for 46% of the daily trips while motorcycle taxis (Boda Bodas), private cars, buses and trucks account for 32%, 19%, 2% and 1% of the daily trips respectively. The average transit speed in Kampala is 14.4 km/h. Compared to the 25 km/h transit speed of Curitiba's transport system in Brazil, which is considered efficient, a commuter in Kampala loses 25.4 minutes for every hour travelled. From a separate study we undertook the estimated average length of a commuter trip in Kampala is 11 kilometres. Therefore 1.457 million hours are lost by public transport commuters in Kampala every day.

In the following section, we describe the conceptual ICT-enabled iDRT based on the three principle indicators, i.e. seamless multi-modal integration, demand responsiveness and ICT integration. Using Kampala as the application case, we discuss how it can be adapted to transform the public transport system of a congested city with fewer disruptions and low capital investment.

5.1 Seamless multi-modal integration

At the core of the iDRT is the need to integrate the three main modes of public transport in Kampala (minibus taxis, boda-bodas and buses) so that they can seamlessly work together and provide an efficient service to the commuters. A fundamental reorganization of vehicles is required. The current ageing fleet of the fourteen-seater minibus taxis and motorcycle taxis could be reduced to 30%, 30%, 40% for minibus taxis, motorcycle taxis, and high capacity buses respectively. The buses would be scheduled to operate on trunk routes at high frequency during peak hours and moderate frequency during other times. Figure 2*a* shows the major trunk roads 1 to 7 where the buses could be deployed. The minibus taxis would be deployed on the sub arterial roads – to carry passengers-on-demand to selected areas and terminating on major trunk roads where the high capacity buses operate as illustrated in Figure 2*d*. The motorcycle taxis (boda-bodas) would operate-on-demand on local roads – to provide direct access to homes and other places, as illustrated in Figure 2*d*.

To facilitate the seamless multi-modal integration, semi-permanent easy to move platforms similar to the one illustrated in Figure 2*b* would be installed at selected bus stops/interchange points along the trunk routes used by the buses. These platforms would be the points of integration between minibus taxi/ motorcycle taxi mode of transport to the buses or Bus Rapid Transit (BRT).

5.2 Demand Responsiveness

A Demand Responsive Transit service provides transport on-demand from passengers using fleets of vehicles scheduled to pick up and drop off passengers per their needs [21]. Owing to the sparse land use pattern in Kampala as a result of urban sprawl, there are considerably longer distances from homes to the trunk, arterial and sub arterial roads. In some cases, 'access roads' are not passable by cars leaving motorcycles as the only option. The DRT on-demand service consisting of minibus taxis and motorcycle taxis operating on sub arterial and access roads could work in such a way that motorcycle taxis feed into the minibus taxis which in turn feed into the high-frequency buses on the trunk routes as illustrated in Figure 2*d*.

5.3 ICT as an enabler for transport services integration

In the last decade, Information and Communication Technologies (ICTs) have changed how transport systems are used [22]. They have provided tools for planning, booking, routing, scheduling, ticketing, and they have revolutionised the provision of transport on demand, i.e. Demand Responsive Transport (DRT).

In the conceptual ICT-enabled iDRT, a robust central ICT system could be used to service passenger requests (trip booking, ticketing, and payment), driver requests (vehicle scheduling and routing, salary and commissions), operators need (fleet monitoring and management),

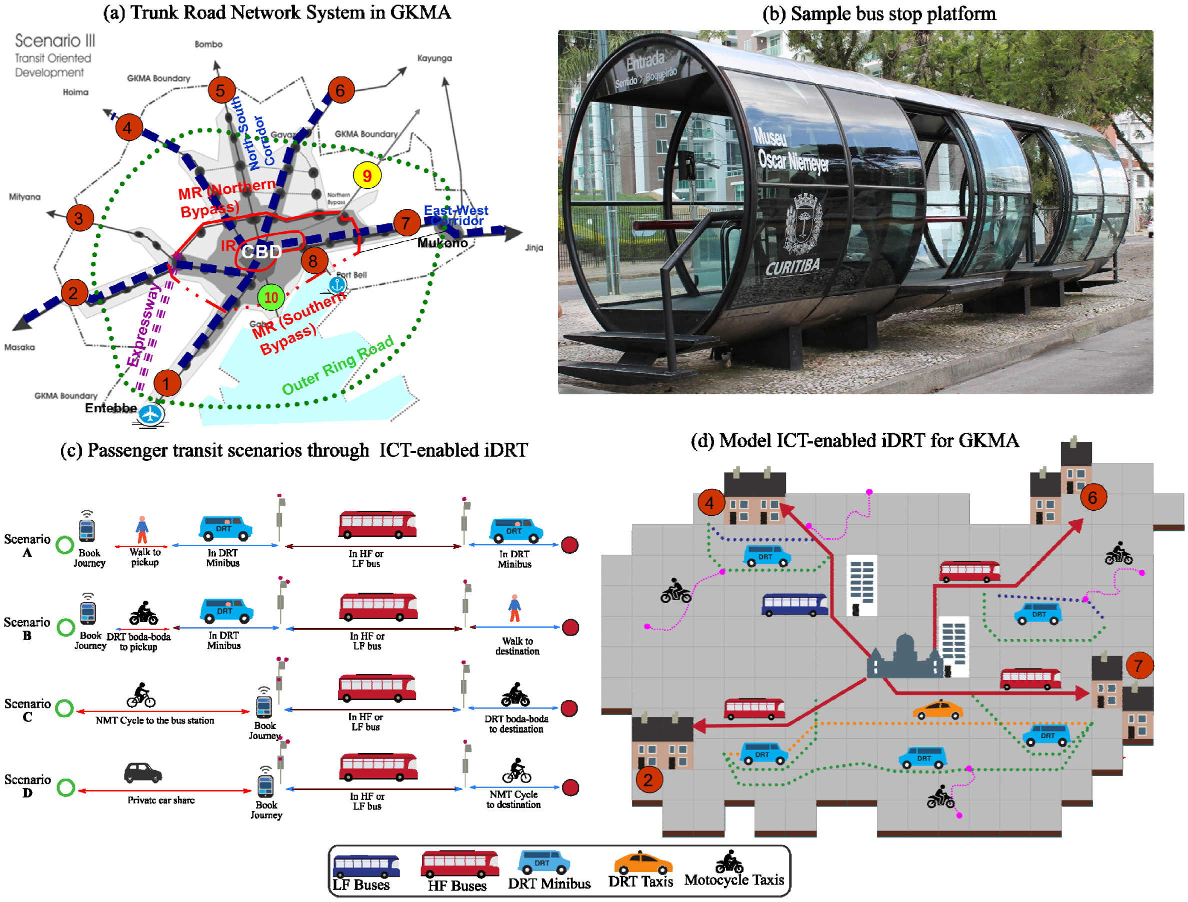

Figure 2: Figures showing (a) Trunk road network system of in the Greater Kampala Metropolitan Area (GKMA) – adapted from [9], (b) Sample bus stop platform – adapted from the Curitiba DRT bus stop, (c) Scenarios of passenger travelling through the ICT-enabled iDRT , (d) The model conceptual ICT-enabled iDRT for GKMA – adapted from [7] and modified

and the needs of the city authorities (monitoring the performance of operators in different zones, general demand and supply). Cognisant of the fact that the urban poor may not have access to smartphones and the Internet, the platforms illustrated in Figure 2*b* could be digitally sufficient to provide terminals for trip booking and several payment methods.

One of the most crucial roles of ICT in this system is to optimise resources by efficiently allocating trips to vehicles such that a few vehicles as possible are used to service demand while maintaining the quality of services.

5.4 Passenger use scenarios

Figure 2c shows four scenarios of a passenger travelling through the conceptual ICT-enabled iDRT. Scenarios A and B illustrate a passenger using the iDRT for all parts of their journey right from origin to destination. Scenarios C and D illustrate some benefits of an organised iDRT with easy integration of Non-Motorised transport (NMT) and encouraging private car users to switch to public transport for some parts of the journey, hence reducing congestion. The ICT-enabled iDRT can seamlessly serve the passenger trips from the first mile of commute to the last mile of commute.

6. Discussion

To improve the efficiency of paratransit in Africa and the Global South in general, we propose a new paratransit transformation framework (ICT-enabled iDRT). To implement the conceptual iDRT requires three radical shifts: (1) from perceiving paratransit as a disrupter of public transport in developing cities to perceiving it as a complimentary service with flexibility, adaptability and near-ubiquitous coverage as its main assets to serve the first and last miles of commute. (2) De-construct the 'colonial mentality' of BRT and redesign scale-down versions of BRT corridors that fit into the existing road infrastructure encouraging shared lanes in addition to low-cost semi-permanent bus stop platforms to act as exchange and inter-modal integration centres. (3) Massive investment in ICT systems in all aspects of the transportation services, such as servicing passenger requests (trip booking, ticketing and payment), driver requests (vehicle scheduling and routing, salary and commissions), needs of the operator (fleet monitoring and management), and the needs of the city authorities (monitoring the performance of operators in different zones, general demand and supply).

7. Conclusion

In this paper, we have discussed the structural origin of the mess in the public transport of developing Cities in Africa and the Global South. We have reviewed the available transport status reports and master plans of four East African Cities (Dar es Salaam, Kampala, Kigali, and Nairobi) based on three indicators, i.e. multi-model integration, demand responsiveness and ICT application in public transport. In general, all of the cities have low levels of inter-model integration, shallow ICT integration and deficient levels of demand responsiveness. We then presented a conceptual ICT-enabled integrated Demand Responsive Transport (iDRT) system and described how it could be adapted to transform a highly congested and chaotic paratransit-dominated public transport system in Kampala Uganda. We believe that if adopted, the ICT-enabled iDRT can fundamentally transform the transport system of a developing city to an efficient system that could make commuters happier, safer, reduce costs of travel and considerably reduce pollution. We welcome any person, entity, or organization, to collaborate with us to pilot our proposed iDRT in one Zone in Kampala City as a testbed towards efficient, clean and cost-effective mobility for all in chaotic developing cities of Africa.

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