Bus Rapid Transit as a Sustainable Mode of Public Transport for Khartoum

by

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ABSTRACT

Rapid urbanization increases car ownership, resulting in congestion, pollution, and road safety problems. Recent studies have considered public transportation the most sustainable solution to economic growth and land-use planning as it improves business opportunities, reduces sprawl, and integrates communities through greater mobility. While comparing various modes of transportation, this major paper suggests Bus Rapid Transit (BRT) as the most effective for the city of Khartoum, based on socioeconomic factors and planning and infrastructural needs. The paper investigates both the benefits and costs/risks of a BRT system, heeding such issues as travel time, integration between communities, environmental costs and benefits, accessibility, and socio-economic and health impacts on communities. A pilot project for Khartoum is also outlined, laying out essential elements, routes, costs and funding mechanisms. The paper suggests that, if done well, a BRT can yield many socioeconomic and environmental benefits for Khartoum.

FOREWORD

This major paper culminates my Master's in Environmental Studies, with a specialization in the Planning Stream. My research shifted from gentrification in Toronto to exploring a sustainable mode of public transportation in Khartoum, Sudan. My research investigates developmental projects aimed at improving a community's well-being. My interest in this topic grew after visiting Sudan in December 2019 and seeing the unformal current transportation and congestion issues. The importance of community members in the planning process is an essential component of the planning process, in my view.

The topics covered by this paper satisfy the following learning objectives and components:

1.4 Learning Objective: To grasp an ample understanding of the current public transportation in Khartoum, address the transportation, and the necessary steps needed to implement a sustainable mode of public transportation.

2 Learning Component: Community Action in Planning aligns with Chapter 4 of my research, a Bus Rapid Transit pilot project in Khartoum with a particular interest in community engagement. The pilot project explored in my research aims at providing a temporary solution to analyze the community's socio-economic needs before implementing a permanent BRT project.

Lastly, this experience contributed to my knowledge and skills necessary to be a candidate for the Ontario Professional Planners Institute. The course work, internship experience with *TTCriders,* and planning for pro-poor communities all contributed to my MES program.

DEDICATION

I dedicate this paper to my late father, **Mohamed Najeeb Elshaikh**. I started this Master's journey with you by my side and unfortunately, you were unable to see it through to the end.

May every drop of your sweat fallen in bringing me up become a river in Jannatul Firdous (heaven). Your sacrifices will not be in vain. There are no words to describe the impact you have left on me. Your love, passion, charisma, and intelligence are unmatched, and your memory will forever carry on.

To Allah we belong and to him we shall return.

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CHAPTER 1: INTRODUCTION TO PUBLIC TRANSPORTATION: CASE OF KHARTOUM

1.1 FORMAL PUBLIC TRANSPORTATION SYSTEM IN KHARTOUM

Rapidly developing cities have improved their urban rapid transit to solve the economic, social and environmental impacts of traffic congestion. Urban transport plays a vital role in the development of cities and dictates the quality of life of millions of community members. In recent decades, cities have experienced rapid growth in transport-related challenges that have contributed to significant congestion, pollution, accessibility and safety issues. The capital of Sudan, Khartoum, is a fast-growing commercial, industrial and governmental centre. The lack of reliable formal transportation creates travel barriers and affects the transport mode of choice. In Khartoum, public transportation continues to be the demise of the city due to its lack of reliability, sustainability and order. The lack of formal public transit in Khartoum limits the city's ability to grow and results in increased amounts of imported cars, causing congestion (Bannaga 2018). A study conducted by MEFIT (2014) on the destination of population movement in Khartoum shows that 49.8% of commuters were going home, 28% were going to work and 16.7% were students going to school and university. MEFIT (2014) estimated that the number of passengers using public transport in 2005 compared to 2015 had increased drastically, with rapid urban population growth playing a factor. To date, there are not many studies observing the data and solutions confronting the transportation challenges of Khartoum.

This research topic stems from the view that a properly integrated transit solution can address the urban mobility issues in Khartoum and provide alternatives to significant urban sprawl and road congestion. My research will briefly explore the most suitable and appropriate mode of public transportation in Khartoum, considering the city's needs and tangibility. My research draws upon available literature to argue that the Bus Rapid Transit (BRT) is, under the circumstances specific to Khartoum, the most suitable mode of transportation to implement as local transportation, the benefits produced from the project, and the possible challenges that could arise during the implementation process. Developing a sustainable form of public transportation can potentially increase connectivity and accessibility, improve air quality, and create more affordable modes of transportation (Venter et al., 2018).

My work seeks to draw upon various literature and case studies done on other major cities to explore the benefits and implications produced by reducing the informal transport sector, reallocating street space, and improving street infrastructure. Over the last decade, the Greater Khartoum area has received high demand for public transport services to help improve road capacity and increase traffic speeds. To conduct my research, I will outline a potential pilot project to examine the best methods of developing the BRT pilot project by establishing ways to finalize it most sustainably. I also aim to explore the importance of community engagement within the planning process and the benefits of a pilot project before creating a permanent transit plan. Properly implemented public transportation in Khartoum can attract investors to revitalize its public transport and encourage participation at a local and institutional level (Bannaga, 2014). Revitalizing public transport systems should be a priority, in my view, as urban form influences the development of cities.

My research consists of a breakdown of the benefits of incorporating a transit system to serve middle- and low-income households in emerging economies (White, 2012). Improved mobility may potentially expand people's travel habits and improve access to employment opportunities. In chapter two, I hypothesize that with an emerging economy such as Khartoum, incorporating a BRT system has social benefits and can bring about traffic and road condition improvements and improve health and air quality. Major cities around the world have integrated Bus Rapid Transit (BRT) into their daily modes of transportation with the intent of addressing environmental concerns and considering other ways to improve transportation service quality using a cost-effective method. According to Bannaga (2014), the UN-HABITAT has stated that BRT systems reduce travel times by 50%, noise and gas emissions by 40% and accident rates by 90%. BRT systems can indirectly improve net air quality by replacing older unmaintained and high-emission mini-busses in Khartoum (Cervero, 2013).

Chapter three identifies the potential barriers and challenges that can arise from transportation projects aimed at improving communities while briefly addressing the failures of Bangkok and Dehli's BRT systems. Often, features aimed to improve the livelihood of lower-income users bring with them additional barriers and challenges such as accessibility, mobility and affordability. To ensure a sustainable form of public transportation is implemented in

Khartoum, critical issues of accessibility, fare affordability, environmental implications and economic drawbacks should be addressed. I intend to identify the key issues that need to be addressed to reach a socially sustainable transit outcome that aims to ensure that target demographics benefit most from community-oriented projects. Public transportation is often implemented considering the needs and limitations of the urban poor; however, many times, the goal and the development outcome do not align. Thus, to maximize the project's success, the planning process should consider all possible outcomes, refer to case studies from failed BRT attempt, and incorporate experience from other case studies.

Chapter four provides essential BRT implementation elements, costs and funding alternatives and the role of community engagement in the planning process. The pilot project discussed in chapter 4 is highly influenced by the work of Toronto-based firm Malik Solutions Group based in Toronto. The chapter also discusses three possible routes for the pilot project based on the road width and traffic. The BRT route assessment is meant to consider the width of the roads, the route length and whether it serves the Central Business District. The pilot project discussed in chapter four this research gives a brief understanding of elements that should be considered if Khartoum intends to build a BRT network. The chapter also approximates the total construction and operation costs and possible funding tools for the project.

According to Brauninger et al (2012), achieving a sustainable form of public transport requires integrating various policies aimed to accomplish medium- to long-term goals. Incorporating a BRT system in Khartoum could reflect similar blueprints used in other cities while remaining conscious of their own unique needs. Cities in South Africa and South America have introduced urban transport networks to improve accessibility needs for large amounts of people. The famous BRT example by the TransMilenio system in Bogota, Columbia, is often referenced as a successful project transitioning from an informal bus operation to a formal operation (Venter, 2013). Despite various policy tools and recorded experiences available, there is no single formula for urban transit. It is essential to understand that cities require unique blueprints that reflect the needs of each local community. Questions of cost, passenger capacity, accessibility, health and environmental impacts, construction disruption, and the design and implementation process are essential considerations when introducing rapid transit. A holistic

solution can be best achieved when exploring BRT projects' benefits, barriers, and implications, using a pilot project as an initial test. The purpose of the pilot project is to consider available options for a BRT project in Khartoum. For example, transit fares should be comparable to current competing services, including combined fares where customers can transfer from other connecting services. The pilot project should aim to meet the current and future anticipated traffic demands while also focusing on constructing new road networks.

1.2 Khartoum's Current Public Transportation System

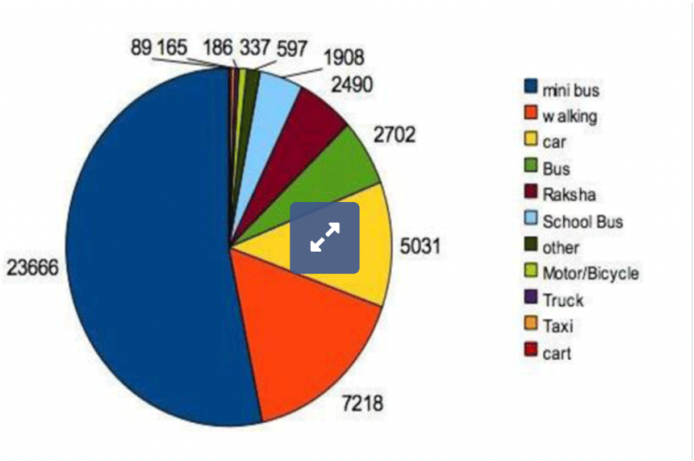
Transportation activities in Khartoum are currently operated by the private sector, with the government's involvement through constructing and maintaining transport infrastructures. The primary issue is the inadequate transportation infrastructure, including lack of paved roads, traffic lights and bus stations/terminals. Traffic signals are fundamental in creating organized and ordered roads to achieve improved conditions and tackle safety issues. The long length of wait times to reach desired destinations are all due to the poor condition of the roads and lack of transit reliability. My research focuses on the capital city of Khartoum; however, those who live in the outskirts of major cities in Sudan rely on more than one vehicle and transfers to arrive at their destination and pay higher fares. The cost comparison of income versus transport fares for a family in the urban outskirts is estimated to be a quarter of their monthly income, amplifying affordability concerns (Bannaga 2014).

Rapid urbanization, population increase, and road congestion have further increased traffic jams and accidents in Khartoum. The current transportation of Khartoum is based on private mini-buses (haflas) of various sizes that travel on the main roads. They do not operate on a formal route and are privately owned and run by local community members. The local government has created a standard route that uses larger buses and operates from larger bus stations; however, these buses are not used as often as Haflas. Haflas are the most used urban transport mode in the Greater Khartoum Area (Figure 1), constituting approximately one out of

every two trips. Haflas are known to come in various sizes: large buses carry 45 passengers, medium buses 25 passengers, and small buses up to 14 passengers (Malik Solutions, 2020).

The implications of inadequate transportation systems are air pollution and associated respiratory health problems, lack of accessibility and a high number of traffic accidents. Bannaga (2014) identifies transport as Khartoum's leading consumer of fuel oil, which leads to air pollution released by vehicles. Air pollution is known to cause health problems that affect the respiratory system. The focus on road infrastructure and signals is important as there appears to be a direct relationship between the number of vehicles on the road and the traffic accidents, especially ones that have caused bodily harm. Bannaga (2014) compares Sudan's road fatalities of 287 per month to other global south countries, where most have one-digit figures. The direct relationship between the number of vehicles on the road and accident frequency indicates the urgency for a sustainable form of public transit that will reduce vehicles on the road.

Figure 1: Number and Type of Vehicle used in 2011 (Bannaga, 2018)



1.4 Comparing Popular Modes of Transport

Khartoum needs to focus on implementing a public transit system that aims to move a larger capacity of people around the city effectively. When considering the best transport option for Khartoum, cost, passenger capacity, construction disruption, and design and implementation complexity should all be accounted for. The debate as to whether to develop bus or rail-based mass transit is a largely deliberated topic amongst planners and government officials (Zhang, 2009). Bus advocates often emphasize its lower costs of implementation and operation. The costs of implementing a metro rail system can exceed $100 million U.S dollars per mile, while a bus system would only require one-tenth of that amount. Rail advocates argue that beyond costs, rail transit offers stronger land development/ redevelopment near rail stations. However, this research assumes that Khartoum's anticipated public transportation system aims to minimize the total cost associated with the passengers and total operation (Tirachini, 2010). I would like to briefly compare Metro Rail Transit (MRT) and Light Rail Transit (LRT) to Bus Rail Transit (BRT) as transport modes for the growing city of Khartoum.

This section only briefly compares the various characteristics between buses versus rail as a comprehensive review requires long-term studies that offer a holistic cost-benefit comparison between rail and buses systems. Instead, an analysis that focuses on buses as the more economical and realistic form of public transportation will be focal point of this research. The capital costs of BRT projects require vehicles, station structures, bus stop facilities and designated lanes. In comparison, trail transit requires guideway elements and trains that require higher capital and maintenance costs which are cost more than BRT infrastructures (Zhang, 2009). Hence, the popularity of BRT is largely cost driven.

Metro Rail Systems (MRT)

While the idea of a metro system seems ideal for heavily populated cities like Khartoum, the geology of the ground makes it unrealistic to sustain and implement a metro system financially. The benefits of Metro systems are that they are fast-moving, cause limited surface disruption, and can move more significant amounts of people while also positively increasing property values along metro routes (Ingvardson 2018). The challenges of a metro system are the power supply system required (solar or battery) and the cost of construction and operation (Malik Solutions Group, 2020).

Light Rail Transit (LRT)

Rail-based transit (LRT) requires separation from road traffic and partially tunneled and/or elevated infrastructure where the rail can travel above grade. Cities in Africa such as Alexandria and Addis Abba have implemented modern LRT networks. The benefit of an LRT is that they can move large volumes of people, and like the metro, can increase property values along their routes. The challenge of the LRT is that they require two lanes with a power supply system (solar or battery) or diesel and imply a high cost of construction and operation (Ingvardson 2018).

Bus Rapid Transit (BRT)

Bus Rapid Transit was developed as a cost-effective way to move large amounts of people quickly along dedicated lanes. As referenced in Table 1, the BRT systems operate at a lower cost, allowing additional lines to be built faster. BRT buses require minimal infrastructural changes compared to LRT and MRT as they would only need a private designated lane in both directions to operate (Malik Solutions, 2020). The BRT is simpler to implement, more infrastructurally realistic, cost less to install and operate, can move large amounts of people, does not require special engineering and operational concepts to function (rail would require expertise to implement and input electricity), primarily produced and create dedicated lanes that can also manage emergency and government vehicles (Ingvardson 2018). The

challenge of a BRT is that it requires two traffic lanes and a regulation that stops other cars from using the dedicated lanes.

Table 1: Key Feature comparison of each mode of public transport based on the investigation carried by the U.S Department of Transportation are addressed in the table below (Zhang, 2009 and studies conducted by Malik Solutions Group (2020):

Key Feature	BRT	LRT	MRT
Average cost per route mile (millions)	10.2	26.4	63.9-169.6
Vehicle cost ($ million/km)	20	2.5	50
Passengers per km per direction	5,000-10,000 (with proper planning)	12,000	25,000
Vehicle dimensions	22.00 x 2.65	24.00 x 2.65	21.00 x 3.15
Typical peak-hour capacity	2,000-10,000	3,000-18,000	13,000-41,000
Increase in property values	High	Higher	Highest

The table above briefly addressed the main features of each mode of public transportation considered in Khartoum. However, the total cost remains the most significant weighing factor when selecting the best option for a developing country such as Khartoum. In many developing cities, the BRT option is usually preferred as it has a low implementation cost than other transit modes and only requires station and road infrastructure to operate. The BRT has been the preferred method of transportation in many cities worldwide and demonstrates positive workability in Khartoum. Moreover, a BRT can quickly be attempted through a pilot project, which is why I will investigate this option later in this major paper. Since BRTs are comparatively temporary, they can be removed if not effective, unlike a metro or LRT, which require substantial initial investments and infrastructure. This is why a BRT in Khartoum is the most suitable option to move masses of people, improve air quality, provide a safer and reliable transit option and reduce traffic congestion.

CHAPTER 2: HOW KHARTOUM CAN BENEFIT FROM A BRT SYSTEM

2.1 GENERAL BENEFITS OF A BRT SYSTEM

Public transportation is considered one of the best ways to reduce traffic congestion and allow for the mass travel of people around urban areas. Policymakers understand the need to increase public transport usage in cities (Gershon, 2005). The ideal transportation mode should meet ridership patterns, be cost-effective, culturally fit and constructed promptly. According to Brauninger and Schulze (2012), achieving a sustainable form of public transport requires integrating various policies aimed to accomplish medium- to long-term goals. A vast majority of the population prefers the use of public transportation, yet it still lacks efficiency. Transitioning towards effective public transport creates more livable cities and helps reduce the effects of urban sprawl and automobile congestion (Gershon, 2005). The integration of public transport is vital in cities with large populations.

The demand for road travel increases as the population increases, especially within urban areas (Zumrawi, 2020). The megacity of Khartoum, Sudan, currently has private buses that move large amounts of people. Urbanization of this city has rapidly increased car ownership, alongside causal problems of massive congestion, pollution, and road safety issues. Rapid urbanization increases the necessity to utilize a sustainable public transit solution to move large amounts of people efficiently and safely around the city. Bus Rapid Transit (BRT) has increasingly been implemented as the sustainable solution to transportation concerns in developed and developing worlds. The popularity of the BRT, mainly in the Global South, originated from the 1930s in Curitiba (Ogundare and Ndulue, 2020). This chapter seeks to examine the general benefits of a BRT system, its role on travel-time, accessibility benefits, environmental benefits, role in improving health and safety, economic benefits, and socio-economic benefits.

Urban transport plays a critical role in poverty reduction through its indirect impact on a city's economic growth. More specifically, its direct role is a necessity for the poor. Intervention

processes aimed to assist the poor and promote structural changes that can help improve the quality of life for the poor (Hidalgo, 2004). The World Bank (2002) identifies four parameters in transport: affordability, availability, accessibility, and acceptability.

- Affordability refers to the financial cost of a travel journey on individuals and households and the ability to make essential journeys to work, school, health facilities, other social services, and visit family members.
- Availability is described as the route possibilities, timing, and frequency of travel. Even if an individual is within proximity to transit stops, their use by the public depends on where they want to travel, how often, and how long their journey is.
- Accessibility is the ease of using public transport for passengers and travel possibilities such as access to bus stops, stations, and the journey's safety.
- Acceptability is described as the qualities of the trip that can either attract or deter passengers based on the quality of the vehicle, security, driver's customer service skills and driving style.

In Bogotá, Colombia, there has been improved accessibility amongst those who reside in communities offering more job opportunities. Additionally, there has been an increase in population density in BRT zones. BRT systems can positively impact urban economic, social, and environmental developments, although more studies have focused on its economic benefit (Deng et al., 2010). The familiar benefits of the BRT are its cost-effectiveness, adaptiveness to change and service frequency. The BRT can effectively be redesigned and adapted in response to market demand and changing geographical activities. It does not require a long-term commitment and can be relocated without many costs and constraints. Considering that the health of the economy can change at any given time, BRT is an easily adaptable form of public transit. The BRT is an attractive transit choice for the simple reason that its implementation and operation costs are lower compared to other forms of transit.

The selection of BRT vehicles should be carefully considered and designed because of their significant impact on travel times, service reliability, operating and maintenance costs,

impact on the environment and appeal to users. The buses should initially aim to be environmentally friendly and minimize noise (Baghini et al., 2013). This chapter seeks to examine the general benefits of a BRT system, its role on travel-time, accessibility benefits, environmental benefits, role in improving health and safety, and socio-economic benefits. This chapter briefly summarizes the successful BRT systems of Bogota for their Gold Standard awards and continued improvements in service.

2.2 The Case of the Transmilenio in Bogotá

The success of the Bogotá BRT, Transmilenio, is often praised and referenced as the focal point when urban planners and transport specialists evaluate the BRT system because of its positive impact on urban form, real estate, and surrounding land value (Baghini et al.,2013). Many African cities have viewed the success of the Transmilenio as a model for achieving a sustainable form of public transit within cities. The Transmileno was implemented in response to the transportation and infrastructure issues in Bogotá. Like many developing cities worldwide, Bogotá faced rapid population growth, increased automotive ownership, inefficient road space and long community times, high air pollution levels and high accident rates (Hidalgo, 2002). Since operating in 2000, the demand and average ridership has increased at an average annual growth rate of 12%. There is an element of competitiveness in which the BRT must compete with the convenience that comes with a private vehicle. However, studies in Bogotá have shown an approximately 10% shift from vehicle users to the Transmileno (Baghini et al, 2013).

The transport system played a role in implementing commercial developments such as shopping centres and supermarkets in the surrounding areas. These developments produced a financial opportunity for private developers to invest and develop in the surrounding lands. Bogotá's building census data analysis directs 75% of newly built area for residential use and moderate growth for office and commercial space. The Transmilenio studies unanimously indicate that the price of commercial property value decreases as the distance from corridors increases, while the prices of residential properties vary based on the studies. Researchers have often studied the case of Bogotá when looking at the value-added to abandoned and empty

properties after the Transmilenio development (Guzman et al, 2020). The ease of accessibility and connections from one neighbourhood to another creates improvements to the urban-built form and serves as an attractive opportunity for public transport implementation.

2.3 Outcome of BRT on Travel Time

The BRT is understood as a more effective and attractive transit option, known to operate more frequently depending on demand (Currie, 2006). The improved travel times are more significant on buses which makes it more time-competitive to cars. The separation of buses from general traffic is shown to increase speeds for buses and motorists. The speed of cars is likely to improve, as buses no longer travel in public traffic lanes, reducing the number of vehicles on the road. Though studies sometimes fail to break down evidence depending on the socio-economic group, it is crucial to understand the distributive outcome of BRT and its effects on different groups of people (Venter et al, 2013).

An equitable approach to measuring the success of a BRT investigates the reduced travel times depending on the socio-economic groups of its users. A study conducted by Hidalgo and Yepes (2005) found that Phase 1 of the TransMileno in Bogota resulted in the saved travel time of 18 minutes per trip for pooper users, compared to 10 minutes for the middle-income users. A different study of the Transmileno by Lleras (2003) reported a potential 2 minute per trip rise in travel time if passengers are required to transfer lines due to increased wait and transfer times. The impact of transit line transfer is more likely to affect lower-income communities who usually live in the outskirts of major BRT lines. Overall, there is a more significant benefit towards lower-income users who typically travel by bus.

The BRT is usually implemented using a traffic lane separate from mixed traffic lanes, allowing for quicker movement throughout the city. Incorporating a dedicated lane is an important trend in many successful BRT projects for its efficiency, reliability and lack of vulnerability to disruptions (Venter et al., 2013) Khartoum can benefit tremendously through an

added BRT lane to ensure traffic moves more efficiently. The redistribution of road space from higher-income to lower-income people produces an outcome that favours the poor, where the spatial location of the transit line, demand and infrastructure are considered (Venter et al, 2013). If implemented carefully, this process is known as a pro-poor intervention (Vasconcellos, 2001).

2.4 Environmental Benefits of A BRT

The rapid urbanization in the developing world calls for concerns about traffic congestion and greenhouse gas emissions. The development of a sustainable form of public transit such as the BRT has recently been prevalent in developing countries. Baghini et al (2014) view environmental quality as an indicator of the overall quality of life through the health of individuals and sustainability of the urban and natural environment. Wright (2014) indicates that the three elements that play a determining role in emission levels are behaviour, land use and technology. The behaviour of users that attracts them to BRT is determined through land-use measures relative to technology (Wright, 2014) and ease of accessing them. To shift private vehicle users from cars to transit, there need to be appealing factors that encourage people (i.e., lower costs and better service) (Baghini et al. ,2013). The BRT ridership gain can result in private car users switching to BRT as their primary mode of transport, which reduces the number of vehicles on the road, thus positively impacting emissions. Removing cars from streets by switching motorists to BRT can reduce VKT (vehicle kilometres traveled), hence GHG emissions. This significant reduction prompted the International Energy Agency in 2013 to call for mass deployment of BRT services worldwide. The BRT has indirectly played an active role in improving the net air quality in thriving BRT cities. In Latin America, BRT systems have replaced the older, poorly maintained, high emission minibusses, leading to positive air-quality results. The ease of traveling without the constant 'stop-and-go' conditions of traffic congestion also plays a role in improving air conditions (Cervero, 2013).

The initial design of the BRT can focus on environmental improvements and strategic designs that aim to lower carbon dioxide emissions (Hugo et al., 2014). Further, the BRT can help reduce excessive noise levels, which is a health hazard. Noise levels are determined using

fuel system technology, size of the vehicle in comparison to its engine, exhaust system, quality of road surface and maintenance. BRT replaces 4 to 5 mini-businesses with one large bus reducing the number of vehicles on the road, and thus the total noise produced. The environmental and noise benefits are dependent variables that can be improved with a good quality BRT system. An Environmental Impact Assessment (EIA) should be strongly considered to assess environmental and noise constraints and identify the best fit BRT vehicles for Khartoum (Baghini et al., 2013).

2.5 Accessibility Benefits

Accessibility is deemed as the ease of traveling to a specific destination. Literature has shown an uneven distribution amongst employment opportunities and residential locations, housing options, and residential segregation limiting access to opportunities (Venter et al., 2013). Public transport plays a vital role in the livelihood of individuals and their ability to access opportunities and services with ease, hence the importance of ensuring that such transport is equitably distributed. BRT is considered an integrated urban revitalization and mobility aid (Delmelle et al., 2012). It is acknowledged for its ability to improve mobility through busway improvements, efficient operations and upgrading of the urban environment (Cervero et al., 2013). The focus of the BRT should be on identifying travel disadvantages and using vertical equity to better serve the poor by using sufficient spatial coverage and reasonable fares (Venter et al.,2018). Vertical equity is the process that directs greater opportunities and resources to individuals who are at a social and environmental disadvantage (Venter et al., 2018). The possible outcome of a successful BRT project aims to decentralize economic hubs and increase accessible networks between communities, optimizing their economic opportunities. New transportation networks can create developments that upgrade communities where the ease of connectivity can strengthen the economy and physical infrastructure (Venter et al.,2013).

For long-term benefits to occur, people need to trust the reliability and accessibility of the BRT as their primary mode of transport. Beyond creating a formal mode of public transport, the BRT project should seek to implement land-use strategies and improve network planning and

other public transportation systems. The most effective BRT functioning cities have implemented well-designed city plans and land-use strategies that include public transit and road networks. Although the planning process involves developing a plan with the intention of inclusivity, the distribution of accessibility patterns indicates that walking access to BRT stops and stations is greatest amongst middle-income groups. These elements were considered in the Transmilenio design, which considered disabled users in their design process, making it more desirable than the older buses (Gilbert, 2008). As the BRT continues to expand, non-radical routes need to be considered to create an inclusively accessible transport mode (Vermeriren et al., 2015).

2.6 Improved Health and Safety

Recent evidence has shown that BRT can reduce traffic accidents, injuries, and fatalities by improving traffic safety. The safety improvements stem from better streets and crossing designs, dedicated busses and pedestrian infrastructure and improved driver behaviours stemming from reduced on-street competition for passengers (Bocarejo et al., 2012). This is evident in the case of the Transmilenio, where after two years of operating, the number of traffic collisions and pedestrian accidents reduced by 94%, injuries to passengers by 76% and fatalities by 94% (Echeverry et al.,2005). These benefits have been skewed more towards lower-income pedestrians who are more likely to walk and use bicycles as their mode of transport.

The health benefit of the BRT is the increase in physical activity from switching from car travel and better air quality. Air quality health improvements can stem from reduced private vehicle usage and replacing existing smaller and less environmentally friendly minibusses. Public transit is also known to increase walking as users travel to and from bus stops and sometimes transfer buses (Cervero et al., 2013). The increase in the number of users walking to reach stations and stops is unevenly distributed towards middle/higher income users who would transition from private vehicles to BRT. Lower-income passengers are more likely to be existing public transport passengers and users of non-motorized transport (Venter et al., 2018)

2.7 Socio-Economic Benefits of A BRT

There is a tendency in African cities to explore motor-oriented infrastructure while ignoring the importance of improving public transport. The process often leads to far too familiar congestion, pollution, and public health concerns (Klopp et al., 2019). The socio-economic impact of vehicle-oriented developments is the lack of consideration for the majority population relying heavily on public transport. These travel barriers often lead to segregation of the population by race and class (Klopp et al., 2019). Unless the upper-class/racially privileged are persuaded away from private cars, automobile dependency will continue to grow, breaking down the potential of the BRT. Consideration of the social impact and needs should be studied because "public transport is critical to the welfare of the urban poor and a crucial element in any poverty-oriented city development strategy" (World Bank, 2002). The principal designer of the Bogota BRT system, Ignacio de Guzmán, claims that the Transmilenio helps "the harmony of the city, internal solidarity and the feeling of belonging to the city." A passenger data study based on the usage of Transmilenio by social class found that 86% of the passengers came from the poorest three social groups. The table below created by Gilbert (2008) with data retrieved from Transmilenio S.A (public-private partnership that constructed and operated the BRT system in Bogota), shows that middle-income users (3 and 4) made up most of the passengers, although the numbers are still skewed towards the lower-income users.

Table 2: Transmilenio Passengers based on Social Stratum (Gilbert, 2008).

Social stratum	*Transmilenio* passengers (%)	Total population in that social stratum (%)	Ratio of users to population by stratum (=Col. 2/Col. 3)
1 and 2	38	47.1	80.7
3	48	40.4	119.0
4	11	7.5	146.7
5 and 6	3	5.1	58.8

Hence, in creating an inclusive and sustainable city, careful planning should attempt to create people-centered public transport systems in the public interest. These changes can strengthen the economic livelihood of Khartoum and create a more sustainable city. In a

developing city such as Khartoum, the BRT can target low-income "hotspot" communities and encourage policymakers to invest in those communities. These investments can include improved power lines and water supply, improvements to roads and infrastructure and the creation of an overall more attractive community. These developments can allow private businesses to open shops nearby, reducing travel for low-income residents, thus creating a more holistic community (Guzman et al., 2020).

2.7.1 Benefit for Land-Use and Real Estate

It is no surprise that public transit can help create more livable cities that can lead to higher economic returns. Transit plays a vital role in a country's economy by improving real estate values and linking cities to suburbs. Generally, public transport is seen as a factor that can improve surrounding properties by creating opportunities for development and redevelopment. The underlying land benefit of easily accessible public transport is the added value it can bring to real estate through easy accessibility (Guzman et al., 2021). Land value is determined through the quality of the built environment, public amenities, and access to economic opportunities (Fensham et al., 2003). Subsequently, residential value is often increased because of ease of access to employment, commerce, education, and recreation. Land value studies assume that people are attracted to and more willing to invest in residential areas within proximity to public transport lines. Proximity to a BRT creates attractiveness in zones identified as unattractive by encouraging urban redevelopment projects that aim to improve the built form and surrounding infrastructures (Guzman et al., 2020). A successful BRT project in Khartoum may potentially add value to empty and abandoned properties and create a more holistic city. In other words, real estate value is not an independent variable but one that is affected by various components that influence land value (Guzman et al., 2020).

2.7.2 Outcome of BRT on Individual Travel Cost

Understanding the importance of travel costs is essential to planning an equitably sustainable form of public transit. Khartoum and many similar cities have an uneven spatial distribution where people spend a higher percentage of their income on transportation because they reside further away from city centre corridors. The mode of transport chosen by individuals

is linked directly to their income, leading to significant mobility gaps and a lack of accessibility for the urban poor. These spatial barriers intensify constraints to access to activities and opportunities for low-income people.

Transportation costs usually amount to 10-40% of daily income, forcing the urban poor to walk to their destination (Vermeiren et al., 2015). The cost constraints of travel disproportionately affect the urban poor, who use 20% to 30% of their income on travel (Venter et al., 2013). Implementing a BRT can reduce public transport operating costs by improving productivity and thus making affordable fares a possible choice (Venter et al., 2013). The urban poor also faces longer travel times to reach their destination, making fare by distance an inequitable form of fare collection in many cities. The BRT can positively impact the lives of the urban poor if two criteria are considered: the physical accessibility from more impoverished neighbourhoods and fare affordability for lower classes. The Transmilenio in Bogota suggests that BRT networks should physically reach poorer neighbourhoods to intensify the connectivity between neighbourhoods. Creating more accessibility between neighbourhoods increases the access opportunities for the urban poor (Vermeiren et al., 2015).

Policymakers can integrate reduced fares to poor users (who travel longer distances) by 'cross subsidizing' their fares using flat fares paid by higher-income users (who travel shorter distances). In the cases where fare integration and flat fare pricing have been introduced, there have been reports of reduced daily savings that can promote equity. The Transmilenio aided in the daily savings of 8%-12% of the daily income of low-income users who were paying two fares using older transport systems (Venter et al., 2013). Understanding the needs of the demographic in the community and the best fit fare systems can result in the best outcome for a sustainable form of public transport. An equitable BRT can thus produce a more accessible transit mode (Venter et al., 2013).

2.8 Economic Benefits of a BRT

There is a growing concern about increasing gas prices and the effect on the Sudanese economy. The high demand for fuel pushes many states, including Sudan, to increase oil prices, as vehicles line up in queues in front of fuel stations for long hours (Dabanga, 2018). Implementing a new efficient mode of transportation such as a BRT system will alleviate the current pressure facing fuel supply. Not only is the BRT system more efficient, but it is also cost-effective. As displayed in the case of Bogota's BRT system, low fares make it affordable to low-income users (Guzman & Oviedo, 2018). This is an excellent benefit as Sudan has been suffering due to record-breaking inflation, which has caused many people in Sudan to struggle when purchasing necessities (Zobedi, 2020). The market law of demand states that as a good or service price increases, people will become less willing to purchase more of the good or service (Britannica, 2019). In this case, introducing an affordable mode of transportation such as the BRT system will deter many people in Khartoum from paying high transportation costs associated with driving. As ridership in BRT increases, the usage of passenger vehicles will decline, therefore decreasing the demand and price of petroleum. Reducing transportation costs will allow many households to increase their savings and spend more money on other items. According to Keynes, aggregate demand is the most important driving force of an economy (Jahan et al, 2014). Therefore, the negative relationship between declining transportation costs and consumer spending will positively impact and push the economy forward. The construction of a BRT system in Khartoum can protect both consumers and the economy from surging gas prices.

According to a study on Sudan's Transport and Mobility, the Ministry of Transport and Infrastructure in Khartoum stated a deficit of 1.5 million in daily seating capacity. This is detrimental to the Sudanese economy as virtually millions of dollars of productivity hours are wasted every day as jobs become harder to access (Murillo, 2009. As of 2020, Sudan's unemployment rate was 17.7%, the highest rate in Sudan's history (The World Bank, 2021). While unemployment soars, the development of an efficient transportation network such as a BRT system is urgently needed to provide solid physical connections between residences and jobs. Reliable transportation is also crucial for students commuting from home to school, as

access to education generates a larger pool of skilled workers for the future. Therefore, a country's infrastructure is essential as it provides services that support economic growth by increasing factors of production, reducing costs, and raising profitability, income, and employment (Department of Trade and Industry, 2006). Investing in a sound transportation system such as the BRT will increase productivity and positively impact unemployment rates. When transportation planning and physical planning are aligned with similar goals, they pose the opportunity to strengthen one another (Vermeiren et al., 2015).

As cities continue to grow and communities move towards urban centers, we begin to comprehend the importance of effective and efficient public transportation. Implementation of BRT systems allows for potential growth in economic centers, upward social mobility, and environmental sustainability. As highlighted in Bogotá's Transmilenio, a BRT creates an upgraded quality of life, with riders experiencing less traffic congestion, greater air quality and increased connectivity around the city center. Successful cases such as the Transmilenio inspire many developing nations intending to implement public transit systems that meet the needs of their citizens. But to ensure my research provides a well-balanced analysis of the BRT, the next chapter intends to address the barriers and implications of BRT systems while highlighting the examples of Bangkok and Delhi.

CHAPTER 3: BARRIERS AND IMPLICATIONS OF A BRT

3.1 GENERAL BARRIERS AND IMPLICATIONS OF A BRT SYSTEM

With Bus Rapid Transit (BRT) systems implemented across 6 continents and over 165 cities, it is fair to say that they have been largely successful. Even in the global south, there is no doubt that BRT systems have progressively impacted populations in terms of travel time, reducing congestion and safety. However, many costs and equity implications interfere with this progressive impact (Nguyen and Pojani, 2018). For BRT implementation to indeed be impactful in the global south, the key risks, costs, and implications need to be addressed. This chapter examines the reasons for failures, which can be as enlightening as the reasons for success. This section of the analysis is structured around the direct implications of the BRT, which are gentrification, spatial coverage, and fare policies. All information presented is from academic papers, industry reports and local newspaper articles. The case studies of Bangkok and Delhi will also be examined in this chapter. Each city has faced different impediments: Bangkok's BRT system, for one, faced a problem of size and was unable to survive at a successful rate. While Delhi's BRT system was so controversially unsuccessful, it has already been removed (Nguyen and Pojani, 2018).

To appropriately discuss how BRT systems take away from social sustainability, the concept of social sustainability must first be addressed. Sustainable development means that any unit of society can exist without depleting the resources for future units to exist (Keeble, 1988). BRT systems across many cities in the global south, including but not limited to Bangkok and Delhi, have not been economically sustainable, have a minimal positive environmental impact and have not been socially just. Therefore, BRT systems have not been a unit of sustainable development.

3.2 Case Study: Bangkok and Delhi

Many analyses of discussion on the failures of BRT systems across the world mention a list of the same cities; that list almost always includes the case studies of Bangkok and Delhi, both of which attempted to implement a BRT system and both of which failed. In Bangkok, five routes were initially mapped out for operation in 2010; of those five, only one still stands and is operating today. One line is a mere 15km long and only transports 15,000 passengers a day (Wu and Pojani, 2016). Delhi faced infrastructural issues mainly due to a lack of proper planning and funding (Misra, 2016).

While Bangkok is like many city counterparts across the global south, researchers have generally attributed its significant inefficiency to weak leadership and a failure to implement competing modes of transport. There were at least 27 government agencies at one point managing the transport system, with a lack of coordination. While public transportation was appropriately a priority to the government, it did not bode well for the city to have so many government agencies involved at once. Furthermore, the BRT system is the third large-scale transport system introduced in Bangkok; before it, there was a rail transit system known as the Skytrain and an underground subway known as the Blue Line, both of which are still operating with excellent success. The difference between the BRT system and its predecessor transit systems is that the central government was entrusted with the Skytrain and the Blue Line, whereas the local government was entrusted with the BRT. It resulted in a power struggle and differences of opinion in the BRT's implementation, leading to delays in governors giving up on the project, complaints from the general public and ultimately the failure of four out of the five lines. Overall, the case of Bangkok highlights how essential unified political backing can be (Hossain, 2006).

The second case study that highlights the failures of the BRT system is Delhi. Home to over 31 million people, the increase in personal vehicles has resulted in an alarming upsurge in traffic congestion and pollution (Singh, 2005). Though Delhi does have a rail transit system, it has never been appropriately accompanied by a quality bus system. Even though it is estimated

that roughly 90% of those commuting in Delhi use the bus as their primary mode of transport, buses are low quality and poorly operated. This makes for a public transportation nightmare. To reduce the number of personal vehicle ownership and keep the number of bus riders consistent, the city invested in a BRT system. The Delhi Metro was also introduced in 2008 and intended to include three lines that span over 65 km for an estimated 2.5 billion USD (DMRC, 2006). However, within only six months of implementing the BRT project, problems began to arise. BRT analysts attribute the problems in Delhi to the fact that the city received a "watered down" version of a BRT system (Misra, 2016), meaning that only the most minimal features of a BRT system were implemented. This included a shortened designated bus lane, and buses spending most of their travel time on regular roads, in turn contributing to traffic congestion and increased travel times for commuters. Similarly, the designated bus lane was not exclusive to BRT buses; numerous other vehicles could travel on the bus lane. Again, this directly resulted in traffic congestion, increased travel times and accidents. Delhi's entire BRT system was eventually scrapped in 2016 as it was causing more problems than it was solving (Misra, 2016). One can assume that it would be difficult to convince the commuters in Delhi to give the BRT system a second chance; hence the importance of proper implementation from the start.

3.3 BRT Accessibility (and Affordability)

The lack of information when discussing those who benefit from transportation systems such as BRT can result in gaps during the implementation phase. Gaps develop when not enough studies and attention is put into tackling social issues that affect the community. Issues of affordability and accessibility to resources are essential when considering BRT networks. There should be measures implemented to ease access to BRT systems for the elderly and disabled (Frye, 2013). The UN data on demographic trends (2009) indicates that by 2050 there will be 22 percent of the population over 60 years old, with 64 percent of these people living in developing countries (Murillo et.al, 2009). When addressing the usability of the BRT for persons with disabilities, there is a failure to understand the barriers to transportation. In many cases, the more severe the disability, the greater the transportation problems. Many BRT systems are often praised for promoting socially sustainable mobility yet continue to leave behind those most in need of accessible transportation systems.

According to the Transportation Research Board (2004), one of the essential features of transit development is having direct walking access to a mode of transportation. Additionally, Graham Currie reports from his personal experience that this feature is hard to achieve with BRT systems (Currie, 2005). Most cities across the global south that have adopted BRT systems or have attempted it find it challenging to provide adequate pedestrian access to bus systems, primarily when they operate on street-level. BRT bus platforms are often located in the middle of the road and in the absence of pedestrian crossings, which is common in many cities across the global south; this makes it very difficult to board the bus and poses a safety concern.

When measuring transportation equity impact on accessibility, we must address the proximity of BRT routes to residential locations of low-income communities that live in the outskirts of cities. Many BRT routes initially begin in city centers and high-volume areas, often surrounding more affluent areas. Through this process, routes have failed to serve poor communities, forcing many individuals to walk longer distances to access BRT routes or take additional transfer routes between modes of transportation, which increases these people's total cost of transportation and takes valuable time away from their days. Gaps in transportation equity can also be seen in the proximity riders have to BRT routes and destinations available. There can also be a reduction in accessibility by poor communities: for instance, Ahmedabad's BRT systems tend to attract a larger group of middle-income riders (Mahadevia et al., 2012). Evident disparities in pro-poor accessibility can be seen in the lack of integration between the price of local public transportation services and those of BRT systems. This is often due to BRT fares being disproportionately higher than those on local services; therefore, those in lower-income brackets tend to be unable to access BRT systems despite intentions for pro-poor accessibility. Moreover, individuals who tend to access feeder transfer systems continue to suffer from additional costs that could be avoided through the implementation of free transfers or pro-poor fare structures.

3.4 Environmental Implications of A BRT

The BRT system promises to increase environmental sustainability by reducing carbon emissions by centralizing public transportation; however, through the continued use of other local feeder bus systems, additional modes of transportation continue to be used. Previous intentions of having fewer vehicles on the road have not considered individuals living on the outskirts of cities. It is only in city centres where we see BRT corridors maximize health and environmental benefits due to reduced congestion. Most studies that focus on the implications of BRT systems have highlighted environmental implications as a primary detriment. Buses have continually proven to produce more toxic fumes and noise pollution than rail transportation. This is primarily due to rail transport having the advantage of relying on 'clean' electric power over diesel-based bus services (Baghini et al.,2014). While environmental implications do not directly affect the efficiency of a BRT system, no transit system can be considered successful if it is not implemented in an environmentally friendly setting.

To determine if a transit system is environmentally friendly, we must assess three main factors. The use of bus technologies, such as up-to-date engine systems, can effectively reduce corridor bus emissions, increase ridership that moves away from private vehicles, and reduce vehicle emissions from lower corridor congestion (Baghini et al.,2014). Based on this calculation method, buses are not entirely environmentally detrimental; however, they are still not the most environmentally friendly mode of transportation. Buses produce high emission levels, which in turn produces poor air quality. However, as we saw in the case of Bogota in the previous chapter, approximately 10% of former personal vehicle users switched to the Transmilenio BRT system (Gleave, 2003).

3.5 Economic Implications

Various obstacles may occur when introducing a BRT system to an economy that has previously worked within the bounds of privately owned transportation services. Ridership in Sudan has relied on rickshaws, taxis, amjads (van-like taxis), and halflas (privately owned buses) as a means of transportation. With the introduction of a publicly owned system such as the BRT

that is intended to be affordable, accessible, and environmentally friendly, those previously working within the transportation industries will likely begin to either lose a substantial amount of their delay revenue or possibly lose their space in the market as feeder routes begin to be phased out. As inflation continues to sweep the nation, privately owned transportation services constantly increase fare prices in response to the changing gas prices. The BRT intends on creating an equitable price breakdown that its users can consistently access. In the current precarious times resulting from COVID-19, there continues to be a risk of an overpacked BRT system. Khartoum's commuters may face the risk of spreading dangerous diseases due to close contact in overpacked transit spaces, which may negatively affect the economy by hindering the health of workforce.

Transportation investment projects can run the risk of being counterproductive by draining the resources of an economy during the start-up phase and driving previous local economies away, instead of creating wealth. Transportation investments such as the BRT are capital-intensive fixed assets that are vulnerable to misallocation. As Sudan is currently on the cusp of an economic crisis, allocating funds towards developing a BRT system will not address the root causes of many issues faced by ordinary citizens who struggle with day-to-day necessities.

One of the most detrimental obstacles most BRT systems face is a lack of funding. Successful BRT systems have often received substantial funding from international agencies such as the World Bank. However, countries such as Sudan, that are experiencing sanctions or are highly indebted by international loan agencies, do not have access to funding to assist with costs. For example, in Delhi, as we saw earlier, funding was so minimal that no extra lanes were created for the BRT, which created significant congestion and ultimately undermined the project (Nguyen and Pojani, 2018).

3.6 Recommendations

To conclude this section of the analysis, while BRT systems improve access to workplaces, reduce travel costs, decrease congestion, and are a safer transport option, there are still many risks and costs upon their implementation, especially in cities of the global south. Most of these cities in the developing world are currently undergoing rapid urbanization, which has caused a high demand for personal transportation. As seen in major cities worldwide, an increase in personal transportation results in issues such as congestion and pollution. Hence the introduction of BRT systems, a method of sustainable transport. The issue, however, is that BRT systems are not a one-shoe-fits-all solution. Bangkok and Delhi are highlighted as case studies of cities that could not successfully implement BRT systems. Issues have included but are not limited to affordability, accessibility, environmental implications and funding.

In addition to addressing the above-mentioned perils and risks of BRT systems, the literature also makes the following recommendations for BRT implementation to succeed moving forward.

- Zebra Crosswalks: A crosswalk marked with alternate black and white stripes and visible to all drivers on the road that would allow pedestrians to cross and give them the right of way to access bus stops located in the middle of the street. These crosswalks also make bus accessibility safer for pedestrians (Kadali and Vedagiri, 2016).
- Priority Green Light Signal: This signal is set up at general traffic intersections for buses could reduce traffic and reduce travel time (Viegas and Lu, 2001).
- "Proof-of-Payment" System: Practicing conventional collection of fares slows the boarding process. An alternative would be passengers boarding through all doors of a stopped bus. This would create enforcement challenges but would speed the boarding process (Malik Solutions Group, 2020).
- Alternative Fuel Buses: Adopting buses that use alternative fuels to operate would reduce the level of emissions produced by large buses and mitigate overall air pollution (Malik Solutions Group, 2020).
- Assisting the Local Economy: Providing private transportation workers a pathway into integrating their services with the BRT to make a profit (Malik Solutions Groups, 2020).

- Environmental Awareness: An initial 10km pilot project route is an excellent start to the project; however, to ensure long-term environmental stability and reduced emissions, an emphasis must be made on reducing feeder transportation (haflas or raksha) routes and encouraging BRT Systems

In closing, with all the recommendations based on the failed attempts of BRT implementation, BRT systems can still be considered one of the most promising transit solutions in the developing world. The analysis of the risks and costs of implementing a BRT system can help other cities that have yet to introduce a BRT. Khartoum's local planners and leaders need to avoid the risks outlined above to implement and effective and efficient BRT system.

CHAPTER 4: ANALYSIS OF BRT PILOT PROJECT

4.1 INTRODUCTION TO A BRT PILOT PROJECT: THE CASE OF KHARTOUM

The United Nation General Assembly's (2016) Sustainable Cities and Communities Goal 11 aims to make cities and human settlements inclusive, safe, resilient, and sustainable. World leaders have identified transportation and mobility as central to sustainable developments and better integration of the economy and diligence to the environment (United Nations General Assembly, 2016). An integrated public transportation network can provide Khartoum with the necessary first steps towards creating a sustainable city. However, there are evident gaps in the needs of the global south where there is a lack of information and data available. Governments and planners need to invest in studies intended to improve existing infrastructure to address this issue.

This chapter is based on the hypothesis that a BRT would be the best public transport mode in Khartoum, and therefore suggests a pilot project as an important initial implementation step. The chapter provides the essential elements necessary for implementing a pilot BRT project, costs and funding alternatives, and community members' role in planning. The pilot is primarily based on information and data put forward to the government of Khartoum by a Toronto based Malik Solutions Groups, based in Toronto, on BRT as a transportation expansion option. Malik Solutions Group assembled a team of professionals from various backgrounds and fields and have international work expertise and knowledge to provide an insightful analysis and project design[1]. The purpose of the pilot project is three-fold: to implement a temporary route, to evaluate technology used, and review feedback received from the public. The pilot project also intends to evaluate the potential risks and provide the public with insight that reassures them that the project can successfully be implemented as a permanent transit system (Malik Solutions

[1] Malik Solutions Groups utilizes the global interconnectedness of the Sudanese diaspora through various research methods. I am currently a research associate for Malik Solutions Group and work directly with the project leads on multiple projects. I intend to continue my work with the team in creating a sustainable and affordable transport mode in Khartoum.

Group, 2020). This chapter aims to reflect on the pilot project, while also incorporating ideas from comparative literature.

4.2 Key BRT Design Elements

To achieve a high-quality BRT, certain elements are required to receive the best implementation outcome. The focus of BRT projects tends to centre around upgrading bus services (advanced vehicles and intelligent transportation systems) with little effort put into performance elements (speed, reliability and image). BRT projects have adopted elements from LRT and Metro to provide high speed, large capacity and high reliability at a cheaper cost. However, the central issue of right-of-way remains unique to the BRT and may require guided busway technologies that operate on elevated tracks and ground-level roads. BRT designs should ensure that these components are carefully planned to create accessibility and inclusivity. The technical details that may appear minor can sometimes be essential components to operate an effective BRT system (Deng and Nelson, 2011).

Table 3 below breaks down general design elements of the BRT, the benefits they offer, and the attendant implications/barriers. The table below discusses elements put forth by Malik Solutions Groups in their *Khartoum Transportation Expansion Options* report (Malik Solutions Group, 2020).

Design Element	**Benefits**	**Implications/ Barriers**	**Comments**
-BRT will operate in its dedicated right-of-way (ROW), likely to be located in the middle of the street	-BRT will be able to move quickly without delays and obstruction -Lane can be used by emergency/ government officials when necessary	-Private vehicles may attempt to use dedicated ROW; the structure is needed to ensure regulations are enforced	-Physical barriers (curbs or medians) can be used to ensure BRT only uses the lanes -May require police reinforcement to ensure drivers do not use the BRT designated lanes

Bus stops should be located where they can be accessed quickly and safely	-Stops can provide access into communities	-Building, implementing and maintaining the stations require funds and employees for constant upkeep	-Stations are essential for uniformity and order -Stops should be located a fair distance apart to achieve an average operating speed
BRT Traffic Priority	-Would ensure the safety and speed of the BRT experience -BRT buses would avoid traffic congestion and road competition	-Reinforcing BRT right of way may become a burden on police enforcement	-Policies should be implemented to ensure the BRT can operate at its full potential without disturbance
Fare Collection using tickets verified at stations	-Customer service assistance can sell and verify fares at stops instead of drivers for more efficient boarding	-Requires the cost of hiring staff to sell and verify fares -Ticket purchase before boarding faces the risk of riders boarding without paying	-robust mechanisms are needed to ensure all riders have paid their fares -Barriers, staffing and inspectors may be required to collect and reinforce fares
Maintaining service quality by hiring supervisors at stations	-Would ensure service quality control -Supervisors can oversee and monitor operations to act on service irregularities and disruptions -job creation for the community members	-Hiring a supervisor at all times requires funds to pay employees	-Supervisors are essential to ensure order at stations and to ensure operations are running efficiently and on-time
The bus should be running frequently and in a real-time manner	-Ensuring buses run on a reliable schedule attracts riders to use the BRT system	-Ensuring constant bus maintenance and upgrading requires funding	-To have a reliable and comfortable vehicle that is required to operate daily and move large amounts of people, there should be constant maintenance and checks

The number of passengers per vehicle would cater to demands.	-High-volume rush hour would operate with more people in the buses (both sitting and standing) similar to other buses worldwide. Buses are still a comfortable option even during high-demand hours.	-Buses that are not maintained and overcrowded can cause discomfort and lure away passengers	-Buses are expected to be fuller during rush hour -buses should still ensure the comfort and safety of their passengers
More opportunity for service reliability with larger buses	- 12-metre buses which can hold more riders and ensure space and comfort -Higher capacity buses require fewer drivers, hence a more economical option	-Larger buses are more costly and require more care while operating the vehicles	-Higher capacity buses should be considered after the initial pilot test project as an option as it is a more costly option
Spare buses to ensure the operation of planned services always continues.	-Extra buses will be on standby to reduce service disruptions. The fewer service interruptions, the more reliable the BRT is and the more users are attracted to its services	-Beyond the buses needed to operate on-street, buses should be purchased to be on standby in the maintenance depot for service and repair	-To avoid disruptions and the need for large amounts of spare buses, the buses should not be old and minimal maintenance

Road Conditions

To operate with minimal building costs effectively, the BRT should be placed on a wide road with multiple lanes. Using existing wide streets with a centre median that can be used for passengers optimizes the existing infrastructure and can reduce construction costs. The BRT would require two dedicated lanes to operate efficiently, while the other lanes would continue to welcome private vehicles. According to Malik Solutions Group, the BRT would require a 6-lane wide street with 7.5 metres of total width dedicated for the BRT right-of-way. The pilot project would require minor road repairs to serve its short-term trial purpose (Malik Solutions Group, 2020).

4.3 BRT Pilot Project Route Options for Khartoum

The survey of the routes detailed in the section was provided to Malik Solutions Group using the expertise of Khairy Construction. The collaboration of expertise analyzed three possible routes to operate the BRT in Khartoum by comparing their one-way distances, number of stops, frequency, predicted daily ridership, and number of buses required (Malik Solutions Group, 2020). To maximize ridership, the BRT should consider connecting to the Central Business District (CBD), the region's largest destination. Subsequently, routes should generate riders and high-density residential neighbourhoods and aim to minimize their total walking trip to the bus stop. Malik Solutions Group has narrowed down the best route options for a pilot project to maximize the number of riders and existing infrastructure (Malik Solutions Group, 2020).

Option 1

The first option outlined for the BRT route would run from west of Jackson's Station: east on Army Road and South on Africa Street to the southern terminal at Madani Street. This option offers a wide street option that can give passengers a platform to enter and exit the buses. This option also serves the Central Business District and connects with major transportation hubs, facilitating trip connections. This option runs 9.8km one way with 20 stops and 68 minutes total round-trip driving time. The line capacity of passengers per-hour-per-direction is 1800, with a projected ridership between 29,600 to 47,1000 people. This route would require 34 buses in service and 17 additional spare buses, using 76 operators per day (including two at each turnaround point all day).

Option 2

The second option would operate from the northern terminal west of Jackson's Station, east on Army Road and Buri Road and south on Africa Street to the southern terminal at Madani Street. Like the first option, option 2 also maximizes on the width of the street, which can be used to

implement passenger platforms. This option will also ensure that cars can still travel along the existing lanes without adding to the already existing congestion. This option is adjacent to the airport, where there would be no stop available for pick-up or drop-off on one side of the route. This option runs 13km one way with 28 stops and 78 minutes total round-trip driving time. The line capacity of passengers per hour is also 1800, with a projected ridership between 39,300 and 62,500 people. This route would require 43 buses in service and 22 additional spare buses with a total of 65 buses and 94 operators per day (including two at each turnaround point all day).

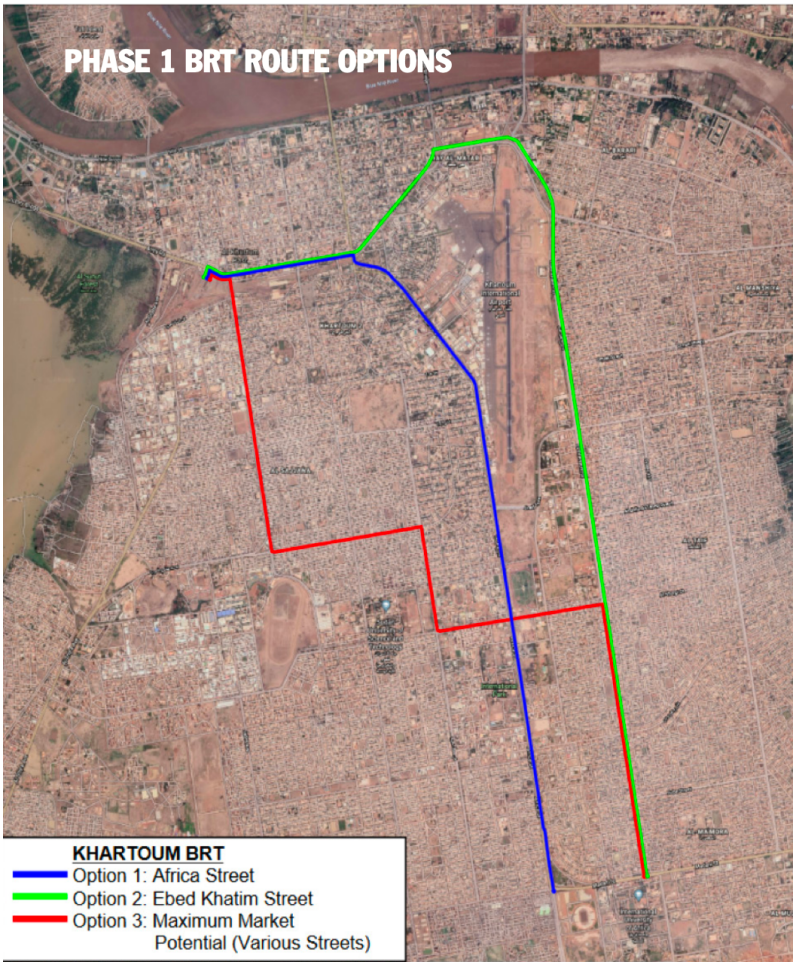
Option 3

The third option suggested from the BRT report would operate from northern terminal west of Jackson's Station: south on Al Huriya Avenue, east on King Abdel Aziz Street and south on Mohamed Najeeb Street, east on Al Shargi Street, south on Ebed Khatim Street to the southern terminal at Madani Street. Option 3 serves well-established commercial and market streets along with the Central Business District. The disadvantage of this option is the lack of centre medians which would require physical infrastructure to ensure the BRT is separated from other vehicular traffic. This option runs 11.5km one way with 27 stops and 69 minutes total round-trip driving time. The line capacity of passengers per hour is also 1800, with a projected ridership between 40,500-64,500 people. This route would require 38 buses in service and 19 other spare busses with a total of 57 buses and 84 operators per day (including two at each turnaround point all day).

Discussion of Route Options

The length of each route, the number of stops and the number of anticipated passengers all differ; the options are presented to offer several options to Sudan's Ministry of Transportation. The three routes service the Central Business District, as shown in the figure below. West of the Central Business District is the bus garage of the Khartoum General Transport Authority, which can house up to 750 buses. The garage would require repairs and new equipment to ensure the building can serve this purpose.

Figure 2: Possible BRT Options (Image Retrieved from Malik Solutions Group, 2020)



4.4 Project Costs and Funding Mechanisms

This section focuses on the projected costs of operating a pilot BRT project for the three route options discussed, as well as the mechanisms used in other cities to fund large transport projects like the BRT. Funding and costs pose huge limitations on project implementation; thus, governments must consider financial options to reduce financial barriers. International aid, Tax Increment Funding (TIF) and Public-Private-Partnerships (PPPs) can alleviate some of the financial concerns.

4.4.1 Project Costs

The section briefly discusses the project's cost estimate and funding for the pilot project based on Malik Solutions's report to the Sudanese Ministry of Transportation. The report

predicts a total construction cost of $35,000 to $40,000 per kilometre for the pilot project. Stations would cost approximately $10,000 per kilometre, where raised platforms (30cm above ground) would be required to ensure safety and easy access to buses. The design would include 2 stations per kilometre; hence the cost would be $20,000 per kilometre. The design of the station would include bench seating, a covered roof and lighting using solar panels. Maintenance for the existing facility of the Khartoum General Transportation Authority is expected to cost $50,000 (Malik Solutions Group, 2002).

The project anticipates using existing buses donated by the Government of Sudan, which would require $500 to $5000 per bus for repair purposes. Additionally, 20-30% should be anticipated as an added budget cost that covers unforeseen costs. The pilot project is intended to be self-financed using the Khartoum General Transport Authority buses and a series of local and international donations of materials and services. The National and State government may be asked for capital if more than the 10km pilot project is required. Alternatively, funding of joint application to an international funding body such as the African Development Bank or World Bank may be assessed if needed. The permanent project would require substantial investments to fund part of the construction/vehicle costs. The fare costs are intended to cover the project operational costs and part of the construction/vehicle costs (Malik Solutions Group, 2002).

The pilot project can be regarded as the initial step for Khartoum's future transportation shift, leading to a permanent implementation plan. The BRT network anticipated after the pilot project's success would be around 200km and would connect the surrounding cities of Omdurman, Khartoum, Bahri, and south of Khartoum to the Central Business District. Haflas are still intended to operate as feeder buses in mixed traffic regions and for transfer purposes.

4.4.2 Tax Increment Financing (TIF)

Tax Increment Financing (TIF) is a tool used to fund infrastructure for urban regeneration projects. The process of TIF involves forecasting the net tax revenue impacts of future land value, which increases through the influence of value improvement projects. TIF is a "self-

financing scheme where development projects are financed by increasing local government taxes using local sales tax revenues generated from new developments" (McIntosh et al., 2015). Transit projects like the proposed Khartoum BRT are anticipated to generate sustainable economic growth and public sector revenues. TIF is a fiscal tool commonly known to finance projects associated with commercial and industrial development and redevelopment projects. Ultimately, TIF can be incorporated where the community/government foresees a development opportunity and where the revenues can be implemented on a "pay-as-you-go" financing basis. The benefit of this mechanism is the positive impact it can have on building affordable housing, assisting in the revitalization of neighbourhoods and redevelopment projects (Johnson and Cole, 2013). The use of TIF is largely to be found amongst transit projects in the USA, where land and property taxes for investment is used in urban renewal and transit projects (McIntosh et al., 2015).

The advantages of incorporating TIF are the following (Johnson Cole,2013):

- Provides financing for projects that would not have been financially feasible
- The city does not lose tax revenue
- TIF bonds are not included in general debt commitments
- Urban redevelopment is funded from an increase in the tax revenues generated and not subsidies

In the context of Khartoum's anticipated BRT project, the financing would be generated from the tax revenues anticipated to come from the increase in property values in areas that the BRT is expected to redevelop. Countries like Sudan often face budgetary constraints when attempting to implement large development/ redevelopment projects; thus, the use of land value-based funding can attempt to relieve financial obstacles. Introducing an easily accessible transit line promotes new businesses and redevelopments in blighted areas, which also aids in an increase of land values in the surrounding neighbourhoods (Johnson and Cole, 2013). Hence, new transit lines are estimated to increase property values by 30% or more (Malik Solutions Group, 2020), which maximizes the benefits of BRT in Khartoum.

4.4.3 Public-Private Partnership (PPP) Model

Additional funding can be obtained through equity financing, where private partners contribute to capital costs and take an equity stake. Equity financing is seen mainly in Public-Private Partnerships (PPPs), where private companies interested in the success of a project would contribute financially in return for shares (Malik Solutions, 2020). Public-private partnerships are defined as institutional arrangements between the public and private sector in a long-term infrastructural contract for the construction, operation and maintenance of urban infrastructure projects. The International Monetary Fund (Jahan et al, 2004) identifies PPPs as "arrangements where the private sector supplies infrastructure assets and services traditionally provided by the government." PPPs can offer mechanisms that fill the funding gaps while creating financial revenue for companies (Pojani and Stead, 2018). The private partners usually design, build, finance, operate, manage and deliver the service to the government or end-users. The government specifies the service required from private partners and is responsible for payments for delivering the specified services (Sundaram et al., 2009). The partnerships are intended to offer win-win arrangements for the governments and private providers. This balance can provide profits for private providers, revenue for the governments and livelihood improvements of people who lack access to basic health care, safe water, electricity and other physical infrastructure or social services. However, this form of collaboration can also have negative implications, when for example the government and private providers do not share similar values and objectives (Sundaram et al., 2009): private providers usually seek to gain profit while the government usually focuses on the interests of the public.

PPPs have been encouraged by international financial institutions in developing countries to aid with financial costs (Sundaram et al., 2009). Sudan can benefit from this form of partnership as it relieves the financial burden of implementing a large project like a BRT system. Once the project is built and operated for several years, it can be transferred from private operators to the government for continued operation. The contract with the government usually includes upfront construction and long-term operation and maintenance and tends to run for a minimum of construction time plus 5 to 10 years of operation. The length of the time allocated usually forces the private company to consider long-term costs of operation and maintenance, leading to longevity through better design and service quality (Malik Solutions Groups, 2021).

4.5 Community Engagement in Planning

The process of community engagement in the planning process aims to provide a mechanism for community members to be active members in planning for the well-being of their communities. The process involves a collaborative approach where partners and community members "build an authentic partnership" that values mutual respect, inclusive participation, power-sharing and equity and mutual benefit where all parties can succeed (Tindana et al.,2007). Participation allows stakeholder groups to interact with government agencies, political decision-makers, third sector and non-profit organizations and business organizations to create and implement policies and programs. The redistribution of power gives citizens who have been excluded from political and economic processes a role in determining the sharing of information, goals, policies, resource allocation and programs an opportunity to be involved (Konsti-Laakso and Rantala, 2018).

Planners should develop strategies that focus on community engagement to build trust between stakeholders and the communities involved. Involving all the stakeholders (including and especially low-income and marginalized groups) to help achieve a common goal where participants can design, build and govern the community gives all parties equal opportunities to participate (Brugmann, 2009). The stakeholders involved in the Khartoum BRT should gather the recommendations and concerns of riders following the pilot project to improve services before permanent implementation. As the ones using the BRT, the opinions of community members are essential and should be acknowledged and taken into consideration. Community participation relies on a bottom-up approach that focuses on grassroots initiatives that promote participatory decision-making (Nikkhah and Redzuan, 2009). Holding community consultations builds trust between stakeholders and resolves any conflicts before and during implementation (Konsti-Laakso and Rantala, 2018). While planning typically involves scientific and expert knowledge, local communities have "non-expert knowledge" that is site-specific and experience-based (Van Herzele, 2004) and can thus contribute to long-term sustainability. The emphasis on community participation is viewed as a sustainable practice in development projects; hence the intended BRT project in Khartoum should ensure that the voices of community members are considered.

4.6 Conclusion

The purpose of this chapter was to provide a starting point for implementing a sustainable public transportation network. BRT networks can provide Khartoum with the necessary tools to create a sustainable transportation mode that is inclusive and accessible to community members. The BRT I have discussed above involves a timely, non-disruptive and least costly public transportation network. It helps ease mobility around the city for community members and widens networking opportunities.

Furthermore, the BRT design elements discussed above provide a brief overview of the design factors that should be considered based. The exact route of the pilot project should be decided based on surveys and studies that investigate the best use of the network. To facilitate the implementation and operation costs discussed, Tax Increment Financing and Public-Private Partnership should be considered as funding options. Implementing future transportation infrastructure can result in better economic, social, and environmental outcomes for Khartoum. The community's role in the planning process is crucial to the project's success, hence the importance of their participation.

CHAPTER 5: SUMMARY OF FINDINGS, RESEARCH GAPS, AND FINAL REMARKS

Public transportation is the pillar of sustainable cities and should be regarded as such. Improved public transportation is the foundation of a thriving city as it means less road congestion, faster mobility, more comfort and lower emissions. Mobility improvements provide people with access to employment opportunities and day-to-day necessities. Where public transportation is successful, communities are economically prosperous and offer location advantages to businesses and individuals who chose to live near them. Public transportation is created as a socio-economic land-use means of mobility where those who need to use it do so affordably and those who choose to utilize its services do so with comfort. Communities — particularly low-income and marginalized communities— that live within walking distances of transportation networks are the ones who benefit most from the implementation of transit lines. The research paper focused on BRT systems as the most attainable form of public transportation and identified the many benefits that can be achieved if implemented. But the paper also attempts to consider challenges and barriers to present a more holistic study. A brief pilot project is also considered in the context of Khartoum to examine the key elements required of a BRT.

As population density and urbanisation continue to increase, solutions for sustainable travel are needed to ensure efficient and accessible transport. The BRT has changed the way public transport is perceived in many growing global south nations. Typical public transportation models that are often found in megacities such as Toronto or New York cannot be replicated or afforded in many cities currently in the process of urbanizing. Importantly, the BRT provides a pro-poor model, focusing on affordability and accessibility of travel. A holistic pro-poor focus allows for prominence to be placed on the availability and accessibility of routes. The BRT attempts to ensure that riders are in proximity of routes as this is a crucial solution to reducing traffic congestion less reliance on feeder routes or personal vehicles.

As discussed, the following is a summary of the main benefits of a BRT network:

- Improves and eases mobility between communities in the city
- Ease of mobility supports economic growth and increases potential employment opportunities
- Improves road infrastructures, reduces congestion and the number of vehicles on the road
- Improves overall individual health; fewer vehicles on the road can reduce carbon dioxide emissions and improve net air quality
- Improves overall real estate values by attracting residents and businesses to communities surrounding BRT networks
- Conducive to attracting development/redevelopment projects and new businesses
- Designated lanes can be used by emergency vehicles in times of crisis
- Reduces accidents by decreasing the number of cars on the road

In addition, as discussed in chapter 3, the following are the main challenges and barriers to a BRT:

- Political leadership gaps
- Lack of data and information on BRT systems
- Accessibility and Affordability:
    - Implementing new system routes that are inclusive and accessible
    - Ensuring fares are affordable
    - BRT within proximity of the urban poor populations
    - Ensuring the proximity to the BRT does not gentrify communities and push the urban poor out of their communities
- Environmental Implications:
    - Ensuring bus technology is new to reduce vehicle emissions
    - Ensuring buses reduce noise impact on roads
- Economic Implications:
    - Affordable fare costs
    - Lack of funding

Implementing an initial pilot project ensures that government officials and community members react positively to the new implementation and their needs and concerns are considered. Selecting the ideal routes for the BRT pilot project requires the expertise of the best

design elements unique to the needs of Khartoum. Furthermore, chapter 4 evaluated the route options to implement the pilot project, including road width, road condition, traffic flow and connection to Khartoum's Central Business District. Moreover, BRT projects often fail due to cost constraints; hence the need to carefully consider alternative funding tools such as Tax Increment Financing and Public-Private-Partnerships using the build-operate-transfer method. For development projects to succeed, community engagement mechanisms would need to be incorporated. The bottom-up approach redistributes power to community members and promotes involvement in decision-making. The pilot BRT project team would need to conduct consultations with community members that gather opinions and concerns about the pilot project before implementing the permanent BRT project.

The findings show the benefits of a BRT system in Khartoum and the positive impact for community members if appropriately implemented. High standards and equitability in travel, cost, ease of use and travel time should prioritize the BRT project in Khartoum. Yet, undoubtedly, additional research and data collection are required to ensure best practices are implemented to create a sustainable mode of public transport. For example, the collection of traffic patterns needs to be conducted on various roads to find where the project would be most successful, followed by expansion projects to intensify BRT mobility. Improved coordination with planners and government officials can also amplify BRT's potential. Additionally, an Environmental Impact Assessment would need to be conducted to identify the impact the proposed BRT project has on the environment, while identifying the socio-economic and health impacts.

The lack of literature and documented case studies on public transportation in Khartoum makes it challenging to understand community needs and user impacts. Despite the successful case study in Bogota, the long-term effects of BRT are unknown, seeing that it is a newer mode of transport. Yet the lack of data notwithstanding, a pilot project is a suitable method of gathering missing information. A pilot project can bring to light social, economic, and physical issues with the BRT system early on before permanently implementing a BRT project. Further,

the pilot project is the stage of development intended to build trust between the city and passengers, hence the importance of transparency and community participation in the process. With proper attention to the recommendations and improvements gathered in the early stages, government officials and the BRT planning team can better understand the project's needs. Visibly prioritizing road space with projects intended to help the urban poor can create a sense of inclusion and empowerment that can have positive long-term effects. In a time of urban urbanization, Khartoum can achieve a long-term inclusive and sustainable mode of public transportation, providing it is affordable, accessible and community oriented.

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APPENDIX

(Images of Khartoum's roads and current transportation modes; photo by Khalid Kamal)