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POSITION PAPER: THE STATE OF KNOWLEDGE AND RESEARCH PUBLIC TRANSPORT SYSTEM DESIGN AND MODAL INTEGRATION IN SUB-SAHARAN AFRICAN CITIES



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EXECUTIVE SUMMARY

Purpose

The overall aim of this position paper is to provide Volvo Research and Educational Foundations (VREF) and other researchers with state-of-knowledge overviews of issues related to mobility and access in African cities¹. One of the core themes identified for future research is System Design and Modal Integration.

Objectives of this position paper

- To provide an overview of the state of current knowledge regarding the design and integration of fixedroute public transport systems in Sub-Saharan African (SSA) cities;
- To highlight gaps in knowledge that might be addressed by future research and education; and
- To summarise the state of research and research capacity around this theme.

Key findings regarding the state of knowledge

Mobility in Sub-Saharan African cities is generally very problematic due to a combination of underdeveloped road infrastructure, inefficient traffic management, land use that tends to be unsupportive of efficient public transport, and insufficient government ability to upgrade and improve public transport (either through investment or regulatory actions). There is also little appetite amongst governments to manage or reduce reliance on the private car, leading to serious congestion in cities.

 There is nevertheless growing momentum towards investing in new fixed-route public transport systems in SSA cities, supported by a mixture of local and international consultants and financing instruments. Since 2000, new bus and rail systems have become operational in at least 16 cities, with several more in various stages of planning. These efforts represent a significant shift towards improving mobility conditions in SSA cities.

- In SSA cities that have implemented new fixed-route public transport systems, there is evidence of significant benefits to passengers in terms of reduced travel times, enhanced access, and more reliable services. However, the evidence regarding travel costs is contradictory, suggesting that many low-income passengers cannot afford to use these systems. The evidence regarding the unequal distribution of benefits across groups raises key questions around how, and for whom, transport interventions are planned in Sub-Saharan African cities.
- Bus Rapid Transit (BRT) seems to be the preferred mechanism through which many governments and development agencies in Africa want to improve passenger transport. This is despite some interest in rail investments, and some efforts at bus service modernisation via contracting and franchising schemes (with mixed results). Cities, on the other hand, take a more pragmatic approach based on investment priorities and affordability.
- BRT implementation is problematic, however, as evidenced by delays in the expansion of starter BRT routes in some cities (Lagos); the failure of pilot BRT schemes in others (Accra, Nelson Mandela Bay); long implementation periods (e.g. Dar es Salaam, Rustenburg, Nairobi); and the higher cost and lower than expected financial performance of some systems (e.g. Cape Town, Johannesburg, Dar es Salaam). BRT projects are probably more complex than previously thought in terms of the demands put on institutions, finance, and the need to involve existing industries.
- BRT implementation has followed an incremental approach, starting with one high-volume

¹ See http://www.vref.se/macprogramme

corridor along a high-density radial arterial, and followed (potentially) by a gradual roll-out of further corridors. However, undue focus on a single corridor is harmful to metropolitan mobility as it deprives the rest of the network of needed investment.

- There is a growing criticism of BRT as an imported solution that is insufficiently sensitive to African realities, and too easily captured by special interest groups; this reflects a growing awareness of the political nature of public transport interventions.
- A related issue is one of appropriate standards for BRT. Two design approaches are discernible in Africa: the so-called 'BRT Classic' with median bus-lanes, fully enclosed stations, and advanced ticketing; and 'BRT Lite', which depends on lighter infrastructure such as non-continuous buslanes segregated within existing rights of way, open stations, and standard buses. The pros and cons of each approach under different local circumstances are being debated.
- Key to the issue of standards is the question of affordability and financial sustainability, as most SSA cities are financially strained, and most governments seem unable or unwilling to provide ongoing subsidies for public transport. The pressure for systems to be self-sustaining affects many aspects of the design, system extent, vehicle standards, and fare policy.
- Another key issue for fixed-route public transport is its relationship to informal (paratransit) operators. Questions include whether it is inevitable and desirable to displace informal operators from fixed-route corridors, or if a more complementary role can be found in a hybrid system². Dealing with incumbent operators has proven to be a significant point of contention (and source of cost and delay) in most BRT implementations, suggesting that this issue needs better approaches.
- Financing of rolling-stock in new public transport systems is another key issue. It has too often been presumed that the private sector will respond appropriately to the business opportunity presented, but this is only possible if fares are increased or explicit government subsidies committed.

- Integration between fixed-route systems (either rail or BRT) and other existing services (e.g. buses, informal modes) has generally been done poorly, although it seems to be improving. This is true both in terms of interchange facilities and first/last mile issues. Integration through ticketing and integrated fare systems has been wholly neglected. Poor road environments affect the safety and accessibility of pedestrians, limiting the beneficial impact of the public transport investment.
- The adoption of technology in the course of upgrading public transport has also often been problematic. In some BRT and rail systems, electronic ticketing (smart cards) was either not implemented (despite the intention of doing so), or poorly rolled out due to faulty procurement or poor management. Smart cards (particularly EMV) act as barriers to usage by the poor, and prevent ticket integration. Although some good practices exist, bus tracking and passenger data are generally not used effectively for operational management and planning, suggesting that a mismatch exists between the sophistication of technology provided, and the authority/operator's ability to make effective use of it.
- Governance is commonly accepted as another key constraint to the effective deployment of better public transport (and better cities in general). In some cities progress is being made towards the establishment of metropolitan-wide transport authorities that will assume functions of coordinated transport implementation. Yet institutional fragmentation, lack of policy that is supportive of public transport, and lack of appropriate regulatory frameworks, bedevil effective intervention. In many countries public transport is a devolved responsibility, but central governments are loath to release necessary funding, and development agencies find it difficult to relate to the sub-national level.
- These knowledge gaps and controversies should be seen in context. It is important for the future of mobility in Africa that they do not detract from the higher priority of helping policy makers, funders, and implementers to move from reflexive car-based projects towards better public and non-motorised transport systems that benefit cities more broadly.

² The two issues of business models of informal operators, and institutions/governance/politics, are examined in more depth by

two other MAC position papers. We merely note the interface between these issues and the deployment of fixed-route public transport systems.

State of research capacity

A review of the main research groupings within Sub-Saharan Africa doing work on public transport systems highlighted research capacity in the following countries: South Africa, Ghana, Nigeria, Ethiopia, Kenya, Tanzania, and Rwanda. The disciplines involved display an encouraging diversity, including not only transportation engineering but also planning, development studies, and economics.

Key research gaps

Key knowledge gaps were identified around the following issues:

- Planning and political processes
- Systematic documentation of project information
- Standardisation of investment appraisal modalities
- Appropriate standards and their consequent trade-offs
- Affordability, financing, and subsidisation of public transport

- Fare systems
- Pathways to multimodal integration
- Effective harnessing of technology
- Relationships between transit and land-use change
- Impacts on specific stakeholders
- Development of professional capacity in public transport.



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INTRODUCTION

Background and objectives

The overall aim of this position paper is to provide Volvo Research and Educational Foundations (VREF) and other researchers with state-of-knowledge overviews of issues related to mobility and access in African cities³. One of the core themes identified for future research is System Design and Modal Integration.

The objectives of this position paper are threefold:

- To provide an overview of the state of current knowledge regarding the design and integration of formal public transport systems in African cities;
- To highlight gaps in knowledge that might be addressed by future research and education; and
- To summarise the state of research and research capacity around this theme.

Scope

Although lagging other continents, Africa has seen a slow growth in investment in its urban transport sector over the last few decades. A number of new bus and rail systems are in place, while new service models involving shared use of motorcycles, vans and private vehicles are emerging. Yet the majority of motorised trips are served by so-called *popular* modes, characterised by fragmented ownership, the use of small vehicles, and operations largely outside of government regulation. These services take many forms, and have also been called informal, artisanal, or paratransit modes⁴ (Behrens et al., 2015a; Schalekamp and Saddier, 2020). Although some efforts are afoot to regulate and/or modernise informal services, both from within the industry and by authorities, informal modes differ fundamentally from formal ones in terms of customer service quality, operating practices, organisational environments, and citywide impacts.

We focus this paper on *formal* public transport, and explicitly exclude popular or informal modes from

its ambit. The focus is on systems that are typically fixed-route, scheduled⁶ services (sometimes called institutional transport), and operated under some measure of government supervision, if not control. Typical modes under this definition include commuter rail, light rail, BRT, and fixed-route bus services.

This division of material is partly for pragmatic reasons, to minimise overlap with the other position papers prepared as part of the MAC exercise, which deal with topics of user needs and practices, governance and finance, emerging business models, and safety, health and environment, as they relate to access and mobility within Africa. However, it is important to acknowledge the many key linkages among these topics: the decisions made during the design and deployment of a fixed-route system will, for instance, have critical implications for which passenger needs are met and who is excluded, and for air pollution and traffic safety within the city. Moreover, public transport interventions - and BRT in particular - are often seen not just as transport projects but as instruments of public transport reform, and expected to drive significant institutional changes (Flores, 2016; Klopp et al., 2019), with its accompanying implications on governance and finance. The deployment and performance of formal systems is often closely tied to how informal incumbents are dealt with (Poku-Boansi and Marsden, 2018), and to wider governance and political economy realities. This paper tries to highlight these linkages, but only to the extent that they directly influence the formal systems under review.

Geographically, we focus only on Sub-Saharan Africa (SSA), reflecting the geographical focus of the MAC initiative. We thus exclude the cities of North Africa (including Marrakech, Cairo, Tunis, and Algiers) where significant recent investments have been made in light and heavy rail systems. We also include only urban transport, and not rural and intercity transport such as Kenya's new Mombasa-Nairobi rail line.

Most of the new investments in formal transit in SSA have occurred since about 2000, and especially since 2007.

³ See http://www.vref.se/macprogramme

⁴ While acknowledging the difficulty of standardising terminology given the variation within this mode, we use the term *informal transport* throughout this report, as a matter of convenience.

⁵ Although some services that we call formal do not follow fixed schedules but are more flexible. For instance, the Kigali Bus Service operated 5 routes in Kigali City along fixed routes but without timetables (Van Zyl et al., 2014).

The literature search thus focused on sources from the last 20 years, and with the time-lag in reporting, inevitably not all information is up to date.

In keeping with the objectives of this position paper, the intention of the review is not to assemble a comprehensive encyclopedia of knowledge around the topic of public transport systems in Sub-Saharan Africa, but rather to surface and synthesise major themes, findings, and questions that emerge from the collective evidence.

Method

Knowledge related to mobility interventions is dispersed across academic institutions (covering diverse disciplines such as engineering, economics, political science, and urban planning) and the practice community; in the latter, the knowledge is tacit and embedded within the experiences and views of people who have been or are involved in the planning and delivery of transport on the ground. We accordingly attempted to draw on a wide range of secondary sources:

- Published academic literature, including journal articles, research theses, and conference proceedings;
- Grey literature, including policy reports, unpublished reports, and newspaper articles;
- An extensive review of experiences with BRT planning and implementation in selected SSA cities, prepared by one of the co-authors who has been active in 18 countries in Africa over the past 45 years;
- Webpages reflecting existing research capacity within SSA universities;
- Interviews conducted with experts from the public and private sector with knowledge of public transport development within SSA. A list of interviewees is included in Appendix A.

Identification of relevant literature started with the review of knowledge and research environments prepared by the University of Cape Town for VREF in 2015 (Behrens et al., 2015b). The reference list was extensively expanded and updated through a literature search undertaken in May to September 2019.

The review was guided by the following research questions:

- What are the **policies**, **planning processes**, **and objectives** for the delivery of fixed-route public transport systems?
- How is the relationship between new public transport systems and other components of the mobility system, including informal and non-motorised modes, conceptualised? How does this affect the level of integration achieved across systems?
- What technical features relating to **infrastructure design, system insertion, vehicle specification, and fare systems** are evident; to what extent are these linked to local conditions and constraints; and what evidence exists about the outcomes or implications of these features?
- What specific **knowledge gaps exist, and what research questions** could be answered in order to move towards a better understanding of the optimal role and deployment of fixed-route transit systems in SSA cities?

Outline of this paper

The next section sets the scene by providing a brief overview of the state of fixed-route public transport in SSA cities. We first outline some of the major contextual factors affecting mobility in Sub-Saharan Africa, and their implications for the effective delivery of public transport. We then briefly discuss the extent of fixedroute systems across the continent, and provide general comments.

The third section summarises the findings regarding the state of knowledge, essentially following the outline listed under the research questions above. The fourth section of this paper discusses the state of research and research capacity within SSA and abroad. The fifth and final section summarises the key research gaps and questions emerging from the foregoing reviews.

OVERVIEW OF THE STATE OF FIXED-ROUTE PUBLIC TRANSPORT IN SUB-SAHARAN AFRICAN CITIES

Public transport is not deployed on a blank slate but embedded within local systems, with their particular histories and dynamics. These dynamics, both physical and socio-political, not only drive the key problems of mobility, but also shape or constrain what can feasibly be done about them. Notwithstanding local differences in underlying conditions between places, we identify five key constraints or contextual factors fundamentally affecting public transport in Sub-Saharan African cities.

Key contextual factors

Inefficient land use

Sub-Saharan African cities by and large tend to have land-use patterns that are not optimal for efficient public transport. Public transport thrives under density. Most cities have dense but small cores, where some 6 to 8km from the CBD population density drops rapidly; beyond that lies low-density sprawl (Antos et al., 2016). Lowaverage densities are exacerbated by poor development control, resulting in unplanned suburbanisation and the spread of informal settlements on city peripheries (Lall et al., 2017; Mahendra and Seto, 2019).

In addition, many cities have a large proportion of commercial activity concentrated in or near their central areas, with inadequate secondary nodes (Cervero, 2013b; Howe and Bryceson, 2000). Cervero (2013b) reports that, in Africa (as in South America), more than one-third of formal jobs are located in historical central areas.

The effect of this spatial mismatch on transport is twofold. On the one hand, some people are forced to live within walking distance of their jobs (often under poor housing conditions), due to poor or unaffordable transport (Campbell et al., 2019; Salon and Aligula, 2012). On the other, for the majority living farther away, daily commutes over long distances are needed to get to jobs and services (Andreasen and Møller-Jensen, 2017). The average distance between informal settlements and main job centres is estimated at 9.6km in Addis Ababa and 7.2km in Nairobi (Antos et al., 2016). Some Southern African cities even have negative population gradients, with more people residing on the peripheries (due to historically segregated settlement policies) than in the centre (Harrison and Todes, 2015), leading to distances to work of 30km or more.

Long travel distances are difficult to serve efficiently with public transport: vehicles are poorly utilised as they cannot make multiple return trips during the peak period; and revenue is depressed by low seat turnover (depending on fares structures). In addition, land-use development is rarely coordinated with public transport and road supply; informal transport operators respond quickly to increases in demand density, but this often degrades service quality due to rises in congestion in the absence of coordinated efforts to enhance road infrastructure (Avner and Lall, 2016; Ka'bange and Mfinanga, 2013; Stucki, 2015).

Neglect of the transport sector

Over the last few decades SSA governments have neglected urban transport in general, and public transport in particular. A combination of economic problems and fast urbanisation overwhelmed the formal bus and rail systems that were operational during the 1970s and 1980s, while unrealistic fares controls combined with neoliberal policy stances meant that governments had little appetite for investing in or subsidising these systems, leading to their demise.

For instance, by the 1990s the two state-owned bus companies serving the Acora metropolitan region had collapsed due to rising financial losses, mismanagement, and stiff competition from the private sector (Addo, 2002). Other cities had benefitted from professionally run private-sector undertakings, but these were mostly nationalised and suffered the same fate⁶.

Very few cities have operational rail systems, and those that exist have seen a rapid decline in quality and ridership (Agunloye and Oduwaye, 2011; Apanisile and Akinlo, 2013; Godard, 2013). Commuter rail in South African cities has lost 67% of its passengers in the last decade⁷ due to poor management and corruption⁸ (George et al., 2018).

The bulk of transport investments has tended towards externally financed car-oriented projects, with a focus on infrastructure for cars rather than transit or pedestrians (Klopp, 2012; Porter, 2007). Governments tend to have "a bias towards large, physical infrastructure such as roads as opposed to the more politically complex task of managing a reorganisation of public transport and planning" (Klopp et al., 2019:19). The result is high (and rising) congestion levels, poor service quality, and high externalities (Kumar and Barrett, 2008).

Some efforts have been made at renewing urban bus services, particularly in West Africa (Ali, 2010; Baah-Mintah and Adams, 2012; Godard, 2013; Nwaogbe et al., 2013; Osiyemi, 2019). Often these efforts amount to little more than governments procuring new fleets, and handing them over to private or state operators without addressing underlying issues of competition from paratransit modes, operating efficiency, and network development⁹. Not surprisingly, these services remain difficult to keep running in the absence of state support and subsidy (Godard, 2013). Even in South Africa, where bus services *are* subsidised, their modernisation has all but drawn to a halt due to policy uncertainty and stakeholder conflict.

Dominance of the informal sector

The emergence of the informal transport sector has done much to fill the supply gap left by the demise of the formal systems. The benefits in terms of delivering mobility to otherwise stranded populations have been most obvious on the fast-growing (informal) periphery of cities, where informal operators are usually the first to introduce services that link the peripheries with the urban core.

Governments tend to have limited capacity (and willingness) to guide, plan, or regulate the provision of informal public transport. Klopp et al. (2019:3) refer to the operators and workers in this sector as "*bottom up planners*", with nearly all aspects of routes, stops, and fares being determined through internal processes. As a result, informal services are not always optimal from a passenger perspective, as route development is aimed at maximising cashflow and avoiding conflicts between associations rather than providing optimal origin-to-destination connectivity (Kaenzig et al., 2010).

The foregoing has several implications for efforts to upgrade or modernise urban transport. Firstly, upgrading efforts proceed from a low base in terms of quality and user experience. Introducing better services requires government role-players to manage complex change processes across a wide front, from building infrastructure to a complete renewal of vehicle fleets to addressing industrial relations and reregulation. In addition, the currently poor condition of public transport may create scepticism amongst non-users that efforts to upgrade and modernise public transport will be successful, thus depressing political support and options for fund-raising.

Secondly, the demise of formal systems means a loss of professional experience and institutional memory from among operators as well as regulators/planners. Significant knowledge regarding local operating conditions and passenger needs resides within the informal transport sector, but it is unclear how to exploit this for the purpose of delivering better services. Several interviewees highlighted the critical lack of skills around the basics of operating bus and rail systems as among the key constraints to upgrading public transport in SSA cities. This makes it more difficult to manage the transition to new supply models based on network planning and competitive tendering (Walters and Heyns, 2012). It also makes governments more dependent on international consult-

⁶ Some exceptions of successful public ownership supported by city governments include Anbessa in Addis Ababa and municipal bus services in South African cities.

^{7 &#}x27;War room' working to get Prasa back on track as passenger trips plunge. *Fin24, 11 September 2019*. Retrieved from https://www.fin24.com/Companies/Industrial/war-room-working-to-get-prasa-back-on-track-as-passengertrips-plunge-20190911

⁸ This is despite a R3bn reinvestment programme to upgrade stations and replace ageing rolling stock, which is slowly being rolled out (Walters, 2008).

⁹ This practice persists, and is partly to blame for the slow pace of successful bus reform in Sub-Saharan Africa.

ants who may not have a thorough understanding of local needs and realities (Wood, 2014b). Further, the lack of skills is also a strong argument for service contracting at the route (or route group) rather than network level, creating business units more amenable to management in the local context.

Thirdly, the dominance of the informal sector makes public transport markets highly contested and atomised, stretching governments' ability to plan and manage the transition process. Sub-Saharan African governments have little regulatory and enforcement capacity in public transport, which are basic requirements for lifting the quality of services (Stucki, 2015). Clearly, without systematically addressing the problems and constraints of the informal transport sector, any efforts at modernising urban transport will have marginal success at best.

A necessary first step is to recognise that the informal sector needs to be part of the solution, and not thought of as part of the problem. This approach was taken in both Lagos and Accra, although the patient build-up of trust in the latter was destroyed by a public procurement in conflict with the agreed policy framework¹⁰.

Poverty and affordability constraints

Of the world's 28 poorest countries, 27 are in Sub-Saharan Africa, and they all have poverty rates above 30% (World Bank, 2018). Combined with the inefficiency of public transport, this means that travellers tend to spend high proportions of their personal incomes on daily travel (Diaz Olvera et al., 2008). Travellers adjust to this reality in numerous ways, including by curtailing trips, switching destinations, and walking for all but the most important trips. In Dar es Salaam in 2009 up to a third of public transport users were often forced to walk because they could not afford the *dala dala* fare (Ahferom, 2009).

Poor public transport service levels make car use very attractive as soon as incomes rise, thus the majority of public transport users are poor. In Cape Town, 95% of public transport users are in the low- or low-medium income categories (City of Cape Town, 2018). This leaves operators and cities with a funding dilemma, where the costs of upgrading public transport cannot be borne by passengers alone. One response is to provide a two-class public transport offer, with one class focusing primarily on

affordability and the other on comfort (and thus able to attract medium-income passengers at a higher fare). The services could share running ways but not station infrastructure. This approach was shown to be commercially viable in Harare and Nairobi in the early to mid 1990s¹¹, and can provide the basis for politically acceptable private-car demand management. However the consequent segregation (though welcomed by middle-class passengers) is politically unpalatable and has generally been rejected, for example by the World Bank¹². In consequence, as Godard (2011: :245) states, "[i]n Sub Saharan Africa the affordability of public transport [to both users and to service providers], appears to be a major issue".

Institutional disconnects between central and local governments

Urban mobility is essentially a local function, and is enshrined as such in several countries' constitutions and national legislation. However, progress towards decentralisation and devolution of functions, powers, and services to local councils is sometimes honoured more in the breach. This problem may be exacerbated when central and local governments are of differing political persuasions, and when local governments have few tax-raising powers and are almost wholly dependent on central government for their funding. In the specific case of BRT and its infrastructure development, ownership of the principal arterial highways by central government may also act as a barrier to implementation.

The World Bank Group recognises the reality of this disconnect. Success for its transport business strategy in the sector will depend on progress made by the Bank Group as a whole in developing modes of direct engagement with city authorities, by using subnational lending instruments in particular. However, resistance from national governments for the Bank Group's assistance to municipal authorities persists.

State of investments in public transport

The review of the literature and practitioners' input identified 16 projects to upgrade or construct fixedroute public transport systems in Sub-Saharan African cities since 2000, most of which are summarised in

¹⁰ Interview: Samson Gyamera

¹¹ Interview: Edwins Mukabanah

¹² It has been suggested that the two-class service was explicitly rejected in the system design for TransMilenio in Bogota, and that this has subsequently been carried forward into projects based on the TransMilenio concept.

Appendix B. In line with the paper's focus on recent efforts at upgrading public transport systems, the table excludes legacy systems such as older commuter rail operations in Lagos, Maputo, Nairobi, and South African cities, as well as ferry operations in Lagos. Not all of these 16 projects are operational: of the 16 systems for which substantial planning has been done, three have not yet been implemented (Kigali, Nairobi, Kampala), three are under construction (Rustenburg, Ekurhuleni, eThekwini), and two have been withdrawn due to poor performance (Nelson Mandela Bay, Accra). BRT systems are currently in the early stages of implementation with World Bank funding in Dakar and Abidjan¹³. Preparation for BRT is at a very early stage in Polokwane, Addis Ababa, Maputo, and Luanda; these are not included in the table.

The predominance of Bus Rapid Transit (BRT) among operational and planned interventions suggests that BRT is the preferred mechanism through which governments and funders seek to modernise urban public transport. The scope of BRT systems varies between the single corridor and tributary in Lagos to the somewhat larger systems in Dar es Salaam, Johannesburg, and Cape Town. The latter three cities are all constructing additional trunk routes at the moment. Ekurhuleni in South Africa is running a starter BRT service while completing its infrastructure.

Evidently due to their high costs, new rail systems are sparse, and are limited to the Gautrain rapid rail project in Gauteng, South Africa and the Addis Ababa Light Rail¹⁴. In addition, four upgraded commuter rail services on existing alignments are operational in SSA, but with limited service and ridership; these are in Abuja, Dakar, Dar es Salaam, and Nairobi.

In terms of geographic spread (Figure 1), the majority of projects are in South Africa, with the rest spread evenly between East and West Africa. Interestingly, interest in BRT projects has been lower in Francophone West Africa than in Anglophone East and Southern Africa. This perhaps coincides with the greater popularity of BRT in the English (and Spanish) speaking world than in the French-speaking world, where rail tends to more popular, and Buses of a Higher Level of Service (BHLS) are the preferred feeder mode.

Looking at the sizes of the implemented projects, it is worth noting that upgraded public transport reaches only a fraction of urban passenger markets in Africa. For instance, in Lagos the 195 000 passenger trips per day on the BRT Lite amounted to an estimated 0.9% of trips¹⁵ (Integrated Transport Planning Ltd, 2009). South Africa's four operational BRTs serve 2% of urban trips (Hunter van Ryneveld, 2014). The importance of the BRT systems lies not in their current reach but in the way in which they serve as test cases for future mobility interventions in other cities and countries.

Figure 1. Extent of public transport systems identified



¹³ See http://documents.worldbank.org/curated/en/810361495936883655/Senegal-Dakar-Bus-Rapid-Transit-Pilot-Project and http://documents.worldbank.org/curated/en/532181561946508500/Cotedlvoire-Abidjan-Urban-Mobility-Project

¹⁴ The Blue Line LRT in Lagos is still under construction, but appears to be facing financing problems. It is not included in the analysis for lack of information.

¹⁵ A better metric of impact would be passenger-kilometres, as it takes the length of trips into account. As a high proportion of BRT Lite ridership was end to end, by this metric it would carry a higher proportion of total mobility. Unfortunately data of this nature is universally lacking in Africa.

STATE OF KNOWLEDGE

Introduction

This section provides an overview of the extent and nature of the literature on fixed-route transit interventions in Sub-Saharan Africa. A search for relevant sources in the (English language) academic and grey literatures identified more than 100 publications, concentrated around five main themes:

- System planning, infrastructure, and service design (33% of references)
- User needs and experiences (16%)
- Relation to paratransit reform (14%)
- Political economy, implementation pathways, and wider impacts (25%)
- Urban design and land-use impacts (12%).

A few recent documents provide overviews of the state of knowledge regarding public transport within the larger context of mobility and access in low-income countries (Institute for Transportation and Development Policy (ITDP), 2019; Stucki, 2015; Venter et al., 2019). It is fairly difficult to judge the actual impacts of the public transport interventions, as limited independent analysis exists on their success and failures and overall impacts (Klopp et al., 2019). The earliest literature comprised relatively uncritical descriptions of the implementation of individual systems (e.g. Gauthier and Weinstock, 2010; Kaenzig et al., 2010), based on information originating from the local authority itself or from other project proponents. These studies tended to exclude more subjective assessments of system impacts (Mason-Jones and Cohen, 2012).

The gap was barely filled by a small number of academic studies reporting *ex-ante* assessments of the likely impacts of BRT systems on users and others affected, for instance in Dar es Salaam (Ahferom, 2009; Joseph et al., 2018; Nkurunziza et al., 2012), Kampala (Vermeiren et al., 2015), Addis Ababa (Aklilu and Necha, 2018), and Johannesburg (Venter, 2016). These are typically based on small-sample qualitative work, accessibility analyses, and mobility surveys. In recent years more studies have appeared, offering oritical *ex-post* analyses of actual impacts of Gautrain (e.g. Thomas, 2013; Trangoš, 2015), Johannesburg's Rea Vaya (e.g. Lionjanga and Venter, 2018), and DART (e.g. Andreasen and Møller-Jensen, 2017; Ka'bange and Mfinanga, 2013). Also useful have been comparative studies between BRT systems in Africa, Latin America, and Asia (e.g. Andrade, 2010; Kumar et al., 2011; Salazar Ferro and Behrens, 2015; Scorcia and Munoz-Raskin, 2019).

In tandem with the shift towards more critical research, scholars have also increasingly turned their attention towards the 'softer' issues of, especially, BRT implementation, including institutional issues and paratransit reform. The bulk of work on the nexus between formal and informal modes came from the VREF-funded African Centre of Excellence in Transport (ACET) (e.g. Behrens et al., 2015a; Schalekamp and Behrens, 2013; Wilkinson, 2010). Other scholars focused on the political economy of BRT implementation, offering a critique of the processes, actors, and political alignments at play in South Africa (Wood, 2014a, 2014b, 2015), Ethiopia (Nallet, 2018) and Tanzania (Ka'bange et al., 2014; Rizzo, 2014).

Very little reflection is available on failed schemes, such as pilot BRT schemes in Accra and Nelson Mandela Bay (with the notable exception of Agyemang, 2015; Nguyen and Pojani, 2018, and Manuel and Behrens, 2018). On some systems, such as the Light Rail Transit (LRT) systems of Addis Ababa and Abuja, almost no scholarly work is available – perhaps a reflection of the close involvement of Chinese companies in relatively opaque engineering-procurement-construction contracts (Aklilu and Necha, 2018).

Overall, while there is growing scholarly interest in the system design and implementation aspects of public transport projects in Sub-Saharan Africa, the evidence base is particularly thin on two aspects: planning and implementation processes, and the actual performance and impacts of systems¹⁶. To some extent the reluctance

¹⁶ The one exception is the BRT Lite Evaluation report (Integrated Transport Planning Ltd, 2009) that was commissioned in the year after its opening in Lagos, but has not since been updated.

to release the evidence base is understandable, when there is so little success to report.

The following sections provide an overview of the evidence that is available from the sources consulted for this position paper. We group topics as follows. First we consider planning oriented issues including the choice of technology, and network and service planning. Then follows delivery-related issues, including the design and insertion of infrastructure, vehicle specification, passenger access, interchange/modal integration, and fare policy/ticketing.

Mode/technology choice

There has been a profound shift in the stance towards different transport technologies in Sub-Saharan Africa over the last 30 years. Coming out of the 1980s and 90s, as awareness of the transport crisis in African cities grew, the construction of urban rail was seen as the preferred solution. This was supported by the World Bank and other lenders who were traditionally involved in capitalintensive rail projects. For instance, in Lagos the World Bank-supported Lagos Urban Transport Project (LUTP) included a light-rail component alongside bus system development. The tendency was to describe 'rapid transit' only in terms of high technology, which included dedicated right-of-way, substantive stations, off-board fare collection, passenger information and Intelligent Transport System (ITS) technologies (Kumar et al., 2011).

In this rail-centric vision, enhanced bus services were seen as important, but primarily as a complementary measure to rail. However, the prohibitive cost and time implications of rail deployment soon shifted the focus onto large buses (Kumar and Barrett, 2008). Several schemes, such as those in Dakar, Lome, and Ougadougou, were launched to improve management and operational practices in existing bus systems, with the hope that improved local bus operators could be the kernel from which future systems could emerge (Godard, 2013). Yet most of these efforts over the last 20 years failed, owing to a lack of public transportsupportive institutions, effective regulation, and investment in infrastructure. In addition, new buses simply could not compete with the informal sector while under finance, and consequent defaults resulted in sources of capital being withdrawn.

Enter Bus Rapid Transit. After the initial success of the BRT concept in Bogotá's TransMilenio, where it was first demonstrated as a high-performing mass transit mode ostensibly able to operate subsidy-free, BRT was quickly adopted as a potential solution not only to mobility problems but also to institutional and market difficulties (Gauthier and Weinstock, 2010; Wright, 2006). As a catalytic and highly visible project, BRT offered a compelling vision of a package of interventions, ranging from the dedicated infrastructure that is critical to getting buses out of congestion, to modernising fleets and transformation via the creation of new agencies specifically focused on BRT implementation. From the start BRT was about much more than just buses.

The recent work on policy circulation of the BRT concept has offered glimpses into how this shift came about (Cameron, 2007; Rizzo, 2014; Wood, 2014b, 2015). Klopp et al. (2019:22) argue that behind the decision to adopt BRT in many cities lies a constellation of self-interest, ranging from international consultants, equipment manufacturers, politicians (local and national), and local and international lobbyists that seek "to portray BRT as cheaper, more effective, and easier to implement than it actually is."

The City of Johannesburg provides an interesting case. Its concept of a Strategic Public Transport Network (SPTN), adopted in 2003, envisaged a coherent gridshaped network of public transport priorities (largely) on existing lanes, connecting all major nodes within the city through frequent, reliable bus and minibus-taxi (paratransit) services throughout the day (City of Johannesburg, 2003). However, in 2005 and 2006, after several visits by international BRT consultants, this essentially incremental, home-grown solution was jettisoned in favour of a full-specification BRT plan. Wood (2014a:2662) notes that a visit by city officials and taxi owners "to Bogotá in 2006 was a fundamental turning point after which they no longer considered the SPTN a sufficient solution."

In South Africa the shift towards BRT adoption was cemented by the funding mechanism put in place by the government, which made substantial grant funding available for construction and operations but conditional on the adoption of high-standard IRPTN (Integrated Rapid Public Transport Network) designs (Hitge and Van Dijk, 2012; Manuel and Behrens, 2018). This has led to what has been argued is an inappropriate adoption of full-specification BRT in smaller cities, where lower congestion levels and thinner demand does not justify the significant investments that BRT requires (Muñoz-Raskin and Scorcia, 2017)¹⁷. The exception is the small city of George, which effectively leveraged provincial support to deploy a more integrated and better designed, higher quality bus system that is not BRT (Aboo and Robertson, 2016). The question of alternative standards – of what the essential elements of BRT are for the local context – have surfaced in other cities, where a 'BRT Lite' concept has been advocated (see discussion under *BRT Standards* below).

It is fair to say that a certain level of skepticism towards BRT has entered the academic discourse around technology choice in Africa. This reflects a perception that the rationale for choosing BRT is often unclear. Little evidence is available showing thorough alternatives analysis conducted in order to select the technology with the highest value-for-money proposition¹⁸. However this is also true of other systems, including light rail, and is seen worldwide when politicians and engineers are swayed by an inherent preference for some technology or mode rather than sober analysis (Hensher et al., 2015).

The danger, though, is that BRT may come to be seen as not appropriate *anywhere*, for the same reasons as its adoption – an uncritical bias for or against a particular idea. No persons interviewed for this project believed that BRT as a concept should be wholly jettisoned in Africa. To help make informed technology choices, more evidence-driven research, comparative studies, and critical debate on the actual impacts of all new public transport systems in Africa are needed.

Network and service planning

Network plans and their implementation

Cities implementing new public transport systems have favoured an incremental approach – differentiated from the Transantiago city-wide approach – starting with one or two corridors with the intention of gradually adding further services and routes over time. Gautrain and Addis Ababa's LRT started with two trunk corridors with transfers; all BRTs started with a single corridor served by direct and/or tributary services. This can be seen as a pragmatic approach to the adoption of a new technology; it provides space for learning to take place, allows the network to grow as human and financial capital expands, and is attractive to politicians and taxpayers who do not have to wait for an entire system to be in place before seeing results (Cervero, 2013a). In addition, incrementalism is favoured by lending/development banks as well as the national agencies they negotiate with, who in the interest of maintaining strict control over spending require projects to be limited to very well-defined areas and project activities (Klopp et al., 2019).

Most cities develop some notion of a larger envisaged network (at least at the level of corridors and modes) to ensure that network connectivity is promoted from the outset¹⁹. For instance, the Nairobi mass transit plan identified nine initial corridors, later reduced to five, by linking corridors across the CBD. Dar es Salaam's plan consists of six phases totaling 137km of trunk routes, of which only the 21km Phase 1 is operational (Chengula and Kombe, 2017).

In most of these cases the role of other modes is not clear at the outset. South African cities, with their more extensive legacy systems, have identified specific roles for different modes in an evolving multimodal network, with commuter rail as the backbone and BRT trunk routes serving higher-density corridors in Cape Town, Gauteng, and eThekwini (Durban) (City of Cape Town, 2018; Gauteng Department of Roads and Transport, 2013). These are supposed to be supported by quality bus services as scheduled feeder or direct services where appropriate. However the details of route design and allocation remain unaddressed, reflecting a basic uncertainty about how to transition towards a more functional and integrated multimodal network. The role of paratransit is even more unclear; even the hybrid model adopted by Cape Town, which foresaw minibus-taxis providing finer grain, on-demand services where densities are low, is tentative.

The pace at which new services are rolled out is universally much slower than originally planned. Dar es

¹⁷ See also https://theconversation.com/south-africa-needs-to-revamp-its-new-public-transport-system-84930.

¹⁸ Interviewees expressed some difference of opinion on this point. It was argued that, for instance, Dar es Salaam's Urban Transport Masterplan of 2008 included some form of alternatives analysis that was the basis of the selection of BRT rather than light rail, urban rail, and underground metro. Others argued that DART was substantially designed by 2004 and served as in *input* to rather than an *output* of the Plan. Also, Lagos' selection of a BRT Lite standard was reportedly guided by the basic principles of transport economics to evaluate against the best realistic alternative and not 'do minimum'. True, unbiased alternatives analysis is evidently a complex task.

¹⁹ Some African researchers have studied mathematical methods for designing optimal networks (Mama et al., 2014; Nnene et al., 2017), although these have not been applied in practice.

Salaam's BRT was announced in 2000 but the first corridor only opened in 2016²⁰; Lagos' single BRT Lite corridor, which opened in 2009, remains the only one in the city.

In South Africa, the 2007 National Public Transport Strategy envisaged that by 2020 BRT systems would be running in 12 large cities, but by 2019 only four cities had managed to achieve some form of operation, of which one is a rudimentary starter service (Hunter van Ryneveld, 2014; Manuel and Behrens, 2018). Key reasons given for this delay are that infrastructure costs (and therefore funding needs) are higher, and implementation more complex, than anticipated, especially in relation to the time it takes to negotiate with existing minibus operators (notably in South Africa where their transformation is a key objective of the BRT project) (Manuel and Behrens, 2018; McCaul and Ntuli, 2011). In some cases institutions are not ready for implementing such complex projects, as in Nairobi where the questionable constitutional standing of the metropolitan implementing agency Namata has resulted in a legal stalemate (Klopp et al., 2019).

Thus the danger with the incremental rather than citywide approach to public transport upgrading is that the process will stall, with the city-wide benefits of more comprehensive networks never materialising. Nelson Mandela Bay is a case in point: for the sake of fast implementation during the 2010 FIFA World Cup, starter routes concentrated in the CBD did not penetrate into residential areas, thus requiring most passengers to transfer from other modes. However, without any fare integration or realignment of other bus and paratransit routes, this plan was unpopular and led to poor ridership on the BRT (Royal Haskoning DHV, 2016). The routes were terminated by 2014, and have not yet been restarted (Manuel and Behrens, 2018).

Accra tried to launch a form of BRT Lite on two corridors in 2015/16. Buses were publicly procured, but were overweight and over-length, and failed 'value for money' tests by the Ministry of Finance. Other reasons the system failed include resistance by paratransit unions to operate the buses, and an imported electronic fare collection system that was too expensive.

Corridor location

All public transport upgrade projects in SSA cities have selected relatively high-volume radial corridors for their first trunk routes. In Lagos, Addis Ababa and Dar es Salaam, this delivered relatively effective corridors; it also superimposed a new mode onto what was a corridor already served by high volumes of paratransit operators. This means that from the outset cities faced issues of the displacement of existing operators (Salazar Ferro and Behrens, 2015). The vast majority of BRT passengers come from informal public transport modes (84% in Accra (Okoye et al., 2010); 93% in Lagos (Integrated Transport Planning Ltd, 2009).

Such corridor location patterns also mean that upgraded public transport services predominantly serve older, established neighbourhoods, and not the newer peripheral settlements that are most in need of improved mobility. The equity implications of corridor location have been pointed out by some scholars (Venter et al., 2018; Vermeiren et al., 2015) but have not been adequately studied. Nor have behavioural responses: many households make a conscious trade-off between housing and mobility costs, and anecdotal evidence suggests that improved mobility in Dar es Salaam came at the price of increased rents²¹.

Over time, land-use patterns might shift; new housing and commercial development might be attracted to the public transport corridors. While densification around some Gautrain stations has been studied (Lombard et al., 2017; Mushongahande et al., 2014), very little is known of the drivers, pace, or impacts of land-use change in the case of BRT (Ka'bange and Mfinanga, 2013). Dar es Salaam has formulated a Transit Oriented Development (TOD)-based Corridor Development Strategy for its main BRT corridor²², which has yet to be implemented. The cities of Johannesburg and Cape Town have made the most effort in pro-actively linking their BRT plans to land-use restructuring goals, and have gone some way towards understanding the incentives and conditions for this to succeed²³. As a whole, the interaction of transport interventions and land-use change - including the role of private sector developers - has been understudied in SSA cities (Campbell et al., 2019; Cooke et al., 2018).

²⁰ Construction has now started on Phase 2, a 19km corridor stretching southwards from the CBD.

²¹ Interview: Ronald Lwakatare, DART. See also Rizzo, 2014.

 $^{22 \}hspace{0.1cm} \text{See http://blogs.worldbank.org/sustainablecities/can-dar-es-salaam-become-next-global-model-transitoriented-development.} \\$

²³ The literature on Johannesburg's Corridors of Freedom initiative (e.g. Ballard et al., 2017; Bickford and Behrens, 2011; Ndebele and Ogra, 2014) and Cape Town's Transit Oriented Development plans (e.g. Cooke et al., 2018; Grey and Behrens, 2013; Wilkinson, 2006) are an instructive starting point for future research on TOD in Africa.

Service plans

In terms of route and service plans, SSA systems are evolving. Initial services in Addis Ababa, Lagos, Dar es Salaam, and Cape Town were based on the trunkwand-feeder model, with large buses or trains exclusively plying on trunk corridors, and passengers having to transfer to feeder buses at stations or terminals. Conventional thinking is that smaller vehicles are ideal for providing feeder services, and that the feeder role might be a natural niche for paratransit operators in a transformed system (Del Mistro and Behrens, 2015). In practice, however, feeder services were either new bus routes designed as part of the new system (as in Cape Town and Johannesburg), or existing paratransit routes left to adapt to the new trunk as they wanted to (Lagos).

The trunk-and-feeder model is increasingly being considered to be economically sub-optimal, as was demonstrated during the Accra BRT pre-feasibility study undertaken by an expert seconded from TransMilenio (interestingly, this finding was back-tested in Bogotá, and found to hold true there as well). Direct services (integrated tributaries, with the same buses plying off-trunk routes and joining the trunk for part of the route) appear to be preferable wherever demand justifies the operation of large buses - typically over 1000 passengers per peak hour and direction. Direct services benefit passengers by avoiding the need to transfer (Salazar Ferro and Behrens, 2015), especially when this would involve paying two fares (which is common in the absence of fare integration). Both Johannesburg and Cape Town have introduced an increasing number of direct routes, in the process dramatically reducing the number of pure feeder routes. In the case of Lagos, tributary services were envisioned but prevented by a shortage of buses and the lack of control over the highways on which the tributaries would run.

System insertion and infrastructure

Road supply issues

The provision of road-based priority infrastructure for public transport is hampered by the short supply of high-quality road space in African cities: the average density of paved roads per capita in Sub-Saharan Africa is roughly 65% less than that of other low-income countries (Foster and Briceño-Garmendia, 2010). Moreover, considerable lengths of paved roads lie in middle-class suburbs not amenable to mass transit. Road networks are underdeveloped, with an insufficient number of high-order roads to accommodate especially non-radial movements (Kumar and Barrett, 2008; Sietchiping et al., 2012). This contributes to severe congestion and makes it hard to identify suitable alignments for public transport lanes – it is politically difficult to repurpose existing road space which is already at a premium.

Nevertheless, dedicating road space to public transport is critically important to achieve the step-change in efficiency and attractiveness that is required (Cervero, 2013a; Venter et al., 2019). Buses and trains need to get out of traffic. Poor traffic management, illegal parking, encroachment by informal traders, and other issues contribute to disorderly traffic (Ibitayo, 2012). What is required is what the designers of the Kampala BRT call *"major modification to the existing road space"* (Ephraim et al., 2014:38) – a big ask for already road-poor cities.

BRT Classic and LRT projects shy away from reallocating existing road space from private to public vehicles. Instead, the approach has been to either reallocate lanes from *other public transport modes* to the new system, or to construct altogether new road space. Examples of the former approach include the construction of portions of the Addis Ababa light rail along road medians that were formerly used by buses; and the alignment of portions of Johannesburg's first BRT corridor along the Pat Mbatha Taxiway that was formerly dedicated to paratransit services (minibus-taxis) (Mason-Jones and Cohen, 2012). In both of these cases the reallocation of road space was premised on the replacement of the previous (less efficient/informal) mode by the newer (more efficient/ modern) one.

Where new road space is built, either to offset loss of road space by private vehicles through the construction of new roads, or to construct new lanes for public transport, the implementation costs of BRT projects may be pushed up to the point where they become unattractive to foreign donors (Agyemang, 2015; Ka'bange et al., 2014). The problem is exacerbated where, as is common in SSA cities, the city government owns very little of the right-of-way, and compensation of private property owners contributes significantly to road construction budgets (Agyemang, 2015). In Tshwane, the high cost of land expropriation has led to clashes with the local community and significant delays to the extension of the initial BRT route²⁴.

Decisions around the allocation and reallocation of road space between private and public modes, and between different public modes (and also non-motorised users), say much about power politics and how cities negotiate the terrain between vested interests, yet these decisions have rarely been examined. Apart from the political dimension, the linkages between road space allocation and issues such as implementation costs, transport system performance, and accessibility, need to be better understood.

BRT Standards

A key characteristic of the BRT concept worldwide is its flexibility – while key components such as the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service (according to the Institute for Transportation and Development Policy (ITDP), 2017) are always present in BRT systems, cities combine these components in ways that suit their local circumstances. This very flexibility is, however, not universally appreciated in SSA cities or by the development community, with many cities striving to implement a certain version of the concept that, some analysts now argue, may not be appropriate to the circumstances. The issue of appropriate standards is the basis of a growing critique of BRT planning in Africa, and also reflected by many of the interviews conducted for this paper.

In consequence there are essentially two competing design approaches discernible, both reflecting the same basic objectives for BRT but quite different in the details. The so-called 'BRT Classic' reflects the ITDP's preferred Gold Standard approach (Institute for Transportation and Development Policy (ITDP), 2016) and, as shown in Table 1, depends on more substantial dedicated running ways, station platforms, and boarding areas. The alternative, usually termed 'BRT Lite', is less infrastructure-

Table 1. Two design approaches for Bus Rapid Transit emerging in Sub-Saharan African cities

BRT concept	'BRT Classic'	'BRT Lite'
Example cities	Johannesburg, Cape Town, Dar es Salaam	Lagos, Kampala*, Nairobi*
Typical location and design of running ways	Median	Bilateral (kerb-side)
Typical % of trunk route completely dedicated	~100%	-85-100%
Typical station location and design	Median; fully enclosed	Bilateral, offset; partially enclosed
Typical fleet specification	Require buses with opposite-side doors; articulated	Require buses with standard doors; rigid
Typical bus accessibility	Level boarding from 900mm platform height	Stepped entry from 200mm platform height; floor height 650mm to 860mm (E+1 or 2)

Notes: * Based on initial system design, not implemented

²⁴ See https://rekordeast.co.za/49283/lynnwood-brt-lane-fury-grows/

intensive, for instance in its use of existing rights of way, open (rather than fully enclosed) stations with on-board fares validation, and stepped entry (rather than level entry) to accommodate standard bus fleets and allow operation on tributary routes. The objective of BRT Lite is to reduce the required investment costs and affordability barriers cities and users face – to provide '80% of the benefit for 20% of the cost'.

The exemplar for the BRT Lite concept is Lagos, at the time described as "a new form of BRT, focused upon delivering a system to meet key local user needs ... within a clearly defined budget" (Integrated Transport Planning Ltd, 2009). About 85% of bus-lanes along the 22km corridor are segregated; the rest operates in mixed traffic. Another key ingredient of BRT Lite is the use of bilateral (i.e. kerb-side) rather than median stations (see Figure 2). The biggest advantage is that bilateral stations allow boarding on the usual side of the vehicle, thus obviating the need for special vehicles with doors on the off-side (or both sides). This potentially reduces fleet acquisition and operating costs, increases seating capacity, and, more importantly perhaps, has the potential to be compatible with existing bus fleets to offer trunk or tributary (direct) services. It also allows for the progressive use of infrastructure as it is developed, rather than requiring completion before system launch²⁵.

Initial planning for a BRT system in Nairobi demonstrated the financial attractiveness of BRT Lite. It was found that only BRT Lite was economically viable, offering an Internal Rate of Return (IRR) of 20.5% and a Benefit Cost Ratio (BCR) of 1.79, as opposed to an IRR of 1.7% and BCR of 0.17 for the alternative BRT Classic design²⁶. In general BRT Classic might quite possibly have larger benefits over the project's life cycle, but these might be outweighed (after discounting) by the substantially higher infrastructure costs. The City of Johannesburg's own ex ante economic evaluation demonstrated this: it showed benefit-cost ratios as low as 0.77 and 1.01 for the full-BRT Phase 1A and 1B respectively (Seftel and Peterson, 2014). However this estimate was based on direct transport benefits alone; the World Resources Institute (WRI) calculated a BCR of 1.2 for Phase 1A, when taking wider benefits such as public health and road safety improvements into account (Carrigan et al., 2014). Clearly the economics of the two competing concepts needs further investigation.



Figure 2. Examples of the BRT Classic (left) and BRT Lite (right) concepts

(a) Median lanes and stations, Johannesburg BRT (Source: The Star)



(b) Kerbside lanes with bilateral stations, Lagos BRT Lite (Source: LAMATA)

²⁵ Notwithstanding this advantage, the practice of allowing non-BRT buses to use BRT infrastructure is uncommon internationally, and can lead to operational challenges as was demonstrated in the now discontinued open BRT corridor in New Delhi. In Africa, additional problems with the potential integration of non-BRT buses into BRT systems stem from the poor condition of existing bus fleets, and differences in driver incentives and discipline. Clearly these challenges require an appropriate regulatory and enforcement framework.

²⁶ Nairobi Urban Transport Improvement Project, BRT Feasibility Study and Business Plan Preparation, BRT Line 1

Perceptions seem to be shifting in favour of the BRT Lite concept. In South Africa, criticism has mounted of the first BRT systems deployed, based on their high cost, slow roll-out, and poor cost performance (Browning, 2017; Schalekamp and Klopp, 2018; Seftel and Peterson, 2014). Although the reasons for these failings are manifold, including management problems at local authority level and problems with competing services, the full-BRT standards that were adopted have also been blamed. Subsequent BRT planning has shown a willingness to move towards lighter approaches. For instance, Johannesburg foresees the roll-out of Rea Vaya's next phases to scale back on the amount of dedicated trunk routes and run services to outlying areas in mixed traffic (Jennings and Behrens, 2017). Cape Town is considering the use of low-platform, open stations for part of its new trunk route, and is also investigating the possibility of allowing regular buses operated by Golden Arrow Bus Services to use dedicated bus lanes (though perhaps not BRT stations) to boost the number of direct services as well as trunk capacity²⁷.

Other variations on the concept of BRT Lite demonstrate its versatility to grow and adapt with changing demand patterns (at least conceptually, if not yet demonstrated in practice). In Kigali, a 2014 study suggested the initial introduction of High Occupancy Vehicle (HOV) lanes along future public transport corridors, until increased congestion and available funding allows for kerb-side dedicated bus lanes to be implemented (Van Zyl et al., 2014).

Bus-lane design

Our review of the designs of BRT bus lanes illustrates the challenges of finding enough space for BRT in congested SSA cities. Sometimes this leads to decisions being made that are sub-optimal from an operational perspective. In 2006 Lagos attempted to pilot bus lanes using only painted lane demarcations but no priority measures on the local road network to and from the terminal; this ended in failure due to a lack of enforceability of the former, and chronic congestion on the latter (Integrated Transport Planning Ltd, 2009). This experience demonstrated the importance of physical redesign and protection of the right-of-way.

The BRT Lite subsequently re-allocated bilateral (kerbside) lanes on an existing radial expressway to buses whilst retaining at least two lanes per direction for general traffic, through construction in the median (and rebuilding pedestrian over-bridges as required). Additional traffic capacity is provided by a separate service road on each side, running parallel to the main roadway over much of its length (Integrated Transport Planning Ltd (ITP), 2009). However, lane widths are somewhat narrow, at 3.3m, which is the minimum to allow safe operations; in places severe cross-section constraints reduce lane widths to only 2.8m. Bus lay-bys are inserted in the highway/service lane separator, but their dimensions are barely adequate and can result in lane blockage if buses fail to dock accurately at the station.

In addition, about 20% of the trunk route used painted lines to deter lateral intrusion rather than the concrete separator kerbs used on the longest part of the route, partly because of insufficient space being available and partly because of a reluctance of the highway authorities to allow extra weight on fragile bridge structures. Physical separation proved much more effective at deterring incursion than painted lines (Integrated Transport Planning Ltd, 2009). Approximately 15% of the trunk corridor runs in mixed traffic in the CBD. The routing was compromised by the one-way elevated highway, where dedicating road space for buses was not deemed politically acceptable but congestion impacts are low. However, some localised congestion in the CBD was unavoidable, and had a disproportionate impact on service reliability²⁸.

Where the Dar es Salaam BRT enters the narrow streets of the OBD, system designers turned the entire street into a bus-only street. The impacts of this bold step on traffic patterns, commercial activity, and bus performance have not been reported, but anecdotal evidence suggests that local traffic congestion has grown in the face of inadequate traffic management measures. In addition, while the rest of the network has passing lanes at stations, these lanes are lacking in the CBD where they are most needed, with consequent bus queuing and restricted throughput at peak times.

In Kampala, with typical highway rights-of-way of only 25m between kerbs, BRT insertion with two residual general traffic lanes and passing lanes at stops has been a major challenge. The original design suggested median operation (rather than kerb-side, due to excessive side-friction in the CBD area, with longitudinally offset

 $^{27\}$ Information supplied by City of Cape Town planners, June 2019.

²⁸ It was noted in Lagos that reallocating one lane each way of a dual 3-lane carriageway actually improved general traffic flow through eliminating station spill-over effects that act to block this. Imaginative options are also possible for dual 2-lane carriageways where there is a pronounced tidal-flow at peak hours, and traffic flow also benefited from the moving of the small commercial buses, comprising one third of traffic, onto the service lanes.

Figure 3. Examples of closed (left) and open (right) shelter designs in Sub-Saharan African BRT systems



(a) Closed station, Dar es Salaam BRT (Source: G Hayes)



(b) Open station design, Nairobi BRT (Source: Integrated Transport Planning)



(c) Closed station, Cape Town BRT (Source: C Venter)



(d) CMS Terminal, Lagos BRT Lite (Source: LAMATA)

bilateral stations with minor compromises to lane widths, which are consistent with (low) city-centre bus speeds. However, later detailed design rejected these dimensional compromises, and expanded the BRT crosssection to include full-length cycle lanes but reduced general traffic to one lane per direction. This was deemed unacceptable by city authorities and contributed to the subsequent freezing of the project.

Shelters, stations and terminals

The provision of shelters and stations is fundamental to the concept of quality public transport, for two reasons: (i) they increase customer comfort by providing protection against the elements, particularly sun and rain; and (ii) they facilitate faster and more orderly boarding and alighting by accommodating pre-boarding fare payment and multi-door operations²⁹. The issue of *order* appears to be particularly important in the African literature (Integrated Transport Planning Ltd, 2009). Order reduces dwell time at stops and allows for more predictable and reliable services (Cervero, 2013a; ITDP, 2017).

Shelter and terminal standards substantially affect the capital and operating expenses of BRT systems; shelter design therefore reflects the competing design approaches mentioned above. BRT Lite uses shelters that

²⁹ It is noted that the evidence on this is contradictory, as some practitioners argue that using both (or all three) doors for both boarding and alighting at the same time promotes disorder, and makes it impossible to control overloading. It is argued that using fare validation on boarding, those problems are avoided and dwell times are only increased slightly at the busiest stations.

are more open, with an emphasis on orderly queuing (often using queuing barriers) and low platform heights, as in Lagos and Kampala (see Figure 3). In Kampala, low fences separate platforms from buses, and passengers access buses through gaps in the barriers. This avoids the expense of station doors that open and close on bus arrival, typical of BRT Classic designs (Ephraim et al., 2014) but not actually used in Dar es Salaam.

Low platforms of 150-200mm reduce construction costs and difficulties with station placement (as shorter access ramps are needed), and allow platform oversweep for accurate bus docking within a limited length at multi-bay stations. However, they introduce issues with boarding into the vehicle, as standard bus floor heights are approximately 650-850mm. One option is to procure new buses with low or semi-low floors (to provide step-free boarding into at least part of the bus), as in Tshwane. However super low floor (300mm) buses are not technically viable under typical road conditions. Alternatively, standard/existing bus fleets require stepped boarding with one or two steps into the bus. This option significantly reduces fleet costs but compromises boarding efficiency and access for wheelchair users, and is therefore contentious. The 650mm standard in the Indian JnNURM specifications³⁰ allows for manually deployed wheel-chair ramps meeting ADA standards for gradient and offering high reliability.

The BRT Classic concept depends on fully enclosed stations, typically using high platforms, and therefore avoids issues of compromised access between the platform and the bus. However construction costs as well as fleet costs increase because of the need for trunk buses with high-entry side doors. Examples are Johannesburg, Cape Town, and Dar es Salaam (Figure 3).

Both designs make provision for off-vehicle ticket purchase, as both systems agree on the need to separate cash from the vehicle, but differ in their validation modalities. BRT Classic makes use of turnstiles to gain access to the station, adding cost and issues of mechanical reliability, and requiring considerable platform width for necessary capacity. BRT Lite prefers validation on boarding the bus, bringing order into that process and allowing for revenue allocation to the specific vehicle – crucial in a multi-operator environment with integrated ticketing.

Cost and performance trade-offs

Notwithstanding this variation in standards, there is no doubt that dedicated rights-of-way deliver substantial travel time savings to passengers, at least along the trunk. Lagos' BRT Lite was reported to shave 25 minutes, or about a third, off a passenger's trip along the whole corridor (Kaenzig et al., 2010), while reducing average waiting times from 45 to 10 minutes (Gorham, 2017). Substantial travel time savings are also reported for Dar es Salaam (Chengula and Kombe, 2017), Johannesburg (Carrigan et al., 2014; Vaz and Venter, 2012), and Cape Town (Hunter van Ryneveld, 2014).

However there is some evidence that, with the lower specification of the BRT Lite concept, benefits are lower than what they could be. There is thus a trade-off between investment costs and performance. In Lagos, for instance, the pared-down specification allowed delivery of an operational system for USD 1.4 million per kilometre (Integrated Transport Planning Ltd, 2009), putting it in the lower decile of systems internationally (Carrigan et al., 2014; Hensher and Golob, 2008). It is operated without operational subsidy or development bank assistance (apart from some technical guidance), and was deployed within a 15-month timeframe – both factors proved very attractive politically (Kumar et al., 2011).

However, average bus speeds (in 2009) were "disappointing" at around 20km/h, largely as a result of inefficient operations at bus stations and congestion on mixed traffic sections (Integrated Transport Planning Ltd, 2009). These factors also cause problems with reliability: in 2009 journey times from Mile 12 to Lagos Island varied widely between 40 and 70 minutes in the peak direction. Long waiting times (in excess of 20 minutes) have been reported, especially during off-peak periods (Adebambo and Adebayo, 2009; Olawole, 2012). Further problems with reliability stem from insufficient capacity at end terminals, while inadequate pavement designs and drainage led to failure of sections of the buslane within seven months of system opening (Integrated Transport Planning Ltd, 2009).

Johannesburg's full-specification Phase 1A, by contrast, cost in the region of USD 8-10 million/km³¹, but achieves travel speeds of approximately 28km/h (Carrigan et al., 2014). Cape Town's MyCiti Phase 1 cost

³⁰ The Jawaharlal Nehru National Urban Renewal Mission is an urban investment initiative of the Indian government through which several BRT and metro projects are being developed in Indian cities.

³¹ This is an estimated cost for Phase 1A, including all capital and equipment costs (Carrigan et al., 2014).

USD12 million/km³², and reaches similar operating speeds (Hunter van Ryneveld, 2014).

There appears to be no strong correlation between BRT specification and passenger satisfaction: for instance, Cape Town's full-specification BRT scores above 90% on all aspects except reliability, where it scores similar (70-75%) to Lagos' BRT Lite (Adebambo and Adebayo, 2009; City of Cape Town, 2018). Yet reliability is an area where full-specification BRT is expected to fare better than BRT Lite. Meanwhile, Johannesburg's Rea Vaya scores only around 70% for overall satisfaction (City of Johannesburg, 2017). These differences may have as much to do with variations in surveying methodology as real differences in service quality; in addition, customer satisfaction is affected by much more than BRT design. It appears we do not have enough evidence to link BRT specification and performance directly to passenger satisfaction (and thus attraction) (Behrens and Schalekamp, 2010, 2011).

Overall, the economics around the interaction between station and running way design, fleet specification, and passenger access need better analysis. The long-term impacts of these factors on performance and financial sustainability are not well understood, nor is it clear whether the capital-intensive schemes, referencing both infrastructure and rolling stock, are affordable in much of SSA.

Traffic law enforcement

The effectiveness of dedicated lanes is highly sensitive to incursion by other vehicles. Experience in SSA has shown that this can at times be a significant problem, and that special coordination efforts may be required to ensure adequate enforcement of bus lanes.

In Accra, the lack of sufficient regulation denied the pilot BRT scheme legal status and prevented traffic police from enforcing bus lanes. This was considered one of the main factors contributing to its demise (Okoye et al., 2010). In Lagos, LAMATA had to coordinate with the Lagos State Traffic Management Authority (LASTMA) to commit the resources needed to protect BRT Lite's exclusive use of its infrastructure and to manage traffic conflicts at junctions (Kaenzig et al., 2010). Despite this, incursion of private vehicles into the BRT lanes remained a problem (Mason-Jones and Cohen, 2012).

Vehicle specification and finance

Bus specification

Vehicle specification and procurement has proven to be a critical success factor not only for the implementability of public transport projects in Africa, but also for their financial sustainability. The financing of vehicles has implications for the ability of incumbent operators to successfully participate in upgraded public transport projects. As a result of these factors, vehicle procurement has been a contentious issue in many of the projects reviewed.

The acquisition of vehicles is a large expense, which has to be offset by system revenues over the course of the vehicle's service life. There have been several examples of vehicles being over-specified (i.e. more expensive than needed for the purpose), contributing to financial failure of the entire system. Before 2009, the Lagos State Government (LASG) had procured buses through Lagbus Asset Management Ltd (Lagbus), to be deployed on a priority (non-BRT) bus network in Lagos. The buses were to be bought by Lagbus, and leased to the private sector operator, but the state failed to consult adequately with transport operators in making its vehicle selection. The chosen bus from Marcopolo in Brazil was deemed so expensive - and the resulting lease charges to be paid by operators so high - that all of the main passenger transporters in Nigeria declined to participate in the scheme, leading to its collapse (Integrated Transport Planning Ltd, 2009). The pattern was repeated with LASG's 2017 Bus Reform Initiative (BRI) which included the procurement of 820 buses to be deployed to private operators. The high vehicle specification (including low-floor design, automatic transmission, air-conditioning, and wifi) is reported to have an adverse impact on the project's cost recovery (Osiyemi, 2019).

For BRT systems in Africa, the standard 12m bus appears to be the most popular vehicle, for both on-trunk and offtrunk operations, due to its flexibility and availability; in some cases smaller vehicles are used, for instance the 9m buses selected by Cape Town for their feeder services, and 18m articulated vehicles used for trunk operations in Johannesburg, Tshwane and Dar es Salaam

³² In 2019 dollars. This includes 31km of trunk, although the system also operates 375km of off-trunk express and feeder services.

Figure 4. Examples of vehicles used in new public transport systems





(a) Articulated high-floor bus used on trunk routes, Johannesburg BRT (Source: City of Johannesburg)



(c) 8m smaller bus used for feeder services, Cape Town BRT (Source: City of Cape Town)

(see Figure 4). Yet there are questions as to whether articulated vehicles are worth the extra cost, given their underperformance in terms of capacity (Bulman et al., 2014), inefficiency for off-peak operation, and specialised maintenance and depot requirements.

A key issue in setting vehicle standards is the trade-off between purchase price and maintenance costs. The trend appears to be towards more basic vehicles with a lower price tag but shorter economic life cycles, compared to more modern city buses used in richer countries. Greenwood (2011) argues that the basic vehicles' robustness is better suited to the poor road conditions of African cities, and these preclude super-low floor

(b) Standard low-floor bus with doors on both sides, Tshwane BRT (Source: City of Tshwane)



(d) Light rail vehicle, Addis Ababa LRT (Source: C Venter)

designs. However, this may forego some of the environmental and passenger attraction benefits of better buses, albeit that higher seating ratios and better ride comfort are easier to provide on higher floor designs.

In addition, even basic vehicle maintenance has proven to be challenging where the level of professional experience in bus management is low. For example, Lagos' initial BRT fleet consisted of 100 high-floor buses (conventional truck-derivative chassis from Ashok Leyland built in India) with high regular maintenance requirements. However, insufficient maintenance led to bus unavailability and declining service quality once the buses were out of their finance period (during which time maintenance had been provided by the manufacturer), partially owing to questionable management capacity among the unions contracted to operate the service (Greenwood, 2011; Mason-Jones and Cohen, 2012). This is one of the strongest arguments for vehicle acquisition through operating leases incorporating maintenance contracts, as all the necessary incentives for optimising life cycles are aligned.

The availability of suitable buses in Africa is sometimes a constraint, but this often reflects the duty and taxation treatments of imports. In South Africa the quantum of investment in BRT has stimulated local assembly of buses. However the same is not true for other parts of Africa, where locally assembled buses are typically for rural or long-distance service, with inadequate accessibility standards and internal passenger flow needed for urban operations. Plans for assembly of specifically urban buses have been frustrated by the requirement of the authorities for non-standard vehicles for planned BRT systems that have uncertain markets both locally and regionally. Examples of stranded bus assembly facilities can be found in Ghana, Ethiopia, Kenya, Nigeria, Tanzania, and Zimbabwe.

An approach sometimes taken is to base bus specification on international standards such as the Indian JnNURM³³ standards used for Nairobi's BRT specifications, to ensure affordability and availability of bus stock and spares. Unfortunately the importation of vehicles from abroad often attracts significant additional costs – in Kenya duties and taxes of 85% would be levied on imports of fully built-up buses. Nairobi project planners stated that the BRT would be financially unviable unless the government agreed to waive these charges, which they have done for other similar schemes in the past.

Research is needed on measures to promote regional assembly or manufacture of buses, how this relates to market size and investment strategies, and appropriate standards for road-based public transport vehicles.

Financing of vehicles

The financing of vehicles is problematic because the economics of urban public transport in Africa do not favour commercial operations. It has proven very difficult to secure commercial finance for fleets over a five-year period (the typical term required for capital affordability), as the loan cannot be serviced based on typical current fare levels even at relatively low international interest rates, given local affordability and vehicle productivity constraints (see discussion on contextual factors above). For full cost recovery of new buses at current fares, financing needs to have a tenor of 8 to 10 years, and the investor needs to have operating security over at least that period. Commercial lenders also tend to see public transport as risky, given the failure of earlier initiatives to encourage fleet investment of long distance services (Godard, 2013; Integrated Transport Planning Ltd, 2009).

The preferred approach for some systems has been to engage in operating leases, where only some 70% of the capital cost needs to be financed in the first five years, with the rest financed separately later. Operating leases for technical equipment in Africa typically include a maintenance contract that should ensure high levels of vehicle availability and reliability, and maximise residual value for on-sale after completion of the service life. However, this usually requires extra security to come from government, to reduce the risk financiers are exposed to. One way of doing so is to obtain a lien on the revenues generated from passenger fares, which is facilitated by a centralised fare collection agency separate from the operator. In the case of Lagos, the bank was given the right to act as ticket distributor and security monitor. However, the banks still required the participating operators to accept collective liability for all the obligations that they had entered into, notwithstanding the fact that the vehicle supplier helped by offering to accept deferred payment over two years (Integrated Transport Planning Ltd, 2009).

The question of vehicle ownership is important, as the requirement that private operators should own the vehicles has been identified as a major stumbling block for local bus operators (including formalised paratransit) to enter the market (Rizzo, 2014). The other alternative is for government to procure the vehicles, in an effort to exert greater control over all aspects of the project, and to reduce the barriers to entry for private companies wishing to participate as bus operators. For this reason the South African government insists on cities owning buses as a condition of obtaining funding (Manuel and Behrens, 2018); buses are then leased to the operating companies. The problems with this approach, though, is the risk that public procurement will significantly raise the capital

33 See footnote 28.

costs of projects and reduce their rates of return. In both Lagos and Accra, the prices paid were three times those available from other sources for vehicles that met the same functional specification.

Whichever path is taken with the ownership of rolling stock, international experience has shown that designing appropriate risk allocation mechanisms between the public and private sector is critical to successful fleet procurement. This goes hand-in-hand with the development of a credible business plan. In addition, a review of the vehicle procurement process in Lagos noted that *"the primary lesson for the sustainability of BRT initia-tives in Lagos... is that the terms for the financing of roll-fing stock need to be realistic and affordable both for the financier and for the operator and passengers"*, taking issues like possible project delays and the need for longer repayment periods, given low fare levels, into account (Integrated Transport Planning Ltd, 2009:53).

Passenger access

Universal design

Most public transport initiatives have the improvement of physical access as a stated goal. In South Africa, universal access on all new rail and BRT vehicles and infrastructure is a prerequisite for any state funding. Some cities have made significant strides in improving accessibility (Aboo and Robertson, 2016; Adewumi and Allopi, 2014); Cape Town's MyCiti project has been lauded by international access organisations for its accessibility policy³⁴. Gautrain stations and rolling stock are fully wheelchair accessible. Full or partial step-free access is also a feature of BRTs in Lagos (through the use of buses with lower floors and manually deployed ramps (Gorham, 2017), Dar es Salaam, and Kampala (Ephraim et al., 2014).

This progress notwithstanding, passengers with mobility impairments still experience problems gaining access to BRT and rail³⁵. (Marmolejo, 2010) reported protests by Lagosian passengers with disabilities regarding accessibility to the system. Nallet (2018) reports that on the Addis Ababa LRT, amenities to provide access to stations (lifts and escalators) are generally out of service. It is likely that better management, maintenance, and ongoing monitoring systems are needed to ensure that improved (if not universal) access becomes a reliable feature of upgraded public transport systems rather than just a goal stated in policy documents and marketing material.

We note that the feasibility of providing full wheelchair access to all public transport users is not universally accepted. Some designers interviewed for this paper were of the opinion that the demand for full access cannot be satisfied on initial public transport projects within present affordability constraints, but is rather a long-term aspiration that will be realised over time. Others contend that the procurement of new vehicles presents an opportunity for extending full access to the many passengers excluded from current systems. This issue is contentious and political in nature, and requires further research.

Street and precinct access

Compared to the amount of literature on the design and deployment of vehicles and rights-of-way, relatively scant research attention has been paid to access to/ from public transport stops and stations. The safety of pedestrians around BRT and LRT stations in Ethiopia and Nigeria has been researched by Imamoglu and Abubakar (2017) and Olawole (2012), who identified poor sidewalk conditions, lack of safe medians and islands, poorly constructed ramps and stairs, and insufficient night lighting as problems. Regarding off-trunk access to public transport, what research there is generally concludes that it is of poor quality. Key issues include poor road conditions and a lack of sidewalk infrastructure on access roads. In Accra, residents identify encroachment of vendors on roads and streets (41%), and illegal parking on and alongside roads (33%), as among their major transport concerns (Okoye et al., 2010).

It is now common practice for BRT Classic projects to include the construction of kerbed sidewalks and bicycle lanes along trunk corridors and stations³⁶, as well as features such as raised pedestrian crossings and speed humps to calm traffic on adjacent streets. Adopting such pedestrian-centered design accords with international best practice (Welle et al., 2015). Yet some questions specific to African cities remain. For instance, the provision of bicycle lanes adjacent to trunk bus routes has been questioned as an urban cycling policy intervention, given cultural barriers to cycling and the shortage of cycling supportive measures inside catchment areas

³⁴ See https://zeroproject.org/policy/cape-town/

³⁵ The MAC position paper on user needs and practices provides a broader overview of the state of access to public transport in general. We focus here only on access on upgraded systems.

³⁶ The World Bank-funded urban transport projects in Dar es Salaam, Dakar and Abidjan include specific components for improving pedestrian and bicyclist accessibility to the BRT corridor and public transport system to ensure last-mile accessibility for BRT users (see footnote 13).

(Morgan, 2019a, 2019b). In addition, anecdotal evidence suggests that ongoing enforcement and management is needed to prevent encroachment and illegal use of these facilities by motorcycles and traders, severely reducing the value of these access investments. Furthermore, the practice of using unsignalised crossings at stations as a way of lowering construction costs is considered unsafe by some interviewees, especially given the high traffic volumes and speeds that are typical around stations; such crossings also impose delays on general traffic, which does much to offset the gains made by the ridership. The alternative of over-bridges is costly, socially exclusive, and acts as its own barrier to accessibility. Further empirical research into actual usage patterns, benefits, and costs of non-motorised infrastructure would be useful.

A final point: passengers in Africa walk longer distances to public transport than elsewhere in the world, often because of fares structures that discriminate against transfer. In Lagos, a quarter of BRT Lite passengers walked more than 500m to the BRT stop (Olawole, 2012). Recent evidence from South Africa suggests that passengers value walking time, waiting time, and the quality and safety of the access trip more highly than travel time savings once they are on the bus (Venter, 2019; Venter, 2018)³⁷.

All of this suggests that the access trip is of greater importance in facilitating (or preventing) the use of public transport than typically supposed, and deserves greater attention. Unfortunately, the attention (and budgets) of public transport projects rarely seem to extend further than the corridor being implemented and the area immediately surrounding stations.

System interchange and modal integration

System-level integration with other modes

The incremental nature of public transport modernisation projects in Africa means that new services have to co-exist with existing services, probably for many years into the future (Salazar Ferro and Behrens, 2015). Since new routes serve only a small proportion of origindestination patterns, most passengers do not depend solely on new BRT or rail services for their mobility needs. This is borne out when looking at modal connections: in both Lagos and Dar es Salaam, about two-thirds of BRT users also use mini-, midi-bus, or motorcycle taxis on the same trip (Chengula and Kombe, 2017; Integrated Transport Planning Ltd, 2009). In Addis Ababa this is 75% (Nallet, 2018).

So obviously there is a high level of de facto integration between new and existing services. Several studies have argued that this integration is generally haphazard, and results in sub-optimal user experiences including excessive waiting and double fare payments (Behrens et al., 2017; Chengula and Kombe, 2017). In no system, other than Nairobi, is the potential for integration through the ticketing system recognised, although there, as in South Africa, there is a regulatory barrier for BRT systems specifically precluding this.

It follows that the interface between new services and existing informal services is a critical issue for integration. Authorities have taken different approaches towards managing this interface. In Lagos, LAMATA planned for interchange between their BRT Lite and informal modes at three terminals, but left it to individual paratransit operators to decide how and when to provide 'last kilometre' connectivity (Kumar et al., 2011). Existing mini- and midi-buses that operated along the corridor were not outright replaced by BRT but merely prevented from operating on the main road. They could continue plying on adjacent streets and service roads. This "self-balanced, partial regulation" (Kaenzig et al., 2010) had the benefit of ensuring community and operator buy-in, and providing additional capacity that could not be met by the BRT Lite³⁸. There was some evidence of spontaneous reorganisation: those still operating independently appear to have adjusted their routes to provide shorter-distance services and capture demand overflow fromtheBRTLitesystem(Mason-JonesandCohen,2012). However, over time, service levels went down as significant numbers of passengers migrated to the BRT Lite (Kumar et al., 2011).

In Dar es Salaam (as in Cape Town and Johannesburg), informal operators were treated more harshly, and initially entirely prohibited from operating along BRT corridors; however this condition was relaxed once it became apparent that the system lacked capacity and/or affordability of fares. Integration with informal *dala dalas* is accommodated in a number of end-of-line and on-

³⁷ This touches on issues of appraisal, and whether the economic value of time savings used to justify projects correctly reflect passenger perceptions, which is a related knowledge gap in Africa.

³⁸ An additional benefit was that main road traffic flow sped up through the removal of slow vehicles that, historically, had a habit of stopping in the carriageway and disrupting other traffic (Integrated Transport Planning Ltd, 2009).

Figure 5. Examples of modal integration facilities



(a) Main CBD transfer station between trunk and feeder services, Cape Town BRT (Source: C Venter)



(b) Terminal transfer station between DART buses and dala dalas, Dar es Salaam (Source: G Haves)

trunk transfer terminals and stations (see Figure 5), with reasonable standards of accessibility. Nevertheless, integration with feeder and tributary routes at other locations is incomplete; only two DART feeder routes have been put into operation, and DART stations are criticised for not being aligned with stops and stands of other modes (Chengula and Kombe, 2017). Planners for Phase 2 reported that they are paying more attention to integration with informal operators, private cars (via parkand-ride), and the standard gauge railway³⁹.

In South African cities, experiences with intermodal integration are variable. The regulatory requirement for integrated metropolitan transport planning pushes cities to consider integration at least during route alignment and the siting of terminals and stations, so as to minimise walking distances between different modes. Thus there are examples of good intermodal connectivity between bus and rail systems such as Gautrain and some Prasa (commuter rail) stations, for example the Park Station precinct in Johannesburg and the Claremont interchange in Cape Town (Verster, 2004, 2010). Some local authorities have put considerable effort into upgrading and managing transfer facilities. As a result, a recent study on the first/last kilometre connectivity of Gautrain, Rea Vaya, and A Re Yeng (City of Tshwane) concluded that integration with other modes was reasonably good, but that suburban locations were worse than more central ones (Venter, 2019).

This applies mostly to formal modes; in general, integration of BRT with paratransit (minibus-taxi) routes is regarded as relatively poor (Adewumi and Allopi, 2014; Salazar Ferro et al., 2013). Recent high-profile attempts at integrating bus or BRT with taxi routes in Tshwane and Bloemfontein have failed, partly due to the difficulty of managing relations with the industry⁴⁰. Klopp et al. (2019) link this failure to plan for proper integration with informal modes with the implicit goal of BRT - of displacing and modernising informal transport. Even if a future role is foreseen for informal operators as feeders to BRTs, structured plans detailing this vision are lacking (Klopp and Cavoli, 2019). Researchers at the University of Cape Town have studied the difficulties in coordinating formal bus and rail with informal taxi services at the Mitchell's Plain interchange, and conclude that lower-cost incentive-based interventions may be more effective at moving towards hybrid systems than current formalisation models (Behrens et al., 2017; Plano et al., 2019).

There is furthermore a surprising lack of attention being paid to integration of public transport with private car modes. Van Rensburg and Behrens (2011), and Wentley and Hitge (2013), studied park-and-ride use at commuter rail stations in Cape Town, and found variable evidence of car users diverting to rail. BRT systems on the continent have an almost universal absence of park and ride facilities – a fact that underscores its positioning as an

³⁹ Information provided by E Hema, DART, September 2019.

⁴⁰ See https://www.bloemfonteincourant.co.za/white-elephant-taxi-rank-1-step-closer-opened/

alternative to other public transport modes, rather than to the private car. The only counterexample is Gautrain, which has invested significantly in parking structures at most stations, and competes (quite successfully) with the private car (Du Plessis, 2010). Nairobi also had park-and-ride provision for its premium transit service offer, which proved particularly attractive for those who struggled to find parking in the CBD.

Regarding the reasons for the neglect of intermodal integration, several studies have highlighted the lack of institutional coordination as a key contributing factor. For example, in Addis Ababa, the fact that the LRT was implemented by the Ethiopian central government and operated by its own company, accounts for its disconnect from municipal coordination programmes (Nallet, 2018). However, it has been argued that better institutional alignment will not necessarily lead to better user experiences. After reviewing the quality of public transport interchanges in Cape Town and comparing them with similar ones in Latin America, Schalekamp and Behrens (2007) conclude that the problem is more fundamental: design approaches and guidelines need a reorientation towards the needs of users rather than the needs of vehicles⁴¹.

Another factor contributing to poor integration is the tendency to deliver trunk routes (rail or BRT) as standalone projects, which takes so much capital and time from city officials that the rest of the network gets little attention. The end result is that effective integration of the new project into the city fabric is not a key concern, as perhaps it would be if the project were more integrated with city processes. Klopp et al. (2019) illustrate this point by contrasting the examples of Nairobi, where the BRT project is largely driven by the concerns of external funders, with Johannesburg, where the delivery of Rea Vaya has been embedded within urban management processes through the involvement of multiple city departments. The travel time advantages of a potential BRT trunk or rail line could be much larger if it were not limited to the main roads but reached further into areas with high residential densities, especially those with poverty populations (Vermeiren et al., 2015). In response, recent BRT planning projects in Dakar and Abidjan have dedicated funds specifically for the integration of BRT into the rest of the urban transport network, including an upgraded artisanal (informal) transport network⁴².

Information integration

Effective integration depends not only on connecting routes, but also on providing users with accurate and easy to use information about different services. Passenger information has not received much specific research attention, apart from a few studies touching on information accessibility to persons with disabilities (Mashiri et al., 2005; Smit and Davies, 2012). South African BRTs and Gautrain are implementing better static and digital information practices (Smit and Davies, 2012; Vanderschuren and Awotar, 2012). Studies including information as an element of the general service quality of public transport have found its quality variable (Behrens and Schalekamp, 2010; Luke and Heyns, 2017; Mokonyama and Venter, 2013; Schalekamp and Behrens, 2007; Verster, 2010; Vilakazi and Govender, 2014). One reason is that, apart from information on train delays, information quality seems not to be high on the list of passengers' priorities, as compared to issues of availability, affordability, and security from crime (Venter, 2019; Verster, 2010).

At a network level, a key problem is that very little information is systematically collected on informal services, making passengers dependent on word-of-mouth for route or fare information. This situation is changing in promising ways. Klopp and Cavoli (2017, 2019) and Klopp et al. (2017) review emerging efforts at collecting paratransit route information using mobile apps, and foresee that this information will over time become easier for passengers to access for trip planning and real-time tracking purposes (Mehndiratta and Rodriguez, 2017).

Fare policy and ticketing

The introduction of new services necessitates a formalisation of fare structures, levels, and technologies as fare policy can either promote or hinder the reaching of the project's overall goals. The World Bank Toolkit on Fare Collection Systems (2011) provides useful coverage of the issues involved⁴³.

Fare structures

A first objective of fare policies is often to regulate the fare structure, which on informal modes is typically

⁴¹ These issues are dealt with in more detail in the VREF MAC position paper: Porter, G., Abane, A., Lucas, K. (2020). User diversity and mobility practices in Sub-Saharan African cities: understanding the needs of vulnerable populations. The state of knowledge and research.

⁴² See World Bank documents cited in footnote 13.

 $^{43\} See https://www.ssatp.org/sites/ssatp/files/publications/Toolkits/Fares\%20Toolkit\%20content/index.html$

unpredictable, exposing users to fare gouging practices. It is common for paratransit drivers to raise fares depending on weather and time of day, or even shortly after an increase in fuel prices has been announced (Agyemang, 2015; Kaenzig et al., 2010).

Fare formalisation usually adopts fixed prices linked to a formal ticketing system. Most systems adopt some form of distance-based pricing, with the fare rising with trip distance. Lagos' pilot BRT corridor used a simple two-zone fare structure (each zone approximately 10km long), deliberately designed to deter short-distance trips to prevent overwhelming the system's limited capacity. DART operates a flat fare system for its trunk operations, but feeder services (i.e. longer trips) are charged separately. Rea Vaya used the same approach in the first few years of its operation, but switched to a more sophisticated distance-based structure with finer graduations. The latter is now the preferred approach in South African BRTs, Gautrain, and the Addis Ababa LRT.

The fare structure implies important trade-offs between the interests of users and operators. The use of distance-based fares is in line with international practice, as it is most efficient for operators if fares reflect costs and if passengers generally recognise the value offer. However, flat fares can be easier and cheaper to collect, though they penalise interchange heavily. Flat fares (or at least tapered fares, where the rate per kilometre reduces with distance) are also more beneficial for passengers traveling long distances, and are often associated with pro-poor equity outcomes (Peralta Quirós and Hernandez, 2016). This might be an important policy goal in SSA cities, given their inefficient land use patterns and the current peripheralisation of poverty. Surprisingly little empirical or analytical work has looked at the interaction between fare structures and fare levels, and the economic viability and social impacts of public transport systems in SSA cities.

Fare levels

Outside South Africa, fare levels are driven by the need to recover the costs of operation fully, given the reluctance of governments and funders to provide long-term operational subsidies, the reluctance of private sector operators to rely on subsidy payments, and the high levels of taxation levied on formal operators. For cost recovery with BRT Classic standards, this results in fares that are set above existing (informal mode) fare levels. The usual argument is that passengers should be willing to pay them in exchange for better service quality. There is evidence that some users are willing and able to do so, but many more cannot, and there is no clarity as to the quality requirements actually required. For instance, the pre-feasibility study for Kampala's BRT found a willingness among current public transport users to pay a small surplus (above existing fares) for a comfortable, less congested ride (Vermeiren et al., 2015). A survey of DART passengers found that 55% of respondents choose the BRT system because of time saving, security from theft, and comfort, and not because it is cheaper than the *dala dala* (which it is not) (Chengula and Kombe, 2017).

In South Africa, with its more substantial resources, public transport fares are set at or just below those of minibus-taxis (paratransit). Thus many passengers save money: a survey in Soweto found that about two-thirds of Rea Vaya users save on average R2.50 per trip, which is a significant 21% saving in travel cost (Vaz and Venter, 2012). However the remaining third reported paying more for their trip, especially those involving transfers between modes. The average saving is negligible.

Users who benefit have been shown to be particularly those who take longer trips, especially where previously multiple trips on paratransit are replaced by a single trip on the new public transport system. In Dar es Salaam, Ahferom (2009) found that longer-distance passengers (from Kimara to Kivukoni and Kariakoo terminals) save by avoiding the double fare paid previously when transferring between *dala dalas*. In Lagos, trips along the full BRT Lite corridor are cheaper than by alternative modes due to a lower need to interchange (Integrated Transport Planning Ltd (ITP), 2009). The Addis Ababa LRT is priced competitively with the paratransit (minibus) there, especially for longer journeys (Nallet, 2018).

The concern is that many passengers who face *higher* fares with the new BRT or rail system are priced off public transport altogether. There is a high chance these are the poorest passengers who are at present not able to afford any form of public transport, but depend on walking to get around (Vermeiren et al., 2015). Vaz and Venter(2012)foundevidencethatReaVayabenefitsmore middle-income than low-income users, partly because of its higher fares than the competing metrorail services;

Rizzo (2014) identified a similar impact for Dar es Salaam. This is in fact a concern with BRT systems worldwide (Venter et al., 2018).

Ticketing technology

Most systems start up with paper tickets, for reasons of ease of use while users and operators are still getting used to new systems. In Lagos, high-security preprinted tickets were colour-coded for single-zone or double-zone trips, to make validation easier⁴⁴, while Rea Vaya used colour-coding to differentiate between trunk and feeder tickets.

Tickets are typically sold on an agency basis at dispersed kiosks and stations prior to entry. Not having employees handle cash is an effective strategy for fighting pilferage and securing revenues, which could be critical to gaining financing (Integrated Transport Planning Ltd, 2009). However, the availability of ticket outlets needs to be carefully considered, as it has been flagged as insufficient in both Dar es Salaam (Chengula and Kombe, 2017) and Cape Town (Ugo, 2014). The practice of making casual tickets available for sale only in the BRT stations can result in excessive queuing, and present an obvious target for robbery.

The switch to smart-card automated fare collection (AFC) seems to be problematic in general, leading to implementation delays or operational problems. In no systems outside South Africa has the transition to AFC been made successfully, despite the stated intention of doing so. In Dar es Salaam, problems with the implementation of the smart-card system meant that paper tickets, intended for casual use, have become the main medium. However, because these are purchased at kiosks inside stations with inadequate numbers of attendants, this leads to long queues. Chengula and Kombe (2017) report that more than half of respondents in a survey were not satisfied with the general services provided by the ticketing agency.

In the case of Rea Vaya, the replacement of paper tickets with EMV-standard smart cards significantly reduced ridership (Hunter van Ryneveld, 2014). EMV cards require a banked and credit-worthy user base, and may impose a transaction fee every time a passenger tops up a card (Joubert and Biermann, 2010) – both features that are problematic in cost-sensitive and unbanked user populations. This is clearly not viable in a cost-sensitive user population. In Tshwane, the entire AFC system had to be replaced after the initial one was found to be unfit for purpose after its implementation. The fact that AFC systems tend to be closed and proprietary systems limits flexibility and interoperability (Joubert and Biermann, 2010)⁴⁵.

A potentially valuable feature of AFC systems is its ability to provide rich data on passenger demand patterns. Coupled with automated system information (like vehicle location), this can be a rich source of management information for forward planning and real-time monitoring. However, it appears that operators have generally been unable to exploit the richness of the data that comes with AFC and other systems (Klopp et al., 2019). This has been linked, in the case of Lagos, to the relative inexperience of the operator (former informal operators) with the operation of a large-scale scheduled bus service (Integrated Transport Planning Ltd, 2009). In effect their prior skills had been based on the management of terminals, with vehicle queuing and passenger boarding being their priorities, with little or no control along the route. Operational problems such as severe bunching and unreliability resulted, which prompted LAMATA to step in to provide additional expertise.

The role of fares and ticketing in modal integration

Modal integration requires that there be no financial penalty for making a transfer. There also needs to be common ticketing across all modes, to reduce the non-tariff penalty of transferring. As stated above, formal systems deal with this matter reasonably well with regard to within-system transfers. However, in terms of crossmode pricing and ticketing, Africa's rail and BRT systems have not progressed far (Joubert and Biermann, 2010). Some South African cities appear to be the most advanced by providing for common smart-card use across municipal bus and BRT services, and working towards integrating with rail services⁴⁶. Some minibus-taxi groupings have experimented with cashless ticketing, but none have lasted (Tinka and Behrens, 2019). The

⁴⁴ Even so, conductors had trouble preventing overriding, which resulted in revenue losses (Integrated Transport Planning Ltd, 2009).

⁴⁵ An alternative approach, developed for Nairobi but not implemented, was to exploit the Kenyan lead in mobile payments, and the widespread availability of smart-phones and 4G networks, to develop an integrated fare collection system using QR codes for validation. These can either be displayed on the smart-phone, through which payment is made, or on a printed ticket purchased at a kiosk. Fast-response QR code readers can be used for the formal system, and operator smart-phones for the informal, with low capital costs. Payment transfers can be managed through the established mobile network, with cloud-based back-office functions. Automatic vehicle location can also be provided through the location capability of smart-phones.

⁴⁶ See http://m.engineeringnews.co.za/article/gauteng-aims-for-integrated-public-transport-ticketing-in-2020-2018-06-20

correct combination of institutional trust, technology, and user acceptance still has to be found to move towards fare integration involving informal modes (Schalekamp et al., 2017).

There appears to be a knowledge gap in terms of understanding the barriers and success factors relating to fare integration in SSA public transport. The first requirement is to have an independent fares collection agency, acting under contract to the relevant authority, to whom all fares payments are made and from whom all operators receive their reward. Such a system was set up for BRT Lite in Lagos, under the control of the counterpart bank for the bus finance. This meant that all system payments were secure, and that the vehicle supplier was able to hold the lien on the revenue stream required for an extended tenor on the bus finance (Integrated Transport Planning Ltd, 2009).

STATE OF RESEARCH CAPACITY

This section provides a brief review of existing research capacity in the field of transport systems planning and engineering in Sub-Saharan Africa, in particular in system design and modal integration in public transport systems in the SSA context. For the purpose of the assessment, guided by the literature review of Behrens et al. (2015b) and based on previous engagements of the authors with universities in these countries, universities in seven countries were selected. Further details of the research activities in the selected universities were then obtained through a web search.

The countries surveyed are South Africa, Ghana, Nigeria, Ethiopia, Kenya, Tanzania, and Rwanda. The first three countries were included because of the published peer reviewed research output emerging from South Africa, Ghana and Nigeria, see Behrens et al (2015b), and the other four countries have well-known research groupings that work on transport systems research in general. This preselection does bear the risk that important resources have been overlooked, as web presence is not necessarily an indication of research excellence, in addition to a clear bias towards Anglophone countries.

The desktop-based inventory for each country was conducted based on the following checklist:

- Output and impact of peer-reviewed literature in the field of public transport systems, in particular system design and modal integration

 a. South Africa, Ghana, Nigeria
- 2. Research capacity in terms of:
 - a. Staffing
 - b. Programmes offered
 - c. Degree options
- 3. Research facilities
- 4. Existing collaborations at the national, regional and international level

The results of the survey are reported in Appendix C.

Based on the analysis, the most prominent research institutions in Africa that undertake research on public transport systems are, by Sub-Saharan Africa region:

 West Africa: Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, and University of Ghana (UG), Accra

KNUST houses the Regional Transport Research and Education Centre, Kumasi (TRECK), which is a World Bank Africa Centre of Excellence (ACE). One of TRECK's research lines is on Sustainable Urban Public Transport Systems, Gender and Governance.

The University of Ghana houses transport systems expertise in the Department of Geography and Resources Development.

• East Africa: University of Nairobi (UoN)

The University of Nairobi's Institute of Development Studies (IDS) is particularly well-known in the transport space. Their focus is transport-related social exclusion, and development impact of transport systems. The Centre for Urban Research and Innovations (CURI) is also part of the UoN, and has a City Lab that houses big data on public transport operations.

• Southern Africa: University of Cape Town (UCT), University of Pretoria (UP), Stellenbosch University (SUN), University of Johannesburg (UJ)

Several universities in South Africa conduct research in public transport system design, mostly published in international peer-reviewed literature.

In terms of facilities for research, computer laboratory and library facilities in the South African universities are mostly world-class, whereas computer laboratory and library facilities in the Kenyan and Ghanaian universities are of sufficient standard for research at the level of postgraduate studies.

KEY RESEARCH GAPS

The following key research questions emerged from the foregoing review, and may be helpful in fashioning a research approach around public transport system design in Sub-Saharan Africa.

- **Planning and political processes:** There are cross-cutting themes between this paper and the position paper Governing Mobility in Sub-Saharan African cities (Cirolia, et al, 2020), that need to be explored. These relate *inter alia* to:
 - the roles of different planning and funding agencies in adopting (or resisting) specific technologies or standards, and their motivations for doing so;
 - the interaction between government agencies, operator groupings, and communities in the planning process and its outcomes;
 - appropriate institutional relationships between local and central governments in relation to public transport implementation, particularly with regard to the ownership of roads and the control of funding; and
 - corruption and incompetence within government – this is a significant issue that researchers shy away from, but on which we need better insight in order to understand implementation choices and the path dependencies they create.
 - Systematic documentation of project information: The knowledge base on the technical aspects of implemented projects in Africa is very thin and variable. This is true, although less so, even in South Africa, with its more substantial professional and academic resource base. The involvement of international contractors in planning, constructing, and operating public transport does not help to promote transparency. During the course of this review, the authors identified factually wrong statements

even in peer-reviewed articles. It is important to promote a systematic repository of project information – including data on operating costs and subsidies – to help aid in comparative analysis and learning.

- Standardisation of investment appraisal modalities: While individual project implementers will adopt appraisal approaches that reflect local goals, it is important that a standardised methodology is applied to allow comparison across cities. While acknowledging the political nature of benefit-cost analysis, its aim should be the identification of the best realistic alternatives to be adopted in response to the target objective(s).
- Appropriate standards and their consequent trade-offs: This study highlighted competing approaches in the design of BRT systems, and the fact that there is little agreement about which features of BRT are critical to their success, and which are optional *under* SSA *conditions*. Academic research could be making a much larger contribution to this debate by searching for evidence and conducting critical and unbiased analysis of implemented systems. Examples of key issues include:
 - network design: performance of trunk and feeder versus direct/tributary services
 - bus-lane design: median versus kerb-side alignments; requirements for dedicated lanes; transit-only streets
 - station design: open versus closed stations, and the interaction with ticket validation, boarding efficiency, and security.
 - vehicle standards: especially with regard to floor height, universal design, and internal layout
- Affordability: The issue of standards has a direct impact on system affordability, both in respect of the parties making the investments in

infrastructure, rolling stock, and any operational subsidy, and the fares paid by passengers. Affordability is absolutely critical to the future of public transport upgrading, but its links with various system design decisions are not clear.

- **Financing:** Research is needed with regard to sourcing, conditionalities and risks; appropriate mechanisms and their treatment in different jurisdictions; and available rates and tenors. There is a clear opportunity for greater involvement of scholars of economics and business studies in this research.
- Subsidisation of systems: Issues include both the economic justification of subsidisation in the development context, and effective mechanisms that accurately target those in real need. Potential sources of additional income need to be explored, such as climate funding.
- Impacts on specific stakeholder groups: Better implementation (and perhaps more success at motivating for funding) requires a better understanding of how public transport projects impact populations of different income levels, abilities, and needs, for instance in terms of improved employability, health or educational outcomes, and housing decisions. Impacts on other stakeholders such as incumbent transport operators, landowners, and businesses also need to be better understood.
- **Fare systems:** Much better insight is required into both the operational aspects of fare collection (e.g. how to set up independent fare collection agencies accountable to the municipality), and the user impacts of different fare structures, fare levels, and fare technologies. As digitally enabled fare collection systems emerge, better knowledge is needed of how they might enable or prevent access to public transport.
- Pathways to multimodal integration: Evidence-tested ideas are needed on what the roles of different modal operators, including legacy rail and bus systems, informal paratransit, and new BRT or rail systems should be in different multimodal contexts. The role of new mobility (e.g. e-hailing) should

also be added as these are shaping new opportunities for network integration (e.g. first/last mile trips). Much work is needed on examining different pathways to move towards such integration – i.e. processes, not just end-states.

- Harnessing of technology: We firstly need to better understand the barriers to deploying and integrating vehicle technology, fare technology, and operational systems in SSA transport. The role of technology suppliers and decision makers needs to be examined. Secondly, SSA cities have seen a mushrooming of cashless fare collection initiatives (e.g. *Gona* in Lagos), wayfinding apps (e.g. *Ma3Route* in Nairobi), and e-hailing systems (e.g. *Swvl* in Cairo)⁴⁷. These present opportunities for improving mobility that need to be examined and tested.
- **Relationships between transit and land-use change:** Descriptive work is needed to examine these two-way relationships, and to understand how the design and implementation decisions made by planners (e.g. technology choice, station spacing) affect or constrain the actions of private sector players in the land market. The levers that government players can deploy to promote desirable land use responses need to be better understood.
- Development of professional capacity in public transport: Significant knowledge regarding local operating conditions and passenger needs resides within the informal transport sector, but it is unclear how to exploit this for the purpose of delivering better services. Professional development is needed in all aspects of public transport planning, management, and operations.

⁴⁷ Interview: Roger Behrens

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Name

APPENDIX A: LIST OF INTERVIEWEES

The following people provided written or oral input to this report:

Organisation / Designation

Prof Roger Behrens	Professor/Director, Centre for Transport Studies, University of Cape Town, South Africa
Prof Eric Bruun	Professor Emeritus, Aalto University, Finland
Mr Samson Gyamera	Head, Greater Accra Passenger Transport Executive
Mr Chris Kost	Africa Director, Institute for Transportation and Development Policy, Nairobi
Prof David Mfinanga	Associate Professor, Department of Civil Engineering, University of Dares Salaam
Dr Dayo Mobereola	Former CEO of LAMATA, and later Commissioner for Transport, Lagos State Government
Mr Edwins Mukabanah	Managing Director, Kenya Bus Services (Management) Ltd
Mr Pieter Onderwater	Public Transport Planner / Urban Solutions, HATCH, Umhlanga, South Africa
Mr Bob Stanway	Semi-retired. Formerly Executive Director: Transportation, City of Johannesburg, 2003-2009
Prof Jackie Walters	Professor Emeritus, Transport and Supply Chain Management, University of Johannesburg, and special advisor to Southern African Bus Operators Association (SABOA)

APPENDIX B: KEY CHARACTERISTICS: BRT AND RAIL SYSTEMS STUDIED

BRT Systems: Accra, Dar-es-Salaam, Kampala, Lagos, Nairobi

Characteristic	Accra	Dar-es-Salaam	Kampala	Lagos	Nairobi
First project initiative	2004	2002	2008	2002	1997
Feasibility study	2004/05	2002/03	2009/10	2006/07 and 2009/10	2016/17
System launch	2016, as QBCs	2015 pilot 2016 full operation		2003, as painted lane 2008, as BRT Lite 2016, as BRT tributary	2018, as painted lane
Current status	System collapsed after informal competition	Line1operational Line2committed	Detail design not accepted	BRT-Lite and tributary under financial stress	Painted-lane launch contested
System authority	Assemblies (local)	City Councils	City Councils	State Governments	City Councils
System initiative	Min. of Transportation	Dar City Council	Min. of Works / Trans	Lagos State Gov't	Min. of Trans / Infra
System sponsor	Accra Metro. Ass'y	DART (spec. purpose)	Highways Authority	LaMATA	Highways Authority
System investor	World Bank	World Bank	World Bank	Lagos State Gov't	World Bank
System regulator	GAPTE (local)	SuMaTRA (nat'l)	GKMATA (nat'l)	LaMATA (local)	NaMATA (nat'l)
Rolling-stock investor	Min. of Transport	Gov't supported	Private	Private	Nat'l (MoTIHUD)
Operator	GAPTE (local)	Special purpose (nat'l)	Private	NURTW cooperative	Nat'I (NaMATA)
Running way location, design	Bilateral (part median)	Median	Median	Bilateral (trib. median)	Bilateral
Station location	Bilateral, offset	Median	Bilateral, offset	Bilateral, offset	Bilateral, offset
Station passing lanes	By lay-bys	On trunk, not CBD	Yes	By lay-bys	By lay-bys
Station access	At-grade, signalled	At-grade, un-signalled	At-grade, signalled	At-grade / over-bridge	At-grade, signalled
Station platform height	200mm	900mm	200mm	200mm	200mm
Busaccessibility	Stepped entry, E+2	Levelboarding	Stepped entry, E+2	Stepped entry, E+3	Stepped entry, E+1
Busconfiguration	2-axle rigid	Pusher articulated	2-axle rigid	2-axle rigid	2-axle rigid
Ticketingmedium	Smart card	Smart card/barcode	Printed	High security pre-print	2D barcode / mobile
Ticket point of sale	Dispersed	At stations	Rovingconductor	Kiosks and stations	Dispersed retail outlet
Ticket point of validation	On vehicle entry	At station entry	At ticket sale	On vehicle entry	On vehicle entry

BRT Systems: Johannesburg, Cape Town, Tshwane, Nelson Mandela Bay, Ekurhuleni

Characteristic	Johannesburg	Cape Town	Tshwane	Nelson Mandela Bay	Ekurhuleni
First project initiative	Na	ational Department of Tran	sport, Public Transport Ac	tion Plan and Strategy, 200	77
Feasibility launch	2009	2010	2014	2013, First pilot operations	2017
Current status	Phase 1A and 1B Operational	Phase1Operational	Phase1Operational (selected routes)	Not Operational	Starter route Operational
System authority	City of Johannesburg	City of Cape Town	CityofTshwane	Nelson Mandela Bay Municipality	City of Ekurhuleni
System initiative	National Department of Transport	National Department of Transport	National Department of Transport	National Department of Transport	National Department of Transport
System investor	National Treasury through City Support Programme: Public Transport Network Grant; Global Environmental Facility, Brazilian Development Bank (BNDES)	National Treasury through City Support Programme: Public Transport Network Grants to cities Individual cities			
System regulator	City of Johannesburg	City of Cape Town	City of Tshwane	Nelson Mandela Bay Municipality	City of Ekurhuleni
Operator	2 bus operating companies	4 Vehicle Operating Companies (VOC's): Kidrogen, Trans Peninsula Investments, Table Bay Area Rapid Transit, N2 Express	Public transport operators company		KTVR Bus Service
Running way location, design		A mix of BRT dedicated la	unes and mixed traffic on c	urrent road infrastructure	
Station location		Med	ian stations and roadside s	tops	
Station passing lanes			Yes		
Station access		At-g	rade dedicated lanes, sign	alled	
Station platform height	Raised platforms approximate 800mm	Raised platforms approximate 800mm	Low platform approximately 200mm	-	Raised platforms approximate 800mm
Bus accessibility	Right side: raised platform. Left side: step from pavement.	Right side: level ramp to raised platform. Left side: step from pavement	Right side: level ramp to raised platform. Left side: step from pavement	Right side: raised platform. Left side: step from pavement	Right side: level ramp to raised platform. Left side: step from pavement
Busconfiguration	Articulated and rigid	18m articulated bus/12m rigid bus/9m bus	Articulated and rigid	18m articulated bus/12m rigid bus/9m bus	Articulated and rigid
Ticketingmedium	Smart card	Smartcard	Smartcard	Smart card	Smart card, Paper ticketing
Ticket point of sale	Atstations	Dispersed, at stations	At stations	Atstations	Atstations
Ticket point of validation	At station entry, on vehicle entry	At station, on vehicle entry	At station entry, on vehicle entry	At station entry, on vehicle entry	At station entry, on vehicle entry
References	https://www.reavaya. org.za/ Klopp, J., Harber, J. & Quarshie, M. 2019. A Review of BRT as Public Transport Reform in African Cities	https://www.myciti.org. za/en/home/	Manuel, M. and Behrens, R., 2018. Success and delay in IPTN projects: case study analysis of three South African cities. http://www.tshwane. gov.za/sites/areyeng	Manuel, M. and Behrens, R., 2018. Success and delay in IPTN projects: case study analysis of three South African cities.	https://www.dbsa. org/EN/About-Us/ Projects-2017/Pages/ Ekurhuleni.aspx https://www. ekurhuleni.gov.za/

Rail Systems (empty cells denotes no information obtained)

Characteristic	Pretoria/Johannesburg (Gautrain)	Addis Ababa Abuja		Dakar
First project initiative	1999			
Feasibility study	1999-2000; procurement process (concession) between 2002 and 2005; 20 year concession with Bombela signed in 2006.			
System launch	Opened incrementally: first part in 2010 (OR Tambo – Sandton); Hatfield to Rosebank in June 2011; final part of network (Rosebank-Park) in June 2012	2015	2018	2019
Current status	Full system operational	Operational	Operational	Phase1Operational
System authority	Gautrain Management Agency (GMA)	Ethiopia Railway Corporation		Senegal government's APIX agency
System initiative	Gautrain Department of Roads and Public Transport	Ethiopia Government		Senegal government's APIX agency
System sponsor	System sponsor Initially Gautrain Department of Roads and Public Transport, later GMA Export-Import China		Federal Capital Territory Administration (FCTA), Exim Bank of China	African Development Bank, Islamic Development Bank, French Agency for Development, French Treasury, and Government of Senegal
System investor	Gauteng Province; National Treasury; Private sector banks for Bombela			
System regulator	Railway Safety Regulator (RSR) of South Africa	Ethiopia Railway Corporation		
Rolling-stock investor	Min. of Transport	Gov't supported	Private	Private
Operator	Bombela Concession Company (www.bombela.com)	Shenzhen Metro Group Company	China Civil Engineering Construction Corporation (CCECC)	
Running way location, design	At-grade, tunnel, viaduct; Standard gauge rail	At-grade and elevated; Standard Gauge	Standard gauge	Standard gauge
Routenetwork	Total 80km; two lines	Total 34.3km; Two lines use common track of about 2.7km	Total 45.2km. Two lines, Lot 1-17.89km and Lot 3- 27.2km	б5km
Stationlocation	10 stations among which are elevated stations, underground stations and at-grade stations	39 stations, among which are elevated stations, underground stations and at-grade stations	12 stations	14 stations
Station passing lanes	Double track, except single track between Sandton, Rosebank and Park stations	Double track for the whole route		
Train accessibility	Levelboarding	Levelboarding		
Train configuration	Four and eight car trains	6-axle double-articulated 70% low-floor Light Rail tramcar	Three trains with three rail cars each	15 Coradia Polyvalent trains. Each four-car trainset has a length of 72m
Ticketing medium	Smart card	Papertickets		
Ticket point of sale	Atstations	Atstations		
Ticket point of validation	At station entry	At stations, off-board		
References	www.gautrain.co.za; www.gma. com; www.bombela.com; www. gauteng.gov.za;	Mohapatra, D., 2015. An Economic Analysis of Light Rail Transit in Addis Ababa Ethiopia. <i>European</i> <i>Academic Research</i> , 3(3), pp.3114-3144. https://www.arogis.com/ apps/MapJournal/index. html?appid=a774317 d81ee43ee8bf2dbe 6c4505855	https://www.railway- technology.com/projects/ abuja-light-rail-system/ https://www.railway- technology.com/projects/ abuja-light-rail-system/.	https://www.railtech. com/policy/2019/01/23/ senegal-launches-first- express-train/. https://www.railway- technology.com/projects/ dakar-regional-express- train/

APPENDIX C: TRANSPORT RESEARCH GROUPS IN AFRICA

Country: Ethiopia

Institution	College/Faculty	Programme & Qualifications	Research	Existing Collaboration(s)	
				Local	International
Ethiopia Civil Service University	Urban Development & Engineering	BSc (Urban Planning) MSc (Urban Transport Planning &Management); PhD (Urban Mobility, Infrastructure Planning & Management)	Notknown		
Addis Ababa University	Addis Ababa Institute of Technology	BSc Civil Engineering MSc Roads & Transportation Engineering	Rail public transport, Bus based public transport, traffic engineering	Ethiopia Roads Authority; Ministry of Transport	Several, including University of Cape Town
Mekelle University	Ethiopian Institute of Technology, Mekellele	BSc Civil Engr, MSc, Roads & Transport Engr BSc Urban & Regional Planning	Notknown	Ethiopian Road Fund; Ethiopian Road Authority	Korea International Cooperation Agency (KOICA)
Hawassa University		BSo, MSo, Civil Engr	Notknown	Ministry of Urban Devt. & Construction	

Country: Kenya

Institution	College/Faculty	Programme & Qualifications	Accreditation	Existing Collaboration(s)	
			National	Local	International
University of Nairobi	Engineering	BSc, MSc, PhD Civil Engr With highway and transportation engr components Associate Degree	Public transport, 4IR, NMT	Jomo Kenyata University	Several, including John Hopkins University, USA; National Taiwan Technical University, Taiwan; Technical University of Applied Sciences – Wildau, Germany, University of Cape Town
Moi University	School of Engineering	BSo, MSo, PhD Civil Engr With highway and transportation components Diploma & Associate Degree in Civil Engr	Pavement engineering	Makerere University, Uganda; University of Dar-es-Salaam, Tanzania	Delft University of Technology, The Netherlands; Free University of Brussels, Belgium; Universitatet fuer Bodenkultur Vienna, Austria; University of Paris 6, France
Kenyatta University	School of Engineering and Technology	BSc Civil Engr Diploma, Civil Engr	Not known		
Jomo Kenyatta University of Agriculture & Technology		BSc, MSc, PhD Civil Engineering With highway and transportation components BSc Land Resource planning	Not known	Masinde Muliro University of Science and Technology, Kenya; Athi River Mining Company	Pennsylvania State University, USA; K.S. Rangasamy, College of Technology, India

Country: Tanzania

Institution	College/ Faculty	Programme & Qualifications	Research	ExistingCollaboration(s)	
				Local	International
University of Dar es Salaam	metric for the second s	BSc (Hons) Civil Engineering	BRT, NMT, pavement engineering		
	Dept. of Transportation & Geotechnical engineering	Postgraduate Diploma Transport Operations Management Postgraduate Diploma Civil Engineering with specialization in Transportation Engineering MSc Highway Engineering	BRT, NMT, pavement engineering		
Ardhi University	School of Urban & Regional planning	BSc Urban and Regional Planning BSc Regional Development Planning MSc Urban & Regional Planning and Mgt	Urban transport, rural transport		
National Institute of Transport		BSc Logistics & Transport Management BSc Accounting & Transport Finance Postgrad Diploma in Transport Engineering Management Postgraduate Diploma in Transport Economics Postgraduate Diploma in Logistics & Transport Management. MBA in Logistics & Transport Management	Not known	National Transport Corporation. Open University of Tanzania	International Purohasing and Supply Chain Management Consult (IPSCMC)

Country: South Africa

Institution	College/ Faculty	Programme & Qualifications	Research	ExistingCollab	oration(s)
				Local	International
University of Cape Town	Engineering & Built Environment	BSc Civil Engineering MSc, MPhil, PhD Transport Studies	Paratransit, Hybrid public transport, Highway engineering, Transport justice, Road safety	SAICE	ACET, University of Dar es Salaam, Volvo Research and Education Foundation (VREF) Research collaborations with institutions in Africa, Europe, China, South America, USA
WITSUniversity	Engineering & the Built Environment	BSc Eng Civil Engineering BSc Urban & Regional Planning MSc Development Planning DEng Civil Engineering	Accessibility, transport justice, pavement engineering	NRF, LTA Construction, ESKOM (TESP) & THRIP	
Cape Peninsular University of Technology	Engineering	BTech, Civil Engineering (Transportation) BTech. Civil Engineering (Urban Engineering) MTech, DTech Civil Engineering DTech. Civil Engineering	Not known		
Stellenbosch University	Engineering	BEng Civil Engineering PgDip; MEng; PhD Civil Engineering. CPD courses in Transport Economics, Traffic Engineering, Public Transport, Intelligent Transport Systems, Human Factors in Traffic collision	Road safety, ITS, pavement engineering	Statistics South Africa (STatSA)	Research collaborations with institutions in Africa, Europe, China, South America, USA
Durban University of Technology	Engineering & the Built Environment	BTech, Civil Engineering BTech, Town & Regional planning MEng Civil Engineering DEng Civil Engineering	Not known		
University of Pretoria	School of Engineering	BEng, MEng, PhD in Civil Engineering BEng, MEng, PhD in Industrial and Systems Engineering MTRP, PhD in Town and Regional Planning	BRT, NMT, accessibility, transport operations, transport modelling and optimisation		Research collaborations with institutions in Africa, Europe, China, South America, USA
University of Johannesburg	School of Civil Engineering, Johannesburg Business School	Pavement Engineering, 4IR, Transport and Supply Chain Management			Research collaborations with institutions in Africa, Europe, China, South America, USA.
University of Kwazulu-Natal	Engineering	BSc Eng Civil Engineering (with focus area on Transportation Engineering)	Pavement engineering, traffic engineering		CSIR, eThekwini Roads and Traffic Authority, SANRAL

Country: Ghana

Institution	College/ Faculty	Programme & Qualifications	Research	Existing Colla	boration(s)
				Local	International
University of Ghana	Centre for Urban Management Studies (CUMS)	Multi-disciplinary research and teaching in Urban transport; Urban policy, planning & governance; Urban infrastructure financing strategies	Transport planning, transport geography		
Kwame Nkrumah University of Science and Technology	College of Engineering	BSc Civil Engineering MSc Road and Transportation Engineering PhD Transportation Engineering	Pavement engineering, road safety, traffic engineering		

Country: Nigeria

Institution	College/ Faculty	Programme & Qualifications	Research	Existing Collaboration(s)	
				Local	International
Ahmadu Bello University	Engineering	BEng, PgDip, MSo, PhD Civil Engineering	Not known	Nigerian Institute of Transport Technology	
University of Lagos	Engineering	BEng, MSc, PhD Civil engineering	Not known		
Obafemi Awolowo University	Technology	BEng, MSc, PhD Civil Engineering. (Transportation/ Highway Engineering)	Not known		
University of Benin	Engineering	BEng, MSc, PhD Civil Engineering (Highway Engineering option)	Not known		

Country: Rwanda

Institution	College/ Faculty	Programme & Qualifications	Research	Existing Collaboration(s)	
				Local	International
National University of Rwanda	Engineering	BEng, PgDip, MSc, PhD Civil Engineering	Pavement engineering, traffio engineering, NMT	Nigerian Institute of Transport Technology	





