KHARTOUM TRANSPORTATION EXPANSION OPTIONS

MALIK SOLUTIONS GROUP

TABLE OF CONTENTS


KH
213

CURRENT SITUATION

With its population of over 8 million people, Khartoum -- an industrial, commercial, and governmental centre -- has long suffered from the absence of a high-quality transportation system worthy of its dynamism. The lack of good quality public transit costs the economy hundreds of millions of dollars in lost productivity and makes getting around the city uncomfortable, time consuming, and leads to a large volume of imported cars and fuel, resulting in one of the largest demands on limited foreign currency.

It would be preferable to invest the limited available funds in urban transit because 85% of the residents of Khartoum either walk or use shared transportation. Investing in bigger roads is expensive and will not serve most of the residents of Khartoum well. It would be cheaper and more effective to invest in efficient public transit which, in addition to improving mobility opportunities, would also offer more economic benefits to the residents of the Khartoum region.

OPTIONS REVIEWED

This report outlines transportation-improvement options for Khartoum, including investing in Metro or Light Rail rapid transit transport. Both options provide excellent transportation, but are extremely expensive and require foreign expertise and large amounts of foreign currency for engineering and construction materials that are not available locally. A limited Metro system would cost billions of dollars and an LRT system would cost hundreds of millions as well as requiring ongoing government subsidies.

CHOOSING THE RIGHT TRANSPORTATION MODE FOR KHARTOUM

There are many factors that must be considered in order to identify the best technology or mode for use in the Khartoum context.

These include:

- Ability to meet ridership patterns & volumes
- Capital cost of the installation of the system

• Ability & cost of maintaining the system

• Cultural fit

• Constructability considerations

After careful study of the local situation and a review of options, this report concludes that the establishment of Bus Rapid Transit (BRT) would be the best option for the Khartoum region. A BRT service – initially a single pilot-test line and, eventually, a network of such lines – would provide fast and reliable travel for Khartoum's citizens, especially compared to haflas, the chief public transportation option currently available.

BRT implementation is cost-effective and would improve the city's economic performance, health and social life, and would fundamentally improve the experience of residents in travelling around the city. It would foster economic growth and reduce demands on government for fuel subsidies and foreign currency reserves for the purchase of private vehicles and fuel. BRT could help reduce a tendency to car dependence and, therefore, ease the City's challenging traffic congestion -- facilitating commerce and streamlining the flow of merchandise.

BUS RAPID TRANSIT (BRT)

Bus Rapid Transit (BRT) has design and operating features intended to keep the service moving quickly and efficiently.

The main one is its own physically-separated right-of-way within a public roadway, which is created through the use of a small physical barrier -- made of concrete blocks or poured concrete -- which prevents private vehicles from using the right-of-way, and allows buses to move quickly and without obstruction or delay. There would be simple stations approximately every 500 metres. BRT can accommodate up to 10,000 passengers per hour per direction at the peak point under certain circumstances, but requires passing lanes and other elements like traffic signal priority that will not be available in the first BRT phase. The design of a BRT line would have to be carefully considered, because high ridership would likely occur from day one based on existing information about travel patterns.

To accommodate the high volume of riders expected to use a BRT, the service level (frequency of service) would be set as high as is practically possible throughout the entire operating day to accommodate as many riders as possible. Frequent service would contribute to making the BRT an attractive travel option at any time of the day or evening, and would allow the BRT to take advantage of relatively-low variable costs (salary and fuel) in relation to fixed costs like vehicles and stations. BRT is a relatively-efficient mode and is expected to allow the full cost of operations to be recovered from riders' fare revenues. The fare could be comparable or lower to those of other competing services (including combined fares for trips that involve multiple transfers) which would make BRT service affordable for as many people as possible.

PILOT PROJECT

The project team has identified possible non-government funding and assembled a delivery team to construct and operate a BRT line of 9km to 13km within 6 months of approval by the government. While BRT is a proven technology used in over 300 cities around the world, it has not been used in Sudan. To demonstrate that it would be feasible in a Sudanese context, the use of a limited 1-to-2 year “pilot project” is recommended.

A BRT pilot project would be a temporary operation, the performance of which would be technically evaluated. The government would seek feedback from the public, and the metrics and operations would be evaluated to determine if the line should be made permanent. No major reconfiguration of the roadway would be done, so the BRT pilot could be easily removed if not approved for long-term operation. The use of a “pilot project” would also reduce potential opposition as there would be no commitment that the project would be made permanent.

PILOT PROJECT ROUTE SELECTION

Several criteria were used in the selection of possible routes for the pilot project, although there may be other considerations beyond purely technical ones. Therefore, this report assumes that the government would use this information as part of its decision-making process regarding which route to use if the “pilot project” goes ahead.

The main criterion considered in the selection of a possible route was maximization of the number of potential riders served. Since the single largest destination in the region is the Central Business District (CBD) of Khartoum (around Al Souk Al Arabi), only potential routes connecting to the CBD were considered. Candidate routes would also need to have substantial trip generators along the way, provided by such elements as high-density residential neighbourhoods within a 5 to 10 minute (500m to 800m) walk to stations, or areas with a high density of jobs for people to commute to/from.

Another important criterion was the physical condition of the roads which would be travelled by the BRT-- particularly the width. This is critical because, after dedicating two lanes for the exclusive use of the BRT, it would be necessary to still have two additional lanes of traffic in each direction to ensure that roads can continue to function for all other users. Therefore, for a corridor to accommodate a BRT, it would need to be a minimum of 6 lanes wide, or at least 20m wide.

Many of the traffic pinch points in the capital are around bridges -- which are also important strategic infrastructure -- so, while a BRT network would need to include bridges, the use of routes involving bridges introduces an additional complication, though one has been included for comparison purposes.

PROPOSED PILOT PROJECT ROUTE OPTIONS

In order to deliver a pilot project quickly and affordably, routes of around 10km were considered based on the route-selection criteria outlined above. The options have been narrowed down to the three below.

OPTION 1:

Route: From northern terminal just west of Jackson's Station: east on Army Road, and south on Africa Street to southern terminal at Madani Street.

OPTION 2:

Route: From northern terminal just west of Jackson's Station: east on Army Road and Buri Road, and south on Ebed Khatim Street to southern terminal at Madani Street.

OPTION 3:

Route: From northern terminal just west of Jackson's Station: south on Al Huriya Avenue, east on King Abdel Aziz Street, south on Mohammed Najeeb Street, east on Al Shargi Street, south on Ebed Khatim Street to southern terminal at Madani Street.

BENEFITS OF PUBLIC TRANSIT

Public transit offers many benefits to people and communities; some benefits are more tangible than others.*

1 IT BENEFITS COMMUNITIES FINANCIALLY:

For every dollar invested in public transportation, approximately $4 in economic returns are generated. It also raises property values and would reduce the amount of foreign currency needed for fuel and vehicle imports.

2 PUBLIC TRANSPORTATION REDUCES AIR POLLUTION AND IMPROVES HEALTH:

By moving people more efficiently, public transit produces significantly less air pollution per passenger kilometre than a standard car carrying a single driver. Buses emit 20% less carbon monoxide, 10% as much hydrocarbons, and 75% as much nitrogen oxides per passenger then an automobile with a single occupant. By reducing pollution, air quality is improved reducing pollution linked respiratory illnesses.

Public transportation is also linked to healthier lifestyles, as people who use public transportation get more than three times the amount of physical activity per day than those who don't, just from walking to and from their transit stops and their final destination.

3 REDUCED TRAFFIC CONGESTION AND TRAFFIC DELAYS:

Public transportation can carry many more people in much less space than individual automobiles, which helps reduce accidents and air pollution.

Good public transit also saves travel time and can significantly reduce the amount of time people and goods spend stuck in traffic, increasing work productivity and economic returns, reducing delivery times and costs as well as allowing people to spend more time with friends and family.

4 GREATLY INCREASES MOBILITY:

For those who don't, or can't drive, public transportation allows them to get to work, to school, the grocery store, or medical centres without having to engage a friend or relative to do the driving.

ON THE ROAD TO MOBILITY IN KHARTOUM

RECOMMENDATIONS

This report concludes that Bus Rapid Transit (BRT) network is the best technical solution to quickly improving the transportation situation in Khartoum for the average resident. It would allow for timely, relatively non-disruptive, and inexpensive urban transit improvements. The recommendations below are designed to provide a starting point for moving forward and are backed by further details in the report.

OUR RECOMMENDATION:

1 The Government of Sudan (GoS) endorse BRT as the best technical solution to quickly improve transportation in the Greater Khartoum area, recognizing that a large surface or underground rail network would take many years to build and be cost prohibitive.

2 Prioritizing current and future transportation infrastructure resources on Bus Rapid Transit, instead of investments in road infrastructure, is the best path forward, recognizing that 85% or more of residents travel by mass transit or walking, and that investment in public transit would result in better economic, social and environmental outcomes.

3 The immediate start of work on a "pilot" BRT route of around 10km be authorized, acknowledging that funding for the pilot project may be possible by fundraising and in-kind donations coordinated by the Sudanese diaspora.

4 That the exact routing of a BRT pilot route should be decided based on a detailed ridership study and survey of the local conditions.

5 The pilot project be delivered as a Public Private Partnership (P3), with the government of Sudan providing the land for the route and the maintenance centre, along with the use of buses from the Khartoum General Transportation Authority, for a period of at least one year.

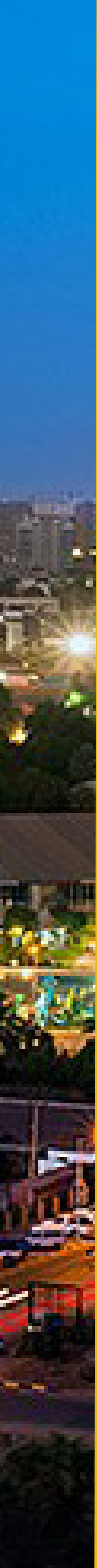
6 Further work be done to identify a possible future network of up to 250km of BRT that could be implemented over the next five years, to serve between 5 and 8 corridors.

7 The government work to get access to cell phone data that could be used to determine population demographics and mobility data in the absence of more detailed studies.

8 A review of the pilot project be conducted after one year to evaluate whether it is a success, and whether additional BRT routes should be established

9 The government consider setting up a dedicated unit with expertise in transportation and finance to oversee the BRT pilot and the possible development of a future BRT network and delivery method.

10 The GoS consider allowing innovative financing techniques like Tax Increment Financing or other associated development strategies to finance the government's contribution to the project.



SECTION A

INTRODUCTION

The twin cities of Khartoum and Omdurman along with their neighbour Bahri are among the largest urban centres in Africa and quickly approaching 10 million residents. Their current transportation infrastructure is not sufficient to support a large population and promote economic growth. Khartoum needs a public transit system to allow residents to move efficiently and cost effectively around the City.

This report reviews the current transportation situation in Khartoum and explores options for improving transportation in the Khartoum metropolitan region.

The purpose of this report is to give decision-makers a strong understanding of the current situation and provide options and recommendations for upgrading the transportation network in Khartoum, recognizing the limited resources of the government.

In addition to recommending specific actions, the report provides background on the key elements of implementing efficient and effective public transit, and provides options for a pilot project that could be quickly implemented at little or no cost to the government. It describes the benefits of public transit, and the history of transportation in Khartoum. Project delivery and financing options are also presented.

The project team which has compiled the report blends international expertise with strong local knowledge and context through a series of partnerships. It is hoped that this report will serve as a call to action for those in government and offer a practical way forward.

MEET THE TEAM

The Malik Group has assembled a team of professionals from a variety of backgrounds, combining technical expertise in a number of fields including engineering, planning, and transit operations, and having work experience in Sudan and around the world.

This combination of international expertise and local knowledge allows us to provide strong and thoughtful analysis and project design, ensuring that solutions are practical and sustainable in the Khartoum context as well as conforming to international best practices.

TEAM LEADER
Adam Giambrone

The team leader is Adam Giambrone who has 18 years in the transportation industry. The former President and Chair of Toronto Transit Commission (TTC), Giambrone was also Director of Studies - Planning and Innovation, for Montreal's Metropolitan Transportation Agency, and was head of Surface Rail Expansion, City of New York. He has acted as a consultant to transit agencies around the world and has participated in providing training and advisory services as part of UITP (International Association of Public Transport) and UATP (African Association of Public Transport). In 2018 he was appointed as the General Manager for the Saudi Public Transit Company (SAPTCO).

Giambrone has an MBA from the University of Toronto (Canada), an EMBA from the University of Saint Gallen (Switzerland), and a BA in archaeology (Nubian) and African Studies from McGill University. He has spent over 20 years working with the Sudanese National Corporation for Antiquities and Museums (NCAM) on archaeological missions in northern Sudan, and speaks conversational Arabic.

Having lived in Khartoum and been a frequent user of its public transportation for over two decades on and off, Giambrone is aware of the realities of the City's public transit and the challenges local authorities and government face in organizing and building capital projects in the Khartoum region.

PRESIDENT
Hussein Malik

Hussein Malik is the President and Co-Founder of Malik Solutions Group. He is a public policy professional specialized in public management. Hussein currently works with Polycultural Immigrant and Community Services, helping them fulfill their mandate to speed the integration of new immigrants into Canadian society. He has worked with other settlement and civic engagement organizations, and recently spearheaded the resettlement of the Arabic speaking Government Assisted Refugees (GARs) and Privately Sponsored Refugees (PSRs) in the Toronto and Peel region.

Over his career, Hussein has provided administrative, government relations, and public management support to different levels of government, working to enhance their institutional effectiveness. He has also led political campaigns at various levels in Canada for elected officials who have demonstrated their desire to bring positive change to communities.

Hussein has a Bachelor degree from York University (Toronto, Canada) and Dual Master's in Public Policy & Public Management from the University of London in the UK. Hussein writes extensively on the challenges facing the Sudanese Government and Canada's involvement in Africa and Sudan.

Having lived and grown up in Sudan, he is aware of the realities of public transit in Khartoum and the challenges the government is facing to enhance their institutional effectiveness.

CHIEF PLANNER

Mitch Stambler

Mitch Stambler worked for 35 years in the Operations and Planning areas of the Toronto Transit Commission – twenty-two of them as Head of Planning and Strategy.

He oversaw a number of landmark projects for the TTC, including the Ridership Growth Strategy, the Toronto Light Rail Plan, Automated Fare Collection, Transit Plan for the 2015 Pan Am Games, Accessibility Plan for the TTC, and various environmental assessment, business case, and transit technology reports.

He has Masters Degrees in Transportation Planning and Business Administration, and has held positions in professional organizations including International Union of Public Transport (UITP), Canadian Urban Transit Association, Institute of Transportation Engineers, American Public Transportation Association, and Canadian Institute of Planners.

PROJECT ENGINEER

Khairy Construction

Khairy Construction was founded in 1970 in Khartoum by Engineer Alsir Khairy. Khairy Construction has extensive experience in civil engineering and construction in Khartoum with over 500 completed private and public sector projects. It is known for delivering high quality projects that use internationally- trained professionals and equipment in a cost- effective manner.

The lead engineer for the BRT project is Hossamaldin Khairy.

Khairy Construction is responsible for the engineering and design work associated with the physical on-street infrastructure of the BRT, as well as for preparing the construction budgets and other technical documents.

KHAIRY CONSTRUCTION
خيري للانشاءات و المقاولات

Other Team Members to be Added in the Next Phase

This report reflects the knowledge and experience of professionals in various fields, including engineering, planning, and transit operations -- experts who reviewed the content to ensure the project benefits from global best practices. Moving forward, the team will expand its roster of on-the-ground experts to include those with expertise in construction projects in Khartoum, and bus operations generally, using their extensive connections in Sudan and internationally

REVIEW OF CURRENT SITUATION

Khartoum is a dynamic city with people from all over Sudan representing many different cultural backgrounds. As the national capital, the twin cities of Khartoum and Omdurman (along with Bahri) are also the economic and the governmental centre of the country.

Well over 50% of Sudan's GDP is generated in the Khartoum area, and the city's average per capita income is well above the national average of around $2,800 USD.

Khartoum's economy resembles that of modern capital cities around the world: it commands around 45% of the national economy based on industry, and well over 80% of the economy focused on services.

The city has seen rapid industrial development in sectors like agricultural and meat processing, electronics assembly, plastics manufacturing, furniture making, tanning, sugar production, and various other light industries mostly located in 10 main industrial areas. These areas, along with central neighbourhood markets, are spread out around the metropolitan region and are important job centres and activity centres, therefore serving as secondary transportation hubs for informal transportation.

The City already has an estimated population of over 8 million today and covers a total area of over close to 1000km^2, although the metropolitan region is much bigger. It has a population growth rate averaging around 8% per year and is surrounded by over 500 villages which, with continued urban expansion, will all soon be part of the urban agglomeration.

Since independence in the 1950s, the City has grown dramatically from its population of around 90,000 in 1956, and is expected to reach 10 million by 2025 and 16 million by 2050.

CURRENT TRANSPORTATION SITUATION

There is a limited amount of information available about transportation in Khartoum as few formal studies have been conducted, and there is not an extensive amount of raw data availability.

The City's transportation system is based primarily on private minibuses (haflas) of various sizes that serve major roads throughout the capital. While not required to operate on formal routes, a network of standardized routes have developed, with the government playing a role in the creation of larger bus stations in places like Stad in downtown Khartoum, and outer locations such as Souk Lefa. These allow for relatively easy transfers between routes, although they offer few amenities.

Over the last 15 years the purchase and operation of private cars by residents of Khartoum has grown exponentially, a consequence of the growing population, the expansion (and widening) of the paved road network, increased incomes (prior to 2015), and subsidized gasoline supplies. A 2018 technical paper written by KIS Consultants reported that over 3 million trips were made per day. It noted that urban public transport's daily ridership for the Greater Khartoum Area in 2015 was 2.2 million, and this makes the metropolitan area's public transport share of all trips equal to **70%.**

Khartoum is a hot city with daily high temperatures hovering around 30C or higher for much of the year. The combination of heat and few passenger amenities such as bus shelters, along with the fact that virtually no haflas offer air conditioning, mean that the experience of most public transit users is unpleasant from start to finish.

While the mini-bus service offers fairly comprehensive service across the nearly 1000 square kilometers of Metropolitan Khartoum, the lack of coordination means some routes do not have adequate service. The service that does exist is slow since the minibuses pick-up and drop off passengers on an on-demand basis, resulting in a large number of stops relative to the operational practices of more organized bus services.

The haflas or mini-buses are increasingly augmented by newer air-conditioned and modern taxis, although the rates are often 40 times the hafla fare, putting them out of reach of most of the population as a means of regular transit. The older yellow taxis still remain a cheaper option (albeit much more expensive than haflas) to people who need to travel at a time when there is little public transit (the midnight to 6am period), or if transporting items.

Besides taxis there are tuk-tuks imported from India, vehicles with a cloth roof and 3 small wheels. These can carry up to 4 people including the driver and are very polluting and loud. They can be rented similar to a taxi (although cheaper and typically for shorter distances), or can be used to connect between two major roads. There is often a set fare and up to three people can ride in the back, usually for a limited journey (less than a kilometer), such as between hafla routes.

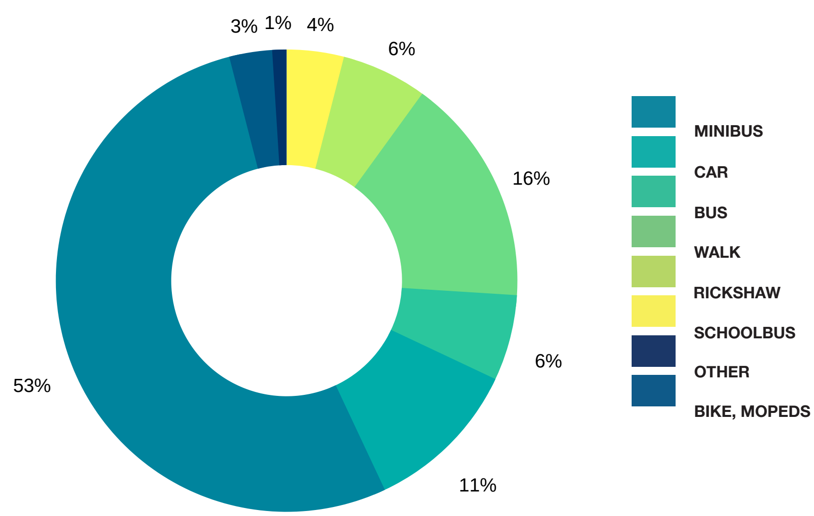
Finally, some of the lower- income areas of Khartoum (e.g. Mayo or Dar-Es-Salam) still employ "dafars" (a passenger compartment with wooden/ metal benches welded to a truck frame) or "boxies" which are pick-up trucks with a roof over the cargo bed and benches, providing a safer ride.

CURRENT ESTIMATED TRAVEL PATTERNS

The minibus or hafla is the most dominant urban transport mode for the Metropolitan Khartoum Area, with roughly one out of every two trips made using this informal and unorganized form of travel. A substantial percentage of the trips are destined for Khartoum's Central Business District or CBD (77%), representing between 250,000 and 300,000 trips each way from Bahri, Omdurman and the area south of the CBD, followed by Omdurman Centre (16%) and Khartoum Bahri Centre (7%).

MODE SHARES OF DAILY TRIPS MADE IN GREATER KHARTOUM AREA IN 2011

Figure 1: Mode shares of daily trips made in Greater Khartoum Area in 2011



As noted above, the daily urban transport ridership estimate for 2018 is around 2.2 million if one takes into account the Metropolitan Khartoum Area's estimated population of more than 8 million (as of 2018), and assumes travel mode shares have remained static since 2011, when the counts were taken, because no further data are available. Annual ridership would likely surpass 600 million rides.

This figure is just one-tenth less than the daily ridership for Tokyo's Toei Subway system, or one-half of all daily passengers riding on New York City's subway or London's underground.

CHOOSING THE RIGHT TRANSPORTATION MODE FOR KHARTOUM

Options for Improving Transportation in the Khartoum Region

RAPID TRANSIT SYSTEMS

As evidenced by many rapidly developing cities around the world, urban rapid transit systems are critical to mitigating the economic, social and environmental impacts of traffic congestion. Metropolitan Khartoum Area's urban transportation characteristics, in terms of land-use and transportation mode share, are similar to those of other key Eastern African city-regions with urban rapid transit systems

Khartoum needs to move away from buses in mixed traffic as they do not allow large volumes of people to be efficiently moved around the Khartoum region. Generally what differentiates a rapid transit system from a collection of privately or publically operated bus routes is that it has its own right-of-way -- protected from the interference and delays caused by other vehicles -- and thus offers faster and more reliable service than a typical surface transit system operating in mixed traffic conditions.

There are several options which may be considered when thinking about the possibility of introducing rapid transit in Khartoum. These differ mainly in cost, passenger capacity, construction disruption and complexity of design and implementation. Based on implementation examples around the world, we can group rapid transit modes into three main categories:

1. **Rail-based transit (Metro)**
2. **Rail-based transit (Light Rail Transit or LRT)**
3. **Bus-based transit (Bus Rapid Transit or BRT)**

1

Rail-based transit (Metro) with extensive grade separation requirements through fully tunnelled and/or elevated rail infrastructure, separating and protecting the service from the effects of parallel and cross traffic.

2

Rail-based transit (Light Rail Transit or LRT), with exclusive right-of-ways separating it from the rest of road traffic. LRTs may involve some degree of separation from cross traffic through partially tunnelled and/or elevated segments (where it operates like a Metro), or through other simpler means of physical separation allowing it to operate on-street within the road network.

3

Bus-based transit (Bus Rapid Transit or BRT) with exclusive right-of-ways separating and protecting it from the rest of road traffic. Most BRTs have no separation from cross traffic.

METRO OR HEAVY RAIL

Metro networks are designed to carry passenger volumes of upwards of 25,000 people per hour per direction, with stops typically every 0.5 to 1 kilometer. Typically, trains are scheduled to come every 2 to 20 minutes, although some systems with heavy ridership have trains arriving every 90 seconds. Metro services can travel at over 80km per hour, but their more normal operating average is usually closer to 40km per hour taking into account station stops for passenger boarding and alighting.

While parts of Khartoum have the densities required for a viable metro system, the high water table and local geology makes the build-out of a metro system complicated and the lack of a strong tax base for the government makes the funding of a metro system unrealistic in the context of likely available budgets.

This option would likely lead to average costs of $200 million or more per kilometre, taking into account both Sudanese wage rates (as well as the much more expensive salaries of required foreign experts), and Khartoum geology/landscape. This figure includes stations, but not a needed multi-hundred million-dollar maintenance and storage facility. Complex engineering and construction issues would drive the need for international expertise in engineering and design, and access to specialized equipment like tunnel-boring-machines (TBM).

Serving Omdurman, Khartoum and Khartoum Bahri would, even in a minimal situation, require a network of at least 20km, leading to costs of $3 to $4 billion minimum, with upwards of 50% of that money going to purchase out-of-country expertise and equipment (thus necessitating foreign currency).

Metros with elevated guideways are usually cheaper than tunnelled metros & Khartoum's wide steets & physical form would like to support this sort of design, but costs are still at **50%** to **75%** of the cost of underground metro systems & they would have the same issues with the need for non-local expertise.

METRO COSTING - 15KM SYSTEM EXAMPLE

Item	Unit Cost	Quantity	Total
Right of Way (includes stations)	$200 million/km	15km	$3,000 million
Maintenance Facility	$200 million	1	$200 million
Vehicle Cost	$50 million/km	15	$750 million
Contingency (30%)	-	-	$1,185 million
TOTAL	-	-	$5,135 million

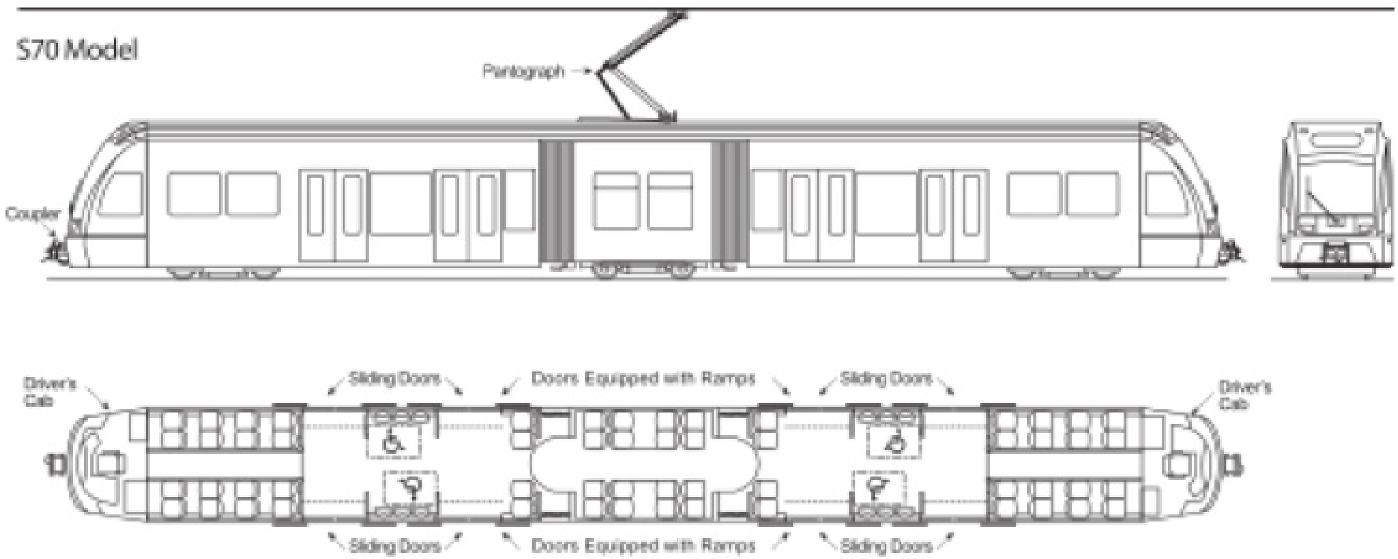
CHALLENGES

- The very high cost of construction and operation
- Most of the expertise and material would need to be imported
- Upgrades to the power supply system and maybe a dedicated source (like solar or battery) will be required

ADVANTAGES

- Comfortable and fast movement of people
- No disruption of surface transit or traffic
- Ability to move upwards of 25,000 people per direction per hour per line
- Possible property value escalation


LIGHT RAPID TRANSIT (LRT)



LRT is an intermediary mode that can carry upwards of 12,000 people per hour, per direction with the right design. The vehicles are typically between 20 and 50 metres long, 2.35 to 2.6 metres wide, and approximately 3.5 metres high. These vehicles can travel up to 70km per hour, and can carry more than 300 people with over 60 seated.

Modern Light Rail vehicles have no steps at their entrances – called low floor -- and hence are fully accessible. Typically the vehicles rely on electricity, although there are diesel models, and the rail can either be installed flush with the street paving or run on ballasted (typical railroad tracks) track. They are used in over 500 cities around the world, and over 15 cities in Africa including Alexandria and Addis Abba, which recently installed a new modern network. Other cities like Nairobi have announced that they plan to build an LRT network.

CHALLENGES

- Relatively high cost of installation
- Expertise would need to be imported and developed locally
- Would require upgrades to the power supply system and maybe a dedicated source (like solar/battery) unless diesel vehicles are used
- Requires exclusive use of two traffic lanes (or a off-street corridor)

ADVANTAGES

- Smooth comfortable, near metro-like ride
- Property value escalation possibilities
- The ability to move high volumes of people really well

LRT COSTING

Item	Unit Cost	Quantity	Total
Right of Way (includes stations)	$1.5 million/km	45km	$675 million
Maintenance Facility	$50 million	1	$40 million
Secondart Maintenance Facility	$20 million	2	$40 million
Vehicle Cost	$2.5 million	135	$200 million
Contingency (30%)	-	-	$292 million
TOTAL	-	-	$1,267 million

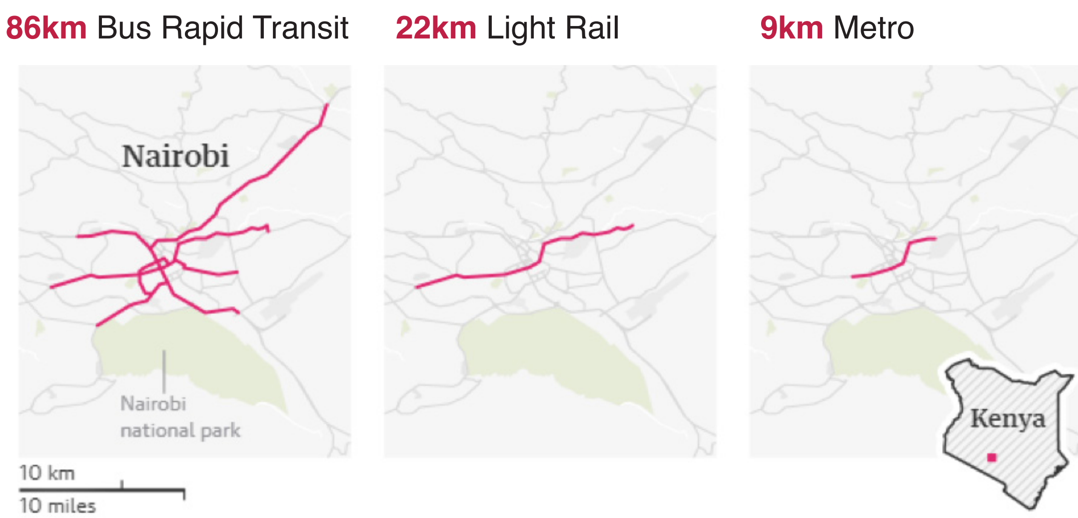
BUS RAPID TRANSIT (BRT)

Bus Rapid Transit was developed in South America starting in the 1980's. It is a cost-effective way of moving relatively large numbers of people quickly and reliably. BRT systems run in dedicated lanes along streets (separated by a curb or other barrier), and often have stations with attendants present where fares are paid in advance – an important feature for speeding up the boarding and alighting of passengers. They range from very simple systems -- with basic separation of buses from traffic and stations with minimal costs -- to projects that have large stations and bus priority measures to speed buses through intersections.

Well-designed systems have been able to carry as many people as light rail or metro systems. BRT can be designed to use different types of buses and, to increase capacity, articulated buses or even double-articulated buses may be used to increase capacity.

BRT typically has shorter implementation schedules because the amount of physical infrastructure requires less design and construction than rail-based transit. Similarly, BRT systems have low implementation costs relative to other higher volume transit options because they only require the construction of stations (which can be much simpler than those for rail based transportation), and can use existing roads with some reinforcing (usually a concrete base) to handle increased wear and tear due to heavier bus traffic.

WHAT $1 BILLION BUILDS IN NAIROBI - AS A COMPARISON



Comparison of rapid transit lengths that can be afforded by US $1 billion

THE KEY CUSTOMER SERVICE ELEMENTS OF A BRT ARE:

- Predictable (on-time and regular) and faster service - few traffic delays because the buses operate in their own dedicated lanes
- Air conditioned vehicles
- Smoother ride and more comfortable vehicles

One issue that often arises with a BRT system is the problem of private vehicles attempting to use the dedicated right-of-way (ROW) likely located in the middle of the street. A number of design features, including the use of rough surfaces -- except where the bus wheels run (cars have narrower axels) -- would make private car use of the ROW less pleasant. Staff could also be placed at barriers to the entry at intersections.

BRT COSTING

Item	Unit Cost	Quantity	Total
Right of Way (includes stations)	$0.5 million/km	250km	$125 million
Maintenance Facility	$5 million	4	$20 million
Vehicle Cost	$0.1 million	1250 buses	$125 million
Contingency (30%)			$80 million
TOTAL	-	-	$350 million

CHALLENGES

- Requires two lanes to be taken away from mixed traffic and re-dedicated solely to buses
- Strategies are needed to prevent cars from using the dedicated lanes

ADVANTAGES

- Rapid implementation due to simplicity and ease of infrastructure deliverability
- Low cost of installation and operation
- Can move large volumes of passengers
- In use in many African countries including Ethiopia, Nigeria, Tanzania, Kenya and others
- Requires no specialized engineering, and operations; concept is easy to run
- Vehicles may be purchased from a wide range of producers
- Creates dedicated traffic-free lanes that can be used by emergency and government vehicles

SO WHAT IS THE BEST MODE FOR KHARTOUM?

There are many factors that come into play when considering the best technology or mode for use in the Khartoum context.

These include:

- Ability to meet ridership patterns and volumes
- Capital cost of the installation of the system
- Ability and cost of operating and maintaining the system
- Cultural fit
- Constructability considerations

The physical size of the metropolitan area and the relatively large public transit ridership require multiple lines to adequately serve the region. This report takes the perspective that the initial public transit plan for the city should have, as its first-phase goal, serving a third of the current public transit ridership with the new system.

In proposing development of a starter system, our assumptions are that the new the line(s) will be fed by private haflas to increase the catchment area, that the system will target the corridors with the current highest ridership and, finally, that it will move people quickly and comfortably around Omdurman, Khartoum and Bahri.

Consideration of the metro mode has been eliminated due to the high cost and complexity of construction, which would limit the size of the system due to budget constraints. In addition, since most of the construction would involve expertise and materials from outside the country, there would be a drain on foreign currency reserves, and a limit to the creation of local economic activity relative to what one would expect from an LRT or BRT system.

Metro systems are often suggested where the geography presents few opportunities for surface transit options. This is not the case in the Khartoum region. The existing road corridors offer enough space to allow for the installation of surface transit, either BRT or LRT in a dedicated right-of-way, capable of providing high quality, fast, and reliable transit service to the residents of Khartoum.

Comparing the three modes of transportation in terms of what a hypothetical initial first phase would likely look like, based on financial cost and construction time, it is estimated that a first phase of a metro system would produce approximately 10km-15 km of transit, while a new LRT system would likely consist of 20km-50km of track. A first phase BRT system, with its relatively- low cost of construction and simplicity of construction, could have 100km, with a network growing to 250km of BRT lines serving many parts of the city.

A first phase would serve, in the case of a metro, approximately 10% of transit trips in the Khartoum region; an LRT would serve around 10-15% of trips; and a BRT system of 100km could service approximately 30% of daily transit trips. A BRT start-up could serve approximately 750,000 to 1 million trips per day, or around 250 to 325 million trips per year.

LRT VERSUS BRT

The choice between LRT and BRT is primarily one of funding availability. The estimated cost of an LRT is $1.27 billion, 8 times more than the estimated $145 million for a 100km BRT which could include about 3 times as many kilometres as an LRT proposal.

An important assumption is that a large number of the existing haflas would be used to transport people to and from the BRT lines, essentially acting as local feeder lines. While a reduction in the total number of haflas would be expected, a large number of them could be used more efficiently, and many of the jobs could be preserved.

The necessity of haflas as feeders to the BRT is why the proposed BRT fares would have to be capped if a BRT were implemented. Many people would still need to pay an additional (albeit a smaller amount) to a private hafla to get them from the BRT to their home, or to an area not served by a BRT. This last point takes into consideration that many residents of Khartoum do not like to walk upwards of 10 minutes, a consequence of the weather, lack of sidewalks, and the quality of the road.

In deciding between BRT and LRT, one critical element is the distribution of ridership among the lines. While the exact capacity and distribution would depend on the final route(s) chosen and the operating conditions, initial survey work determined it would be feasible for the routes to be run either as LRT or BRT.

Examples of variables affecting passenger-carrying capacity of a system are:

- **Dwell Time at Stations**

  The time it takes for people to get on and off a train/bus

- **Traffic Signal System**

  Delays at intersections

- **Minimum Headway**

  The average interval of time between vehicles moving in the same direc-tion on the same route. The shorter the headway, the higher carrying capacity of the route

- **Passenger-Carrying Capacity of Vehicles**

- **Passenger Crowding Levels**

  How many seated passengers, and how many standing passengers would be allowed on each vehicle

- **Peak Hour Factor and Travel Patterns**

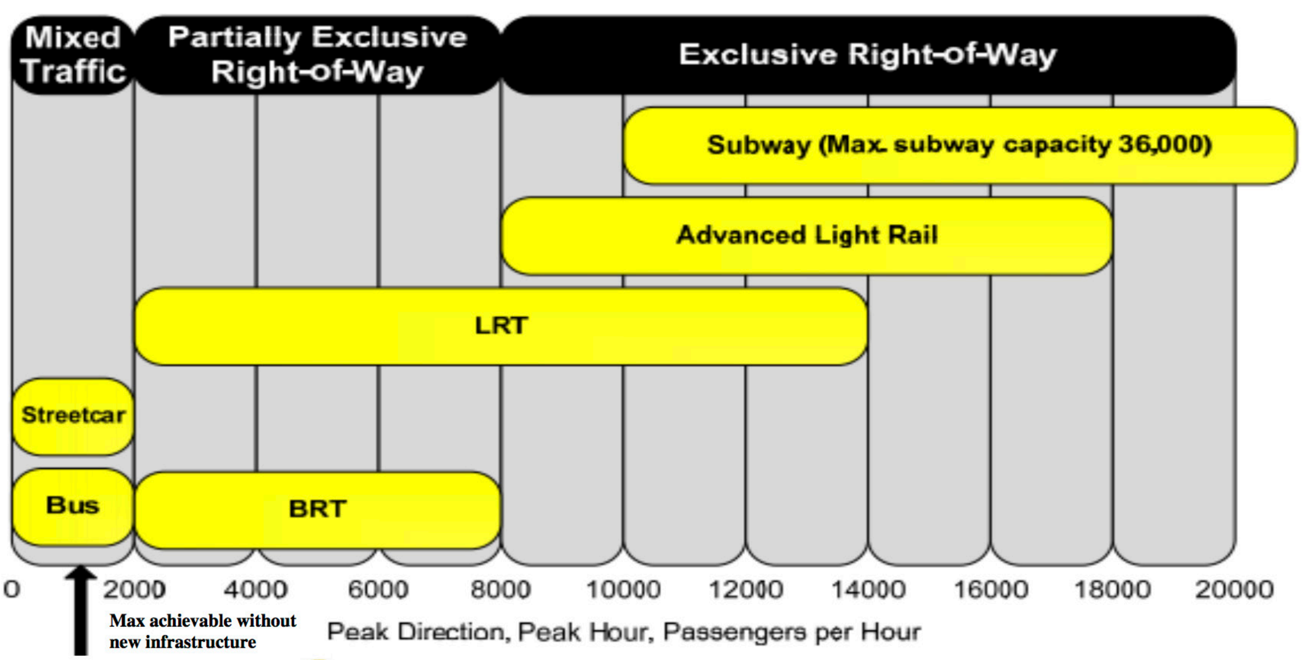
  How many people travel in rush-hour and whether there is local traffic verses commuter traffic patterns

In our view the potential lines will need to carry between 30,000 to 75,000 per day (with the lower number being for the

BRT system that will have lower levels as there will be more lines offering alternatives as opposed to LRT) with peak points in the 15,000 to 20,000 passengers per direction per hour which are both at the upper end of the capacity levels of these transportation modes. This suggests that the design of lines will need to be carefully considered and that high ridership will occur from day 1.

Given the potential demand for quality transportation in Khartoum, each BRT or LRT line – if carefully and thoroughly planned – could carry in the range of 40,000 to 70,000 per day. If more lines were provided – as one expects in a more comprehensive network -- then the passenger demand can be distributed over the various lines, so the demand (and crowding) on any given line can be better managed. The lower cost of BRT, compared to LRT, would allow the construction of more lines for the same amount of money and, therefore, allow this better distribution of ridership among lines. This is important because, while it costs much less to construct BRT than LRT, a BRT can carry upwards of 5,000 to 10,000 (under the right circumstances) passengers per hour, compared to an LRT which can carry upwards of 10,000 passangers per hour. Even though there is only limited available information about travel patterns in Khartoum, it is probable that any quality transit offered - BRT or LRT – would be heavily patronized almost immediately. If demand were unexpectedly heavy, it would be possible to increase the capacity of the lines through means such as the use of articulated busses (image below) or bypass lanes.

Based on existing information about travel patterns, we feel that the lines will be close to capacity on opening day and that the use of double or triple articulated buses will be required to provide as much capacity as possible, although we note they may not be available at the start of service.



SECTION C

THE BASICS OF BRT: CRITICAL BRT DESIGN ELEMENTS

This section describes the key policy, design, and operational elements required for the implementation of a BRT line.

Physical Requirements to Achieve a High Quality BRT Service:

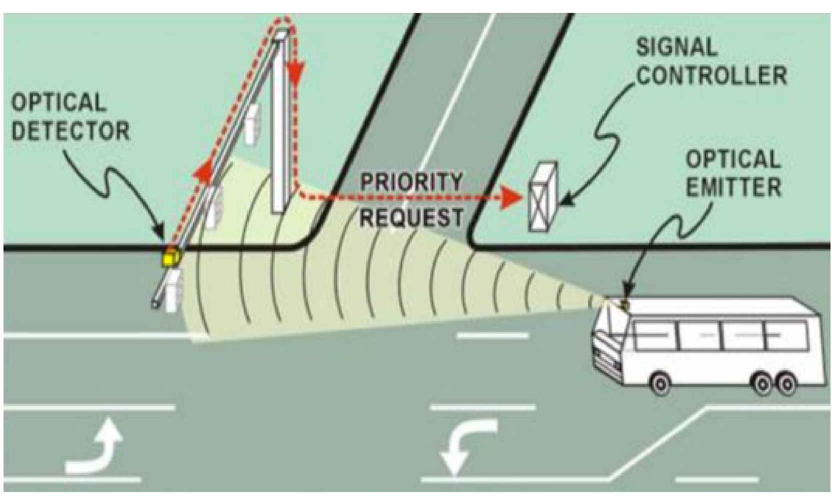
CENTRE OF THE ROAD, PHYSICALLY-SEPARATED LANES

In order to be able to operate a high-frequency service reliably – moving quickly without delays or obstructions -- it would be necessary for the BRT to be operated in its own physically-separated road lanes, completely free of other vehicles and road users except when it passes through intersections.

To reduce impacts on properties along the ROW (Right-of-Way), a BRT should be operated in the centre of the road so as to reduce impacts on parking, drop-offs, and necessary deliveries. Centre-of-the-road positioning also allows a BRT to bypass side-streets, thus avoiding the impacts of traffic crossing the reserved lanes to access the street.

Establishing a ROW could be achieved by means of physical barriers – for example, bollards, curbs, or medians – or by means of police enforcement, whereby traffic officials would ensure that only BRT be allowed in the reserved lanes. Using non-physically separated lanes that rely solely on police enforcement is not an effective long-term, permanent strategy because traffic police have competing enforcement priorities, and because drivers' lack of experience with dedicated exclusive lanes could result in conflict between buses and private vehicles.

TRANSIT SIGNAL PRIORITY



See full description on page 35-36 with further details in Appendix F.

PROPOSED STATION DESIGN

STATION SPACING, LOCATION, & AMENITIES

Bus stops should be located where people can access them as conveniently and safely as possible. Stops located at the intersections of major roads -- which provide access into the adjacent community -- achieve that. Stops should be located far enough apart that the bus service can achieve a satisfactory average operating speed -- so passengers feel they are making good progress along the route -- but close enough together that residents do not have to walk excessive distances to access them. The best stop spacing requires a balance between these competing objectives and, at the same time, must be adjacent to intersecting major roadways.

International experience in major transit systems indicates that customers of public transport will walk at least 500 metres to access transit service, with longer distances being somewhat of a deterrent. These access distances are affected by the directness of the local road patterns, and the availability of safe and navigable walk paths to the service. These conditions vary from city to city. In the case of Khartoum, with high temperatures and low quality pedestrian infrastructure (a lack of dedicated space for pedestrians), it is observed that people prefer to walk shorter distances than in other cities with less extreme temperatures and better conditions for pedestrians.

Some of the customers for a BRT service would access it by transferring from other transport services such as haflas and, therefore, no walking would be required. The attractiveness of this option would be strongly influenced by the agreed-upon arrangements for transferring between other transport services and the BRT, notably what additional fare, if any, is required to transfer between these two types of service.

Another important consideration in making public transport attractive is provision of basic amenities at the stop locations to make any waiting time more comfortable and pleasant. There should be at least a minimum amount of space to allow customers to comfortably congregate at the stop – typically 1.5 to 2 metres wide; there should be one or more benches to allow people to sit while waiting, especially for customers who are elderly or have mobility challenges; and there should be some form of shelter to allow waiting customers to be protected from rain or sun, when it is particularly intense. Another possible amenity to consider is street lighting for security and safety at night. This could be provided by low cost solar panels, thus eliminating the work needed to connect to the electrical system.

The stop locations indicated in the attached appendix are based on a target stop spacing of 500 metres. This is not always achievable – in any city -- and the actual stop spacing and locations reflect a number of factors including the distance between adjacent major roadways and the need to have stops at certain major destinations.

Policy Requirements to Achieve a High Quality BRT Service

TRAFFIC PRIORITY AT INTERSECTIONS

A BRT would have to be provided priority over other traffic at as many intersections as possible, especially where buses must make a turn, in order to maintain high quality operations. This can be achieved in various ways: through the presence of traffic officials to ensure that all other road users yield to buses moving through intersections; through the installation of more-advanced traffic signals with the ability to detect when a bus is approaching an intersection, or through provision of a separate signal phase and indicator allowing only buses to proceed while all other traffic remains stopped.

The latter is a more-expensive and complicated system, which would typically be implemented after the BRT has been in operation for some time, and has an established solid base of ridership. On going maintenance of such a system is also an issue for concern.

See Appendix F for more information.

USE OF ARTICULATED BUSES

BRT lines are expected to be able to carry high volumes of passengers from the start of operations and, when more-detailed ridership studies become available, a thorough cost/benefit analysis should be done on the choice of bus to be used. The analysis would evaluate the trade-off between lower purchase costs, and more expensive outlays for vehicles built specifically for high passenger volumes in a hot climate with limited access to repair facilities. Targeted upgrades from "off the shelf" models that improve durability, would likely lead to better reliability and lower long term maintenance costs.

The use of articulated (21 metres long) or double-articulated buses (up to 28 meters long) that can carry upwards of 130 to 180 people would be available options to maximize a potential BRT system's passenger capacity.

FARE COLLECTION

In order to minimize the amount of time the bus is stationary serving customers at stops, it would be necessary for passengers to board and alight in an efficient and orderly way, using all doors on the bus, and supervised and assisted by Customer Service Assistants. These would be present to sell and collect fares and provide other help as needed. It would be particularly beneficial if these Assistants were responsible for, and able to facilitate, all fare transactions at stops.

This would ensure that little time would be lost in the process of customers searching for the required amount of money, purchasing and then validating a ticket, asking questions or directions regarding their travel, or seeking clarity on other matters while entering the bus. These activities would all be accomplished on the platform before the bus arrives, thus allowing quick and efficient boarding. Using Assistants at stations (like on rail transit systems) would also reduce staffing costs associated with having "Cumsaries" who collect fares onboard vehicles today, and cut down on the number of people handling cash, thus reducing the likelihood of fare revenue loss.

At stations, off-board fare collection and verification would occur by way of purchasing entry through a Customer Service Assistant.

A concern with off-board fare collection is the question of fare validation. Normally, off-board payment allows passengers to board the bus at various doors – not just the one closest to the driver. Without a mechanism in place to validate purchased tickets or the use of turnstiles at the entrance to each station, it is possible for riders to board through any door of the bus without having paid.

Installing a system whereby passengers purchase their tickets prior to boarding, and validate prior to boarding, is essential to preventing fare evasion/revenue loss. This could be done with barriers and staffing to prevent the need to do inspections by fare enforcement officers, who have the power to issue tickets and make arrests. The customer service assistants could also staff turnstiles and sell fares as well as answering questions. Consideration should be given to use of a practical form of electronic payment of fares to limit cash handling. Such systems could initially use "scratch" cards or mobile phone-based money transfer to remain simple and cost effective.

MAINTAINING SERVICE QUALITY

In order to ensure efficient and consistent movement of buses along the BRT route, it would be desirable to have Service Supervisors stationed along the line and at the turnaround points at the ends of the routes. The Supervisors' job would be to oversee and monitor the operation to identify any irregularities in service and to take action to restore the schedule when an unplanned disruption or delay occurs.

Ideally, the buses would have GPS units to track their location (or drivers' cell phones could be used), and Service Supervisors should have apps and good quality cell phones to allow them to see the entire line in operation.

Even with all these provisions, it is unavoidable that some delays to service will occur due to unforeseeable incidents, which can happen on any bus route. Delays could occur, for example, if a bus became disabled (provisions for rapid response and towing service contracts should be made), or if the pavement proved impassable. In order to mitigate against such unpredictable events, it would be necessary to include "recovery" time at the end-of-the-route turnaround points. This is discussed further below.

BUS TURNAROUND LOCATIONS

All transit systems encounter uncontrollable or unexpected delays due to unforeseeable obstructions or disruptions along the route. While it should be the objective of any system to ensure that every vehicle travels reliably and consistently from one end of the route to the other, there are situations when it becomes necessary for a bus to turn around before it gets to its designated turnaround point.

The ability to do this adds resiliency to the operation by allowing for the quick restoration of service regularity. To facilitate such turn-back operations, mid-route turn-around loops or routings should be identified and incorporated into whichever routing option is selected. This has not been done at this early point in the planning of a Khartoum BRT but, when a specific route has been chosen, such turn-around facilities or options should be identified and formalized.


Number
1

DAILY PASSENGER CAPACITY AND RIDERSHIP ESTIMATES METHODOLOGY, BRT OPERATIONAL ASSUMPTIONS, AND BUS REQUIREMENTS

Passenger Capacity and Ridership Estimates

The passenger capacity of BRT, or indeed any transit option, depends on a number of factors that will be briefly outlined in this section. These include vehicle (bus) capacity, passenger turnover rate (the rate of boardings/aligtings per kilometer), line length, frequency of service, and the average speed of the line. The line's average net speed is influenced by the degree of physical separation between vehicles, stop spacing, the speed limit, boarding time, and the degree of priority allowed the vehicle in moving through intersections.

BUS FREQUENCY AND PASSENGER TURNOVER

If the frequency of a BRT service in Khartoum were assumed to be a bus every 2 minutes (the highest realistic level of service) and, based on an average of 60 passengers per bus (on a 12-metre bus), a BRT route would have a peak-point capacity of 1800 passengers per hour per direction. This represents the number of passengers that could travel past the busiest point on the route in one hour, in one direction. Increasing the frequency to greater than a bus every 2 minutes would increase costs, but would not likely increase the capacity because the buses would "bunch" together, due to delays at stations with boarding or at intersections.

In the absence of origin-destination information (i.e. – where people are coming from and going to), it is assumed that there would be a turnover rate in the range of 10 to 15% per kilometre, based on studies of comparable lines around the world. This means that, for every kilometre a bus travels along the route, approximately 10 to 15% of the passengers will leave the bus, and an equal number of new passengers will board.

It is also assumed that, during the midday and early evening, when demand is somewhat lower than in peak periods, approximately 70% of the available capacity of the service would be used; during the late evening, when fewer people are travelling, it would be assumed to be about 60%.

NUMBER OF PASSENGERS PER VEHICLE

The travel needs in every major city are greatest during the morning and afternoon peak periods, when people are going to their jobs and when they are returning home. Since many people make those trips in a relatively-short window of time, the demand for morning and afternoon peak period travel is significant and very concentrated in most cities, including Khartoum.

This extremely-high level of demand means that it is not possible for high-volume public transport systems to provide a seat for every passenger during those peak periods. Instead, some passengers – about one-third of peak period travellers – are required to stand. The scenario where some passengers get to sit and others stand is well established and accepted in public transport systems throughout the world. While standing on a bus is less comfortable, this discomfort would be offset on a BRT service by its relatively-higher speed, the more-reliable nature of the service, and overall, the less time it takes to get to one's destination.

Given the typical seating configuration of a regular (non-articulated) 12-metre bus, it is assumed that, during peak periods, buses would carry, on average, 60 passengers per vehicle – about 35 people seated and about 25 people standing. At any given moment, the total number of passengers, and the number of passengers who are required to stand, might be larger or smaller.

During off-peak periods – such as the midday, evening, and non-work days -- the demand would be lower and, therefore, most customers aboard a BRT bus would have the opportunity to be seated.

LARGER BUSES OFFER THE OPPORTUNITY FOR MORE-RELIABLE SERVICE

It is assumed that, if implemented in Khartoum, a BRT service would initially operate with regular 12 metre buses, possibly from the fleet of the Khartoum General Transportation Authority. This is a practical way to get a new BRT service established as quickly as possible, and with a minimum of capital expenditures.

Although somewhat counter-intuitive, it is easier to provide more-regular, reliable BRT service if the service frequency is lower – that is, if the buses are further apart. With buses further apart, they are less likely to catch up to each other, block one another, compete for space at a passenger stop, or otherwise conflict. In order to operate a lower frequency of service while keeping the passenger-carrying capacity of the route the same or higher, it would be desirable, in the long term, to operate the route with higher-capacity buses or station bypass lanes.

One way of achieving higher capacity is through the use of articulated buses, which are longer than a regular (12-metre) bus and carry more passengers. Higher-capacity buses mean that fewer buses are needed to carry the same number of passengers. In addition to the operational benefits of allowing more-reliable service, higher-capacity buses are more economical, because fewer drivers/operators are required. The option of higher-capacity buses should be considered as a future improvement, assuming an initial pilot test of the BRT service were to be successful.

Double articulated buses, which have been deployed successfully in cities around the world, would increase the capacity of a BRT line.

BRT Operational Assumptions and Bus Requirements

Many of the specifics associated with BRT operations would need further refinement, and should be the subject of a specific operations assessment conducted once preliminary design is complete. Nonetheless, this section offers some of the considerations and initial assumptions necessary for the development of an operations model and budget, as well as outlining some specific bus and staff requirements.

AVERAGE SPEED

Average speeds for transit systems often seem unusually low when viewed for the first time. This is because the average takes into account a number of factors significant and unique to transit operation, as opposed to private vehicle operations. These include the necessity of ensuring the safety of standing bus passengers through typically slower driving speeds; the time required for passenger service (the time it takes for people to get on and off at each stop); and the degree of priority -- the extent of the delay faced by buses travelling on the road, going through intersections, or making turns.

Further variables affecting the speed of transit vehicles include the actual achievable degree of lane exclusivity (the amount of other non-bus traffic slowing down movement); and delay time at traffic signals or other traffic control devices. Other factors that affect the cost (but not passenger travel time) are the time allowed for operators' personal breaks, and the specified operator's break time at each turnaround point.

As a matter of comparison, even a private car driving on a road with a posted speed limit of 40 kilometres per hour (kph) likely operates at an actual average speed of only 20-30 kph, taking into account delays at traffic signals, and waiting for pedestrians crossing the street and vehicles making deliveries, etc. Still, car drivers would rarely, if ever, calculate this as the actual average speed.

Given the large number of variables and limited data, there is no reliable way of definitively forecasting or modelling a BRT's likely operating speed. However, by taking these factors into account, and also recognizing that buses in exclusive/reserved lanes should be able to move faster than those operating in the same lanes as other traffic, we can assume that BRT buses would have an average speed of 23-25 kmph. Calculating the average speed is always more accurate after actual operating experience has been gained, and overall practices established. This is the process used in all compara-ble public transport initiatives.

RECOVERY TIME AT TERMINALS

It is assumed that, regardless of the routing option chosen, there would be four (4) minutes provided at the turn-around points at each terminal, known as recovery time. The purpose of recovery time is to allow a bus (and its operator) to get back on its schedule, in the event that it has fallen behind owing to unforeseeable circumstances. These might include a higher-than-expected number of people getting on and off at stops, or delays along the route at intersections or where the bus needs to turn, or because of an obstruction on the road. Recovery time also allows the opportunity for a bus (and operator) running ahead of schedule to similarly get back on track so as to leave the turnaround point on time, and not too early, thus avoiding getting too close to the bus in front of it.

It is possible to allow more recovery time at the turnaround points of the route, to permit bus operators the opportunity to take a break or to get something to drink. With a service frequency of 2'00'' (2 minutes), it would be necessary to add another vehicle and operator for each additional 2 minutes of recovery time (over and above the assumed 4 minutes).

Providing operators a longer break would also be made possible by positioning one or more additional "relief" operators at the turnarounds. The idea is that when a bus arrives at the turnaround point, the operator goes on break, while another waiting operator (the "relief" operator) takes over the arriving bus. This new driver is then responsible for continuing operation of the bus until the other turnaround point, where another operator(s) would be waiting to take over in the same way. The details of such a strategy would be determined in advance in order to finalize the number of buses and operators needed to provide the service.

CALCULATING THE NUMBER OF SERVICE HOURS AND OPERATORS REQUIRED

The number of hours of operation required per day would vary depending on the routing option chosen, its round-trip time, the service level, and the required number of buses. It has been assumed that the level of service would remain mostly constant throughout the operating day and evening, at 2 minutes – to ensure that the line remains an attractive travel option at all times -- even though the level of demand during these off-peak periods would be lower. It has also been assumed that there would be a 4- minute recovery time at each turnaround point, and 2 additional operators present to take over operation of the arriving bus, so that the driver can have a short break.

The total daily operating hours also includes refreshment and lunch break times, as well as the time required for operators to drive their buses from the maintenance depot to the actual service route, and then back again at the end of their shift, often referred to as "deadhead'' time. The resulting total daily operating hours and the subsequent number of operators required daily, are shown later in the report, and is based on a ten hour working day.

SPARES RATIO (ADDITIONAL) – BUSES

Every bus operation needs to have a specific number of buses to enable the operation of the planned service. But buses also need to be serviced and maintained on a regular basis, in order to ensure that they are reliable and won't break down on the route. Therefore, the total number of buses needed to provide the service consists of the number of vehicles required for on-street operations plus the number needed to be in the maintenance depot for service and repair.

If the buses were new and not likely to need a lot of maintenance, adding another 15 to 20% of the buses required for on-street operation would be a reasonable number of maintenance spares. However, on the assumption that the initial pilot test of a BRT would – for the sake of cost containment – use the Khartoum General

Transportation Authority's (KGT) (or other used buses) older, less-reliable buses needing more maintenance more often, it would be necessary to provide a larger-than-industry-average number of vehicles earmarked for service and maintenance purpos-es.

As a result of the assumed use of older buses for a pilot project, a spares ratio of 50 per cent for buses has been assumed in calculation and is intended to take into account: (a) a higher-than-usual number of vehicles needed to be available for maintenance, given the unknown condition and reliability of buses drawn from the KGT fleet or other used buses; and (b) the constant level of service throughout the operating day, requiring "surplus'' vehicles to be used for revenue service at all times, and removing the possibility – since there would be no true off-peak period – of allowing some buses to be diverted from on-street operation and sent for maintenance and servicing.

If a fleet of newer, more-reliable buses were to become available, then the spares ratio – the number of extra buses assigned to ongoing maintenance – could be made smaller. Determining the appropriate spares ratio would be derived from assessing the reliability of the buses after actual operating experience had been gained and would likely range from 15% to 50%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BRT PILOT PROJECT

Proposed Pilot Project and Route Options

WHY MOVE FORWARD WITH A "PILOT PROJECT"?

While BRT is a proven technology used in over 100 cities around the world, it has not been used in Sudan. To demonstrate that it would be feasible in a Sudanese context, the use of a limited 1 to 2 year "pilot project" is recommended.

The operating principle would be that the BRT would be considered a temporary upgrade, the performance of which would be evaluated. Following that, the government would seek feedback from the public, and finally, the metrics and operations would be evaluated to determine if the line should be made permanent. No major reconfiguration of the roadway would be done so that the BRT pilot could be easily removed if not approved for long-term operation. The use of a "pilot project" concept also tends to reduce potential opposition as there is no final decision on whether the project will be permanent at the starting point and it gives time to prove that the concept will work and therefore gain support.

PILOT PROJECT ROUTE SELECTION

For a possible pilot project, there were several criteria used in the selection of possible routes, noting that there may be other considerations beyond purely technical reasons. This report assumes that the government would use this information to make final decisions on the best route to use if the "pilot project" were to go ahead.

The first criteria considered in the selection of the possible route, was maximization of the number of potential riders served. Since the single largest destination in the region is the Central Business District (CBD) of Khartoum (around Al Souk Al Arabi), only potential routes connecting to the CBD were considered. The chosen routes would also need to have substantial trip generators along the way, provided by such elements as high density residential neighbourhoods within a 5 to10 minute (500m to 800m) walk to stations, or areas with a high density of jobs for people to commute to/from.

The second consideration was the physical condition of the roads which would be travelled by the BRT, particularly the width. After dedicating two lanes for the exclusive use of the BRT, two other lanes of traffic in each direction would have to be maintained to ensure that roads can continue to function, given that the curb lanes could be occasionally blocked for different reasons. The BRT would, therefore, need a minimum of 6-lane wide streets with 7.5 metres (m) of total width for a dedicated BRT right-of-way, with an extra 2m to 4m for stations at key intersections. This means that roads considered for possible BRT would need to be consistently at least 20m wide throughout the route to allow for all road uses.

Many of the traffic pinch points in the capital are around bridges, which are also considered important strategic infrastructure so, while a BRT network would need to include bridges, it might be desirable to stay away from selecting bridge-involved routes at the start, though one has been included for comparison purposes.

While it is hoped that there would, ultimately, be a larger network of BRT services (discussed below), testing the viability of a BRT system would require routes with sufficient distance because shorter routes would offer comparably little time-saving advantages. This is because the difference in time-savings between slow average traffic speeds of 12km or less -- as is typical in rush hour conditions now -- and the projected 22km to 25km, would be less than 10 minutes on a 5km route, especially if people were forced to transfer to/from a route serving their destination further away. The cost and time required for such a transfer would substantially reduce ridership and, therefore, not allow a comprehensive testing of the BRT concept.

PROPOSED PILOT PROJECT ROUTE OPTIONS

Based on the route-selection criteria outlined above, possible options for an initial pilot project have been narrowed down to the three outlined in this section.

OPTION 1:

Route From northern terminal just west of Jackson's Station: east on Army Road, and south on Africa Street to southern terminal at Madani Street.

MAJOR ADVANTAGES: Makes use of very wide streets, with a centre median, which could be used for passenger platforms. Serves CBD and connects with major transportation hub

MAJOR DISADVANTAGES: A large portion of the route is adjacent to the airport, which means there is no one to pick up or drop off on one side of the route.

OPTION 2:

Route: From northern terminal just west of Jackson's Station: east on Army Road and Buri Road, and south on Ebed Khatim Street to southern terminal at Madani Street.

MAJOR ADVANTAGES: Makes use of wide streets. Serves CBD and connects with major transportation hub.

MAJOR DISADVANTAGES: A large portion of the route is adjacent to the airport, which means there is no one to pick up or drop off on one side of the route.

OPTION 3:

Route: From northern terminal just west of Jackson's Station: south on Al Huriya Avenue, east on King Abdel Aziz Street, south on Mohammed Najeeb

Street, east on Al Shargi Street, south on Ebed Khatim Street to southern terminal at Madani Street.

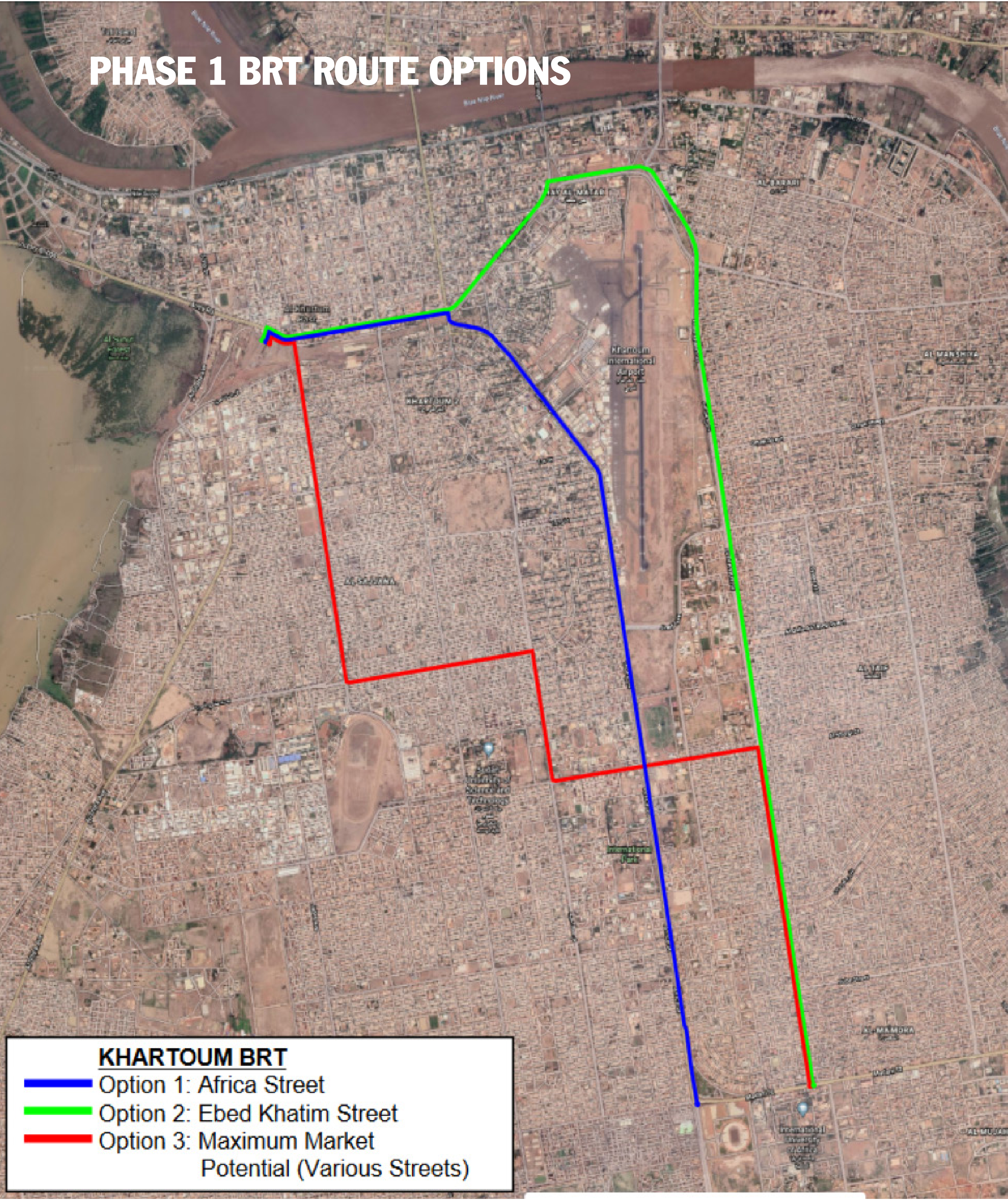
MAJOR ADVANTAGES: There are development and potential customers all along, and on both sides of the route, and the route serves well-established commercial/market streets. The route also serves the CBD.

MAJOR DISADVANTAGES: The streets do not have centre medians, so passenger boarding might need to do so from the side of the road or there would be a requirement for the installation of more physical infrastructure to ensure the BRT is physically separated. The streets that this route would use are not as wide as Africa Street.

SUMMARY OF OPTIONS

Using the assumptions outlined in Section C, and the average length of the three route options (11.4 kilometres), the representative total number of passengers who would be carried, over the whole day in each direction would be in the range of 40,500 to 64,500 (12 million to 19.8 million per year). If the demand were to be equally heavy in both directions – which is unknown at this time -- then the line would carry in the range of 54,000 to 86,000 passengers per day (16.5 million to 26.5 million per year). This total daily demand would be lower on Fridays, and to a lesser extent Saturdays, when fewer people would be travelling to jobs, stores, or offices.

PHASE 1 BRT ROUTE OPTIONS



	Option 1	Option 2	Option 3
One-Way Distance	9.8 km	13.0 km	11.5 km
Number of Stops (one way)	20	28	27
Round-Trip Driving Time	60 minutes	78 minutes	69 minutes
Recovery Time at Each Terminal	4 minutes	4 minutes	4 minutes
Total Round-Trip Time	68 minutes	86 minutes	75 minutes
Frequency of Service (at all hours)	2'00"	2'00"	2'00"
Line Capacity (passengers per-hour per-direction	1800	1800	1800
Projected Daily Ridership	29,600 - 47,100	39,300 - 62,500	40,500 - 64,500
Projected Annual Ridership	8.8M - 14.4M	11.6M - 19.1M	12M - 19.8M
Number of Buses in Service	34	43	38
Number of Additional Spare Buses Required (@50%)	17	22	19
Total Number of Buses Required	51	65	57
Total Daily Number of Service Hours (including breaks and "deadhead" time)	680	860	760
Total Number of Operators Required Per Day (including two at each turnaround point, all day)	76	94	84

PRELIMINARY CORRIDOR, FACILITY AND ROLLING STOCK CONDITION REPORT

In order to ensure that whichever route is selected would have roads which are structurally able to withstand the increased wear and tear that a high volume BRT would cause on a road, core samples were taken along the candidate routes.

The roads' construction method includes a sub-base course of 20cm to 30cm thickness made of aggregate (different sizes of crushed rock) as a foundation. On top of this, there is a 12cm to 16cm (the thickness is not consistent) of asphalt which is of moderate quality and suffers in places because of inadequate density and air voids which create uneven surfaces when combined with high volume and heavy (trucks) traffic.

For the purposes of a short-term pilot project, minor road repairs would be required, but the implementation of a permanent BRT would require more substantial road base repair to prevent extreme rutting. This might need to include concrete bases at stops where loading of passengers, combined with high temperatures for upwards of six months of the year, could lead to extreme rutting.

BUS GARAGE

The existing bus garage/depot of the Khartoum General Transport Authority, located slightly southwest of the CBD, has the capacity to house upwards of 750 buses, but its facilities are dilapidated based on a site visit in early 2020.

In order to facilitate proper storage and maintenance of buses, as well as administration, the removal of old buses (with parts stripped first) would have to occur to free up space. Physical repairs would also need to be made to the bus repair bays and administration building to allow operational functionality.

It is also likely that the existing repair equipment is not adequate and that additional equipment would need to be procured or repaired.

BUS FLEET

There were around 700 buses of various makes and ages at the bus garage, but as of earlier this year these (around 200 that were in working condition) were sold. There are currently a number of commitments to provide buses for use by governments in Sudan from non-Sudanese governments looking to offer assistance. Should these come to pass, this project will seek to use some of these buses for both the pilot project and later stages. In the absence of these buses, the project will seek to procure used buses on the international and domestic markets for use.

PRELIMINARY PILOT PROJECT CAPITAL AND OPERATING BUDGET

The cost estimate of a pilot project is quite different from that of a larger network due to the projected willingness, for an initial pilot only, of various parties to contribute expertise or building materials for free or at below-market costs. This possibility would allow a pilot to be undertaken at an extremely low per kilometre cost.

It is estimated that, based on the assumption of donated labour and expertise, as well as materials being donated or provided at cost, the cost of implementation of the pilot project could be kept to under $600,000 per kilometre. This cost-per-kilometre would have to be refined, but consists of these components:

1 PLANNING, DESIGN, ENGINEERING, CONSTRUCTION MANAGEMENT: $5,000 PER KILOMETRE

- System planning and analysis of potential routes have been provided free and coordinated by Malik Solutions
- Survey of the routes and technical drawings have been provided at cost by Khairy Construction, as were road condition reports
- The physical design was done by Malik Solutions' principal with professional transit backgrounds, along with local engineering expertise provided by Khairy Construction
- Final design and construction would require additional paid resources as well as construction management of the physical work to construct the separated busway and stations

2 CONSTRUCTION: $35,000 - $40,000 PER KILOMETRE

Stations - $20,000 per station

- Stations would be simple platforms raised around 30cm above the ground to provide easier access to buses and protection of passengers. The stations would be 2-4 metres wide and 40-45 metres long (to allow for 2 articulated buses) to load at a time
- The stations would feature limited bench style seating and an overhead roof. Construction would be simple, and use cement and brick (utilizing the existing median where possible) and pillars supporting a roof made of metal. Additional bollards would be placed at the intersection-facing side of the stations to prevent cars from entering the station area and contacting pedestrians
- Lighting would be provided by solar panels
- Control points would be established at the entry to the stations to allow fares to be collected by BRT staff, including the possibility of payment by an Open Payments system
- Consideration of the placement of advertising panels at stations to help provide operating revenue should be factored into the design

- Additional shelters would be installed on the sides of the roads to provide comfort to passengers waiting for connecting haflas

- Stations would be mostly standardized, with some minor variation for heavy volume stations and terminal stations. The presence of a median could reduce the cost of materials for the base of the station, and some stations may need to be narrower than the recommended width due to space constraints. A $20,000 per station budget is estimated

- It is estimated there will be 2 stations per kilometre, which results in an estimated $40,000 per kilometre

Curbs to separate the BRT lanes from other traffic lanes - $16,000 per kilometre

- It is proposed that the dedicated lanes would be separated from other lanes of traffic by concrete precast barriers affixed to the road base with rebars. This would allow their removal if the project is not made permanent. If it were decided to make the service permanent installation, then the BRT could be separated from other traffic lanes by a barrier consisting of poured-concrete curb of around 15cm wide and 25cm high. There would be no curb separation for the BRT lanes where they intersect with cross-streets. Therefore, for every 1km of BRT, it is estimated that there would be 800m of barriers on each side of the BRT lanes

Road Repair - $1,000 per kilometre

- In order to make the ride quality of the BRT better and to reduce damage to buses, minor repairs to the pavement would have to be undertaken along the route. This would include filling potholes, and limited repairs to the sub-base. Some of this money would be held in reserve to repair rutting that might occur during the pilot project

3 MAINTENANCE FACILITIES $50,000 TOTAL

- It is expected that, for the pilot project, the existing maintenance facility of the Khartoum General Transportation Authority, southwest of the CBD, would be used.

- Money would be allocated to bring maintenance facilities and equipment up to acceptable standards for employees and to allow proper ongoing maintenance work to be conducted. A control room would be installed to track and monitor buses

4 BUS REPAIRS OR CUSTOMIZATION: $500 - $5,000 PER BUS

- The pilot project will use buses that are donated to the Government of Sudan and it is expected that some additions or alterations will be needed even for new buses, and therefore a small amount is budgeted. In the event that second hand buses are needed, the best buses would be selected for repair and upgrading in order to improve the operation and reliability of these buses, and to improve their passenger amenities. This program might include resources to upgrade the skills of existing employees.

PILOT PROJECT FUNDING OPTIONS, AND COST IMPLICATIONS OF BUILDING A NETWORK

The new transitional civilian government in Sudan has inspired many international organizations to help the government succeed in advance of multi-party elections scheduled for 2022.

This spirit of optimism is expected to allow a BRT pilot project to procure many of the expertise and supplies at cost or below, including the donation of certain materials and expertise.

In addition, practical value engineering techniques, inspired by local knowledge of local conditions, would be utilized to design low cost solutions for the limited length (around 10km) of the pilot BRT. The result is expected to be a cost of around $50,000 to $60,000 per BRT kilometer (assuming use of Khartoum General Transport buses).

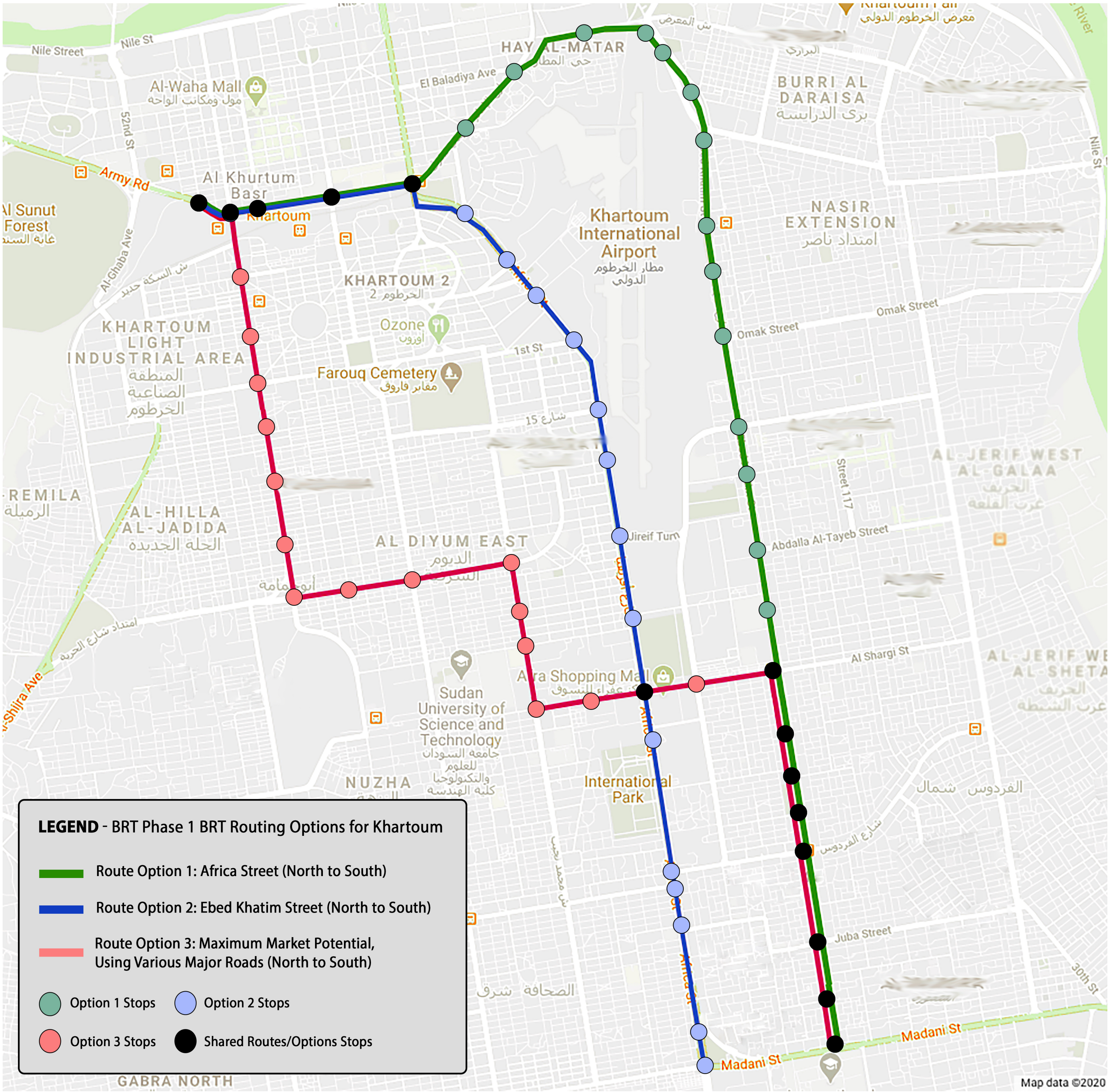
A larger BRT network, while maintaining the value engineering solutions, would not realistically be able to count on volunteer design labour, or the donation of construction materials. This reality, along with the assumption that a permanent BRT would require more-major road upgrades (to deal with the increased road stress of fre-quent heavy buses), and refurbished stations at high volume locations, would increase the cost per kilometre of a BRT by a factor of up to double or $125,000 per kilometre. However, construction costs in Khartoum would remain one of the lowest for BRTs in Africa and worldwide.

A full BRT network would need to factor in the costs of buses, as there are not enough existing vehicles in government hands at this time. The cost of a new, quality bus is estimated to be around $100,000 USD (a customs fee waiver is assumed due to the public good nature of the program). It is estimated that 5 buses (service buses and spares) would be required per average kilometer of BRT, introducing an additional cost of $500,000 per kilometer.

It is, therefore, estimated that the cost per kilometre for an expanded BRT network, including buses, would be around $625,000 per kilometre based on the cost described above. This does not include the costs of an additional bus maintenance depot, if one were to be required. It would be best practice to assume an additional 20-30% contingency on top of that estimated cost, in order to deal with unforeseen cost increases, making the stated cost around $800,000.

A successful pilot BRT project which demonstrated the feasibility and benefits of BRT in Khartoum and generated good will towards a new civilian government along with the lifting of sanctions, would allow funding to be secured from international organizations for an expanded BRT network.

POTENTIAL TRANSIT CORRIDORS PROPOSED FOR UPGRADES TO BRT



Lists of stations names and route maps available in Appendix A. Map from Google. Neighbourhods names may not be totally accurate.

BUILDING A BRT NETWORK TO SERVE THE KHARTOUM REGION

Building a BRT Netwrok

In order to provide a network that would allow reliable, fast and affordable travel across the Khartoum region, it is estimated that a network of around 250km (built in multiple phases) of BRT would be required. This would allow for a starter network of roughly two north/south lines in each of Omdurman, Khartoum Bahri, and the area south of Khartoum, connecting with the Central Business District.

A main transfer hub in Al Souk Al Arabi would allow travel throughout the region if combined with East/West BRT lines along the Shambat bridge, and one East/West route south of the Central Business District. Additional transfer points along the routes would allow transfers to/from local hafla services, which would hopefully organically realign to connect with, and serve the BRT lines, thus extending the reach of public transit throughout the region.

While hafla services would continue to operate in mixed traffic, it is hoped that many of the trips would be destined to connect with the BRT and as a result would be under 5km. Further analysis of how to improve the speed, ease, and safety of transfers would be required for each station along the BRT network.

A minimum viable network might be considered to be one north/south route in each of Khartoum, Bahri and Omdurman, with a total length of 60 kilometres, providing a base spine (with connections in downtown Khartoum) across the city. This could be considered a first part of a larger network.

Building a Long-term Network and its Potential Corridors

With Khartoum expected to reach over 10 million people by 2025, a network of rapid transit lines would be required to ensure that people can move efficiently around the region.

The identification of rapid transit corridors should be done through detailed reviews of ridership and the surveying of streets, as discussed elsewhere in this report. The corridors below are not based on extensive review but, rather, a familiarity with major travel corridors in Khartoum from years of observation.

It is recommended that, after the pilot project has been evaluated, three lines, at minimum, be considered, extending from the CBD and totalling approximately 60-100 kilometres. This would represent a second phase of BRT expansion and would include: one route heading south from Souk Arabi, one heading across the

White Nile to Omdurman, and one heading north across the Blue Nile to Khartoum Bahri. Further analysis should be done to consider which streets would be best to use, keeping in mind residential population densities close to the proposed routes, and popular destinations (employment and social).

In addition, as indicated above, the size of the road needs to be considered, since BRT requires exclusive use of a corridor of at least 7.5 metres (for a dedicated right-of-way with service in both directions), with an extra 2 metres to 4 metres where stations are desired.

While the initial pilot project would operate out of the Khartoum General Transport Authority garage, any future phases of expansion may require additional facilities. The location of maintenance depots needs to be considered carefully because they should ideally be located in a central position, relative to the lines, to reduce the inefficiency and costs of "dead-head" time (running to and from the start of routes with no fare-paying passengers) for the start and end of service.

A phase 3 of a network could consider doubling the number of lines to 2 main north/south lines in each of Khartoum (and south), Omdurman and Bahri, meeting in the CBD to allow easy transfer between lines and increase connectivity.

In addition to the north/south lines, there might be a minimum of two east/west lines, including one connecting Omdurman and Bahri over the Shambat Bridge, and one south of the CBD linking north/south lines in Lefa and Soba.

1. OMDURMAN

Over one of the two northern bridges -- likely the Victory Bridge because it is more structurally sound and wide enough to allow for a dedicated right-of-way for a BRT or LRT. This would connect Khartoum and Omdurman via Al-Mohandiseen towards Ombada/Souk Libya.

2. OMDURMAN

Over one of the two northern bridges connecting Khartoum and Omdurman, via Al-Mohandiseen, towards the University of Khartoum's Faculty of Education and the Omdurman Islamic University.

3. KHARTOUM – SOUK LEFA

South towards Souk Lefa and Al-Kalakla via Africa Street, and east along the Sudan Railways E/W connection through Abu Adam and then south to Souk Lefa.

4. KHARTOUM – SOBA

South towards Soba just east or west of the airport.

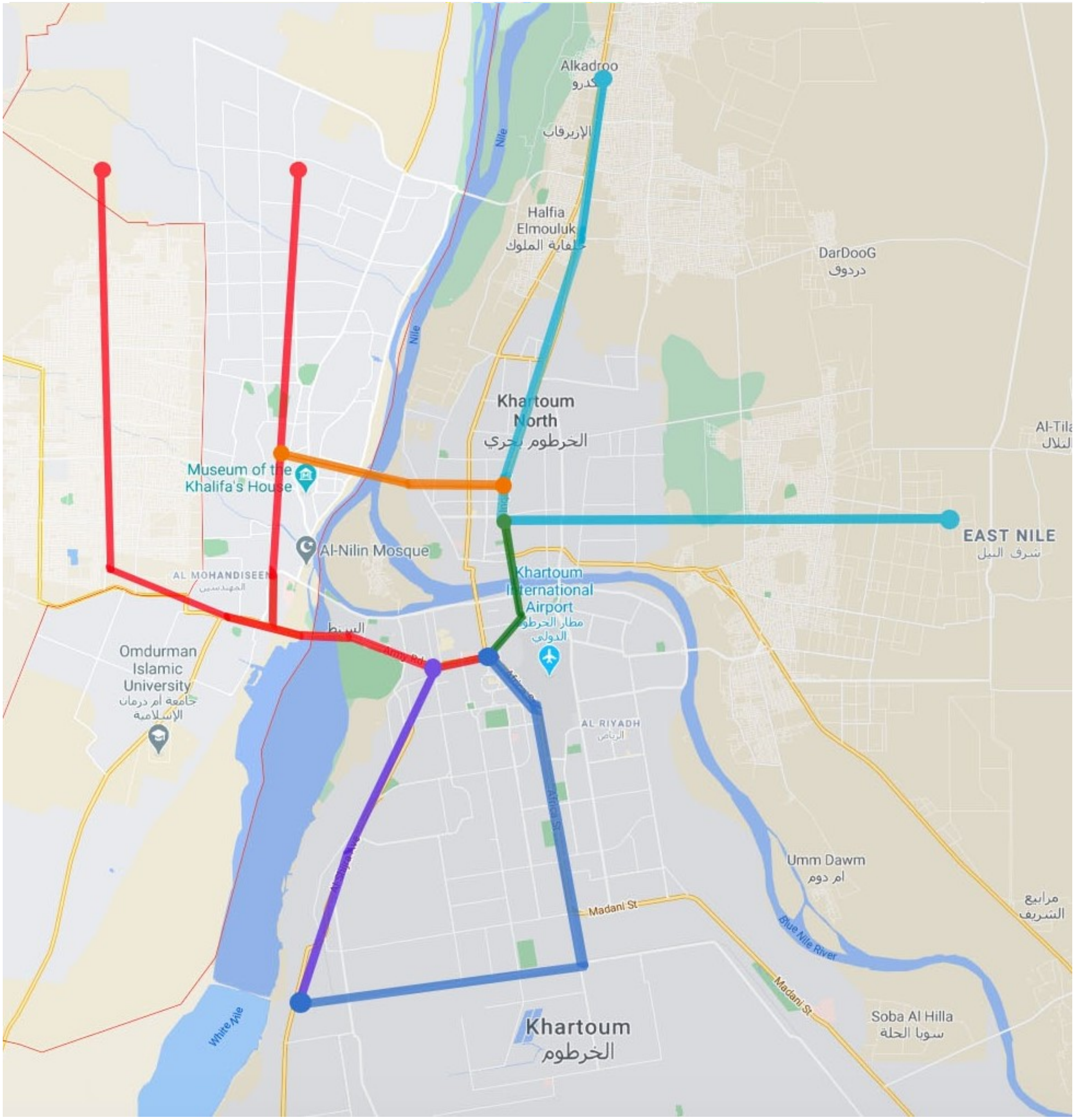
5. KHARTOUM BAHRI

North across one of the existing bridges to Bahri (likely on El Mik Nimir Avenue) and north to Kadrou via Shambat.

6. KHARTOUM BAHRI

North across one of the existing bridges to Bahri (likely on El Mik Nimir Avenue) and then northeast to El-Haj Youssif.

CONCEPTUAL FUTURE BRT NETWORK



OPERATIONAL SPECIFICS AND BUDGET

At existing fares, private operators are able to cover operating and capital expenses. While a BRT would have higher operational costs in some areas -- specifically those associated with stations and central management of the system -- it would have lower costs in other areas, resulting in no likely need for an operating subsidy if fares were kept at or even slightly below existing fare levels.

As noted in Section D, the various proposed routes have slightly different costs in terms service hours (assuming each operator works 9-10 hours a day on average with breaks) and, therefore, number of operators. The service would operate 18-20 hours a day at various levels of service (noting reduced service on Fridays and late at night). There would be “deadhead” operator time (cost) associated with getting buses to/from the bus garage at the beginning and end of service. In addition, there would be a need for training and vacation/sick time provisions which results in a 2.25 multiplication factor for the number of operators indicated for daily operation in Section D.

BRT operation would achieve efficiency through the fact that the 12-metre buses carry 25% or more passengers per driver compared to a hafla and that no cummsaries would be required. It is estimated that, for every 50 buses operated, the Full Time Equivalent (FTE) staff savings would be 100 people due to the absence of cummsaries (people would pay at stations, not on board) and because each bus would need two drivers per 18-20 hour day, as each operator would work 9-10 hour shifts. In addition, there will also be the equivalent of another 50 FTEs saved as the bigger buses carry 25% more people per driver (and this extra capacity also does not require cummsaries) than existing hafla operations. This means that the new pilot BRT will save around 150 staff salaries of drivers/cummsaries compared to a hafla operation carrying the same number of people.

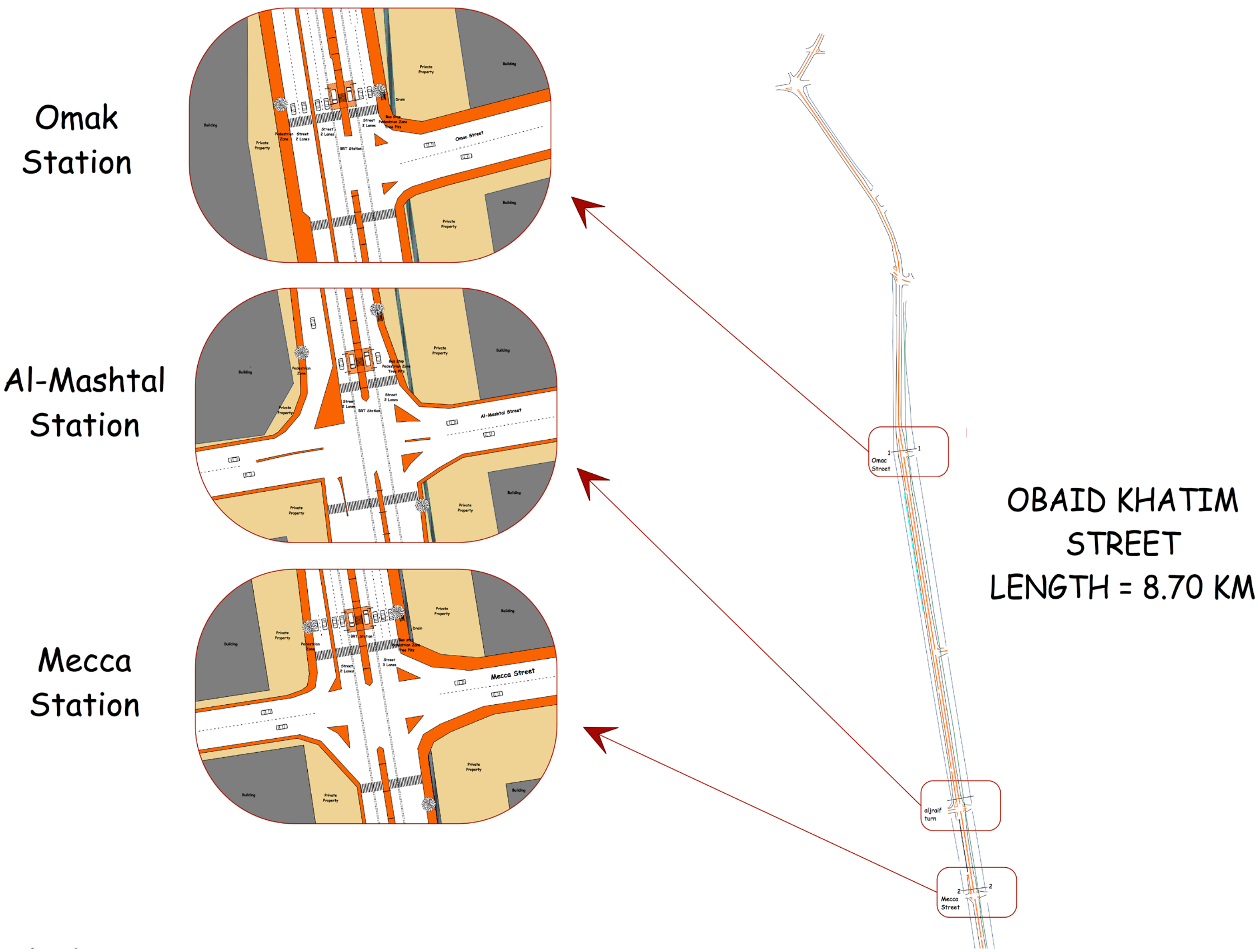
Offsetting the savings in operators/cummsaries would be the need to have two staff at each station to collect fares and provide customer service/security. The three possible routes have different number of stations ranging from 20 to 28. Taking the median amount of 24 stations (with 2 attendants at all times) and applying the same factor of 2.25 per employee to account for shifts, training and vacation/sick time, a total of around 110 station attendants would be needed.

In addition, there would be a need for a mobile repair crew for stations/buses as well as cash collection (from fares collected at stations), and on-street and centralized bus operations supervision. The pilot project would attempt to use creative ways to simplify automatic fare collection to reduce cash in the system and also look into the use of advertising on stations and buses as additional ways to generate savings.

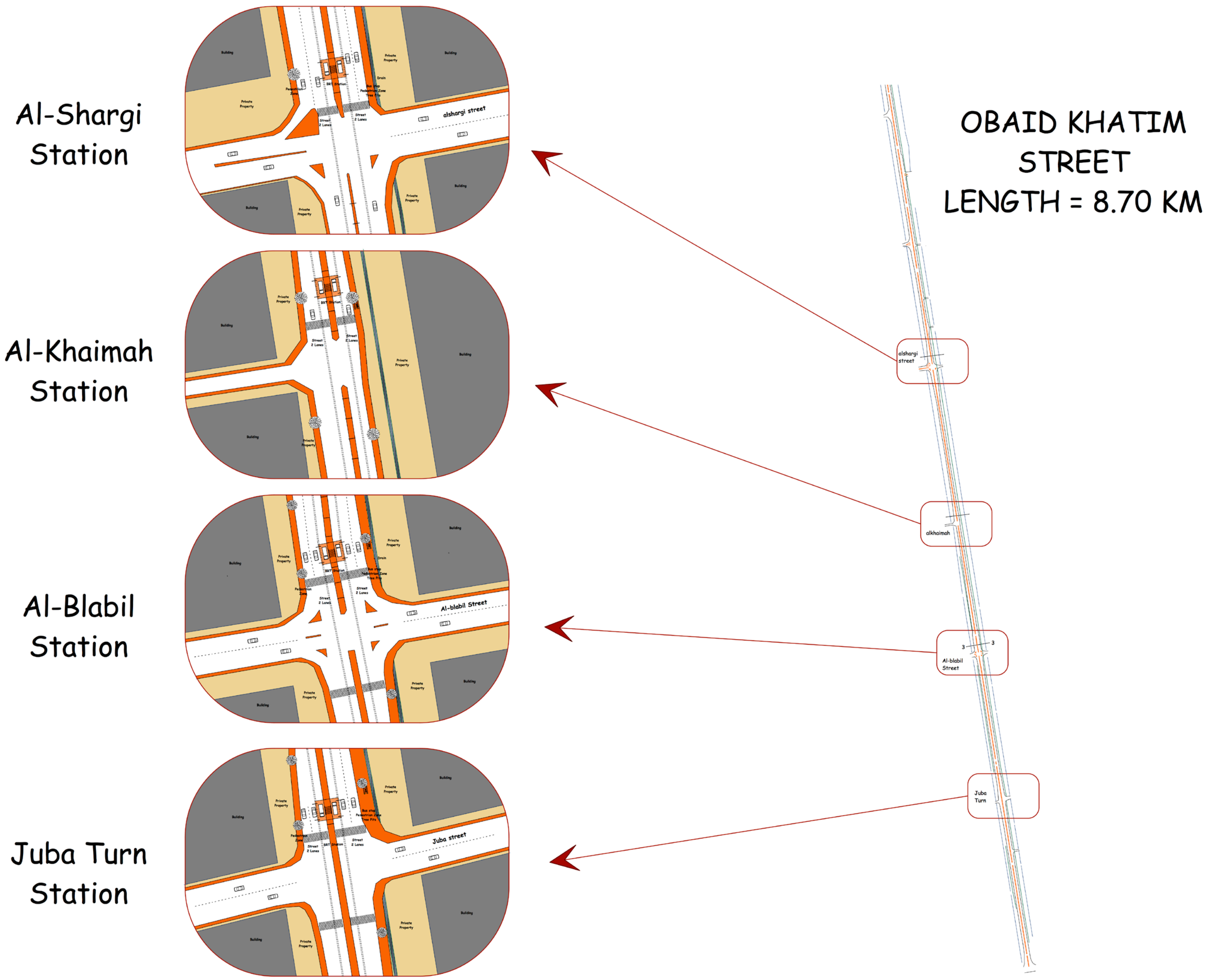
In summary, it would be expected that total staffing and associated costs would be essentially unchanged compared to the current situation. Staffing would be expected to be provided by the Khartoum General Transport Authority, resulting in ongoing employment for existing staff.

OBAID KHATIM STREET PLAN: FIRST HALF

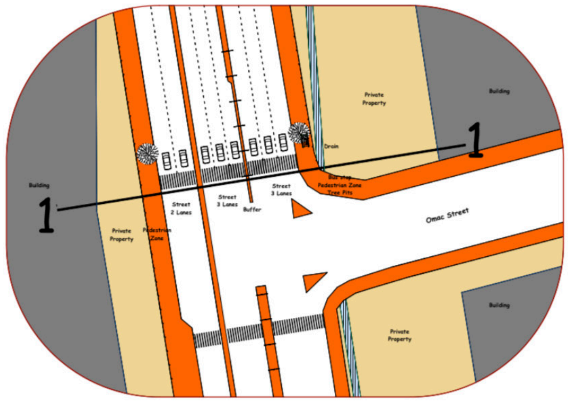
Survey work has been completed along proposed routes to determine the physical form of the road and its characteristics. The example below is Obaid Khatim Street.



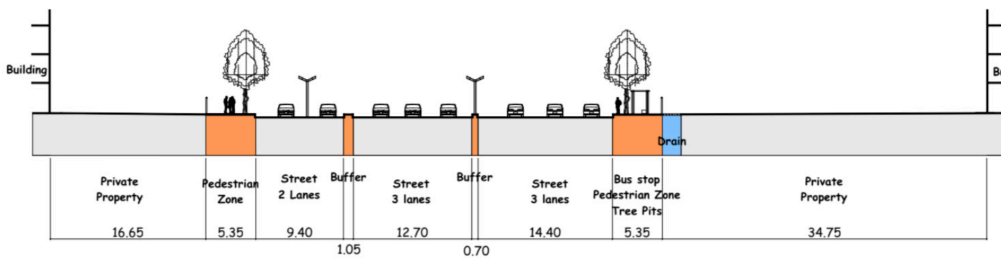
OBAID KHATIM STREET PLAN: SECOND HALF



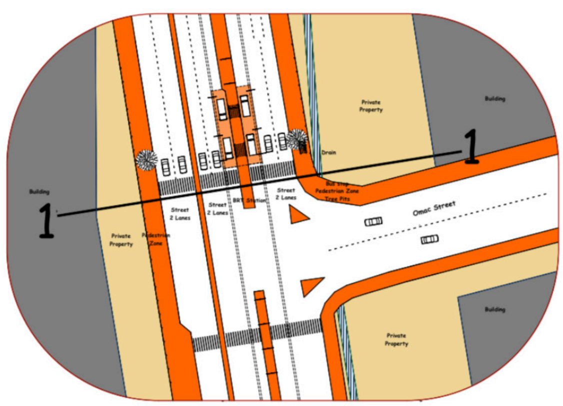
OMAK - OBAID KHATIM STREET PLAN



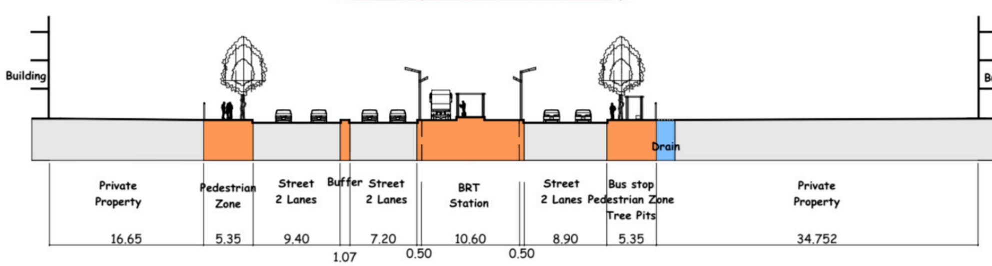
Top Plan
(Omak Station Actual)



Cross Section
(Omak Station Actual)

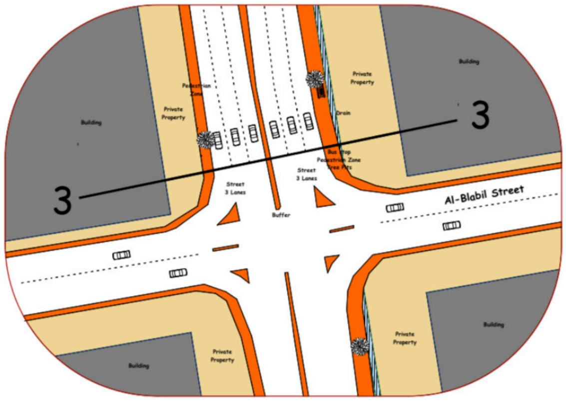


Top Plan
(Omak Station Proposed)

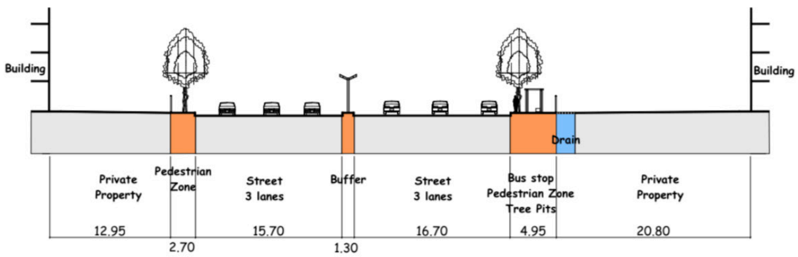


Cross Section
(Omak Station Proposed)

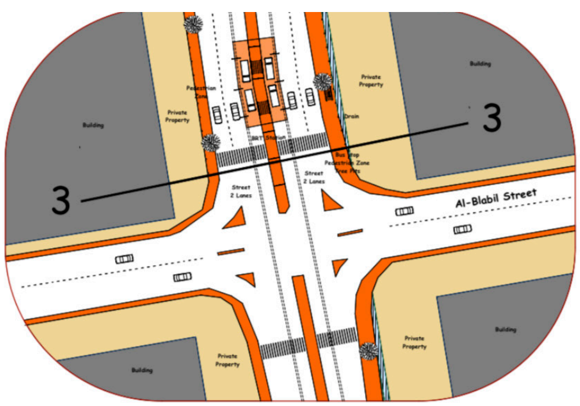
AL BLABIL - OBAID KHATIM STREET PLAN



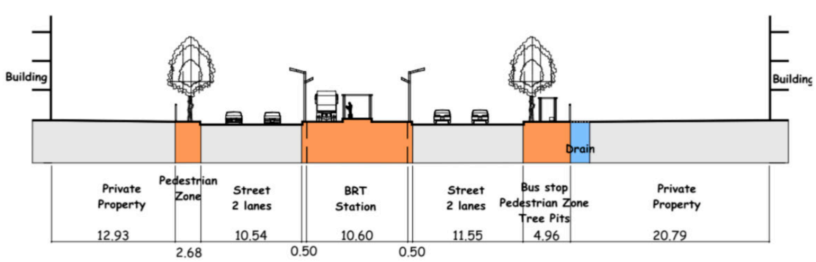
Top Plan
(Al-Blabil Station Actual)



Cross Section
(Al-Blabil Station Actual)

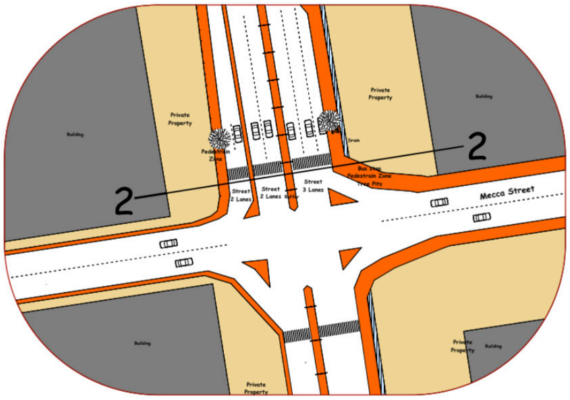


Top Plan
(Al-Blabil Station Proposed)



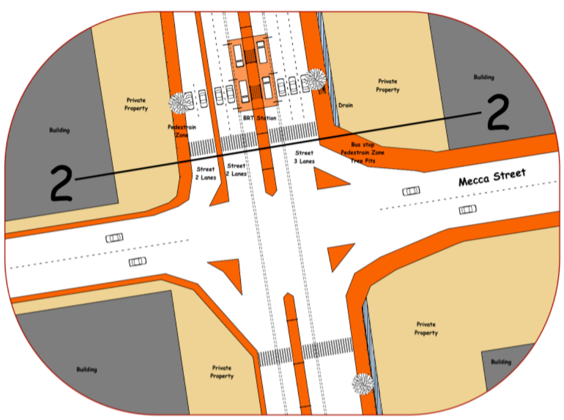
Cross Section
(Al-Blabil Station Proposed)

MECCA - OBAID KHATIM STREET PLAN

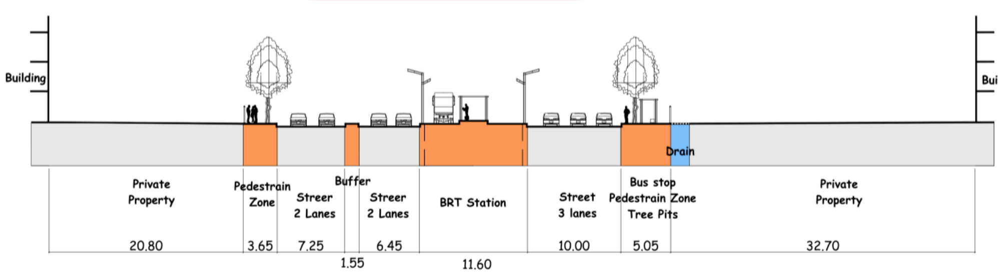


Top Plan
(Mecca Station Actual)

Cross Section
(Mecca Station Actual)



Top Plan
(Mecca Station Proposed)



Cross Section
(Mecca Station Proposed)

FUNDING OPPORTUNITIES FOR A NETWORK BUILDOUT

While it is hoped that the initial pilot project would be fully funded by donors and volunteer work, an expanded network would require a new funding source. While it is expected that fares could cover the cost of the operations and might cover some of the construction/vehicle costs, depending on the fare policy, substantial investment would still be required from other sources. This could come from general government revenue, although it is understood that there are substantial demands currently on public monies for the provision of basic services, which leads to the consideration of other funding sources.

While it is expected that a successful BRT pilot project would allow for a fruitful funding application to major international organizations involved in infrastructure development, such as the World Bank and the African Development Bank, or to international development organizations, the section below reviews funding opportunities available within the direct control of the Government of Sudan.

CAPITAL FUNDING FROM OPERATING REVENUE

The system would require at least 75% of its fare revenue to cover operating and maintenance costs, although policy designed to limit the fare price for riders may mean that 100% of fare revenue is required to cover operations. Depending on the fare policy, this would leave very little, if any of daily fare revenue available to finance capital construction.

If a substantial BRT network (250km of BRT) were implemented, ridership could be up to up to 250 million rides per year and the entire fare revenue available to pay for operations and some capital costs — is likely to be around $25 million to $35 million. If 25% of fares can be allocated to capital expenses, assuming operations only require 75% of fares collected). This would leave $625,000 to $875,000 to pay for capital expenses.

Typically one is able to borrow 15 times the revenue, which should provide funding of around $10 million to $13 million.

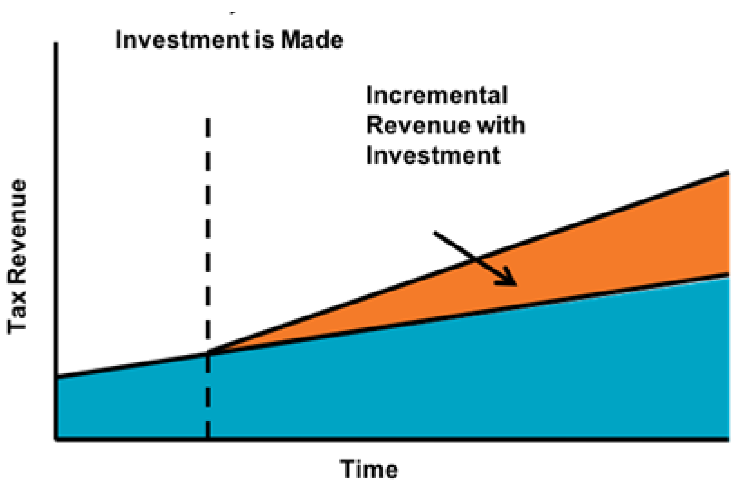
There might be justification and an economic case for slightly higher fares than existing fare levels based on higher service quality, but more analysis would need to be done to determine the price sensitivity of the ridership to ensure that fares were set to maximize revenue.

If the fares were set too low, potential revenue to fund operations and capital construction would be left unrealized, but if fares were set too high, ridership and with it total revenue would suffer. This analysis could be done as part of the ridership analysis work proposed elsewhere in this report. Any analysis of fares must take into account the economic challenges and hardships for residents due to the current economic situation. The government may want to ensure that basic transportation is available at affordable rates for public policy reasons.

TAX INCREMENT FINANCING (TIF)

Tax Increment Financing is one tool often used for developing new transit lines. This financing mechanism captures the increased taxes collected on the increases in land /property value attributed to the new transit investment, tax revenue that is then allocated to pay for that investment. It is not uncommon for new transit lines to increase property values by 30% or more, making this method popular. This funding model requires a certain amount of detailed information, and as such, it may easier to simply levee a new fee or tax on properties within a certain distance of the transit line.

Tax Increment Financing



Assessing a standard levy on all property within a certain catchment area of the project due to increases in property value would be the simplest way to do a version of TIF. It is recommended that such a levy not exceed 25% of the expected value increase to minimize opposition. The levy could also be applied over a few years to limit the need for a large upfront payment, and allow property owners to actually see the value increase. The levy's percentage could also be varied – lower value/smaller properties could be levied a smaller relative percentage so as to reduce the impact on lower income residents. Likewise different rates could be assessed for residential and commercial properties. It could also be collected as a "land transfer tax" to reduce the challenges of collecting the money and immediate burden.

EQUITY FINANCING

Additional capital funding might be available in equity financing, where a private partner contributes some of the money for the capital construction, and takes an equity stake in the project. This type of funding is increasingly common in modern Public-Private Partnerships (P3s) because it ensures that the private company has a vested interest in the success of the investment and does not walk away from the project if costs rise either during the construction phase or the operations once started.

The equity stake is generally between 5% and 25% of the project, and usually costs slightly more than typical public funding through standard government borrowing.

In the case of the BRT and other large transit projects discussed in this report, this would mean between tens of millions of dollars could be available based on the type of what chosen. This would be repaid over 35 years and, in the case of the Sudanese market, would likely require debt denomination in USD or Euros, and the backing of the central government. We discuss the P3 option more fully in the next section.

TRADITIONAL GOVERNMENT SUPPORT OR FUNDING FROM INTERNATIONAL ORGANIZATIONS

As Sudan is removed from various international sanction regimes and its status with international bodies renewed, development aid and project financing from large international organization like the World Bank, Africa Development Bank, etc., will likely become available. If the pilot project were functioning by that point, it is likely that a "proof of concept" and low per kilometre cost would be considered favorably in any project funding request.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PROJECT DELIVERY METHODS, LOCALIZATION TRANSPORT ECONOMICS AND HEALTH BENEFITS

So far, this report has focused on the specifics of different transit modes, examined what a BRT operation could look like in Khartoum, and offered some route and operation details. This section addresses ways in which project delivery could be structured, the opportunities for funding, and methods for ensuring that the project uses local material and expertise to maximize the cost/benefit ratio for Khartoum area.

PUBLIC AUTHORITY VERSUS THE PUBLIC-PRIVATE-PARTNERSHIP (P3) MODEL

Sudan has a long history of government-run corporations providing services to residents. The experience in Sudan, similar to other countries, is that the government has struggled to manage large capital project implementation and long-term operations in an effective and efficient manner.

Many governments are turning to an alternative project delivery method, Public-Private-Partnerships (P3), where the government retains ownership and control, but a consortium takes responsibility for building the project and running the operations. This may allow better control of budgets and schedules, and more innovation.

PUBLIC PRIVATE PARTNERSHIPS IN THE TRANSPORTATION SECTOR

Public-private partnerships are contractual agreements between public and private entities intended to deliver long-term public assets, with the private partner taking responsibility for project design, construction, financing, operations and/or maintenance, depending upon the project needs.

While P3s do not provide a funding mechanism since companies are looking to make a profit on their activities, they can be a type of project financing vehicle for borrowing money. They offer a financing avenue by letting private partners take an equity stake in the project. Some transit agencies view P3s as a means to temporarily cover short-term financing gaps, and to transfer certain project risks to the private sector. P3s have been successfully used for several transportation projects around the world, especially in situations where there is no existing institutional capacity, and may improve on-time and on-budget project delivery at the expense of greater project cost and complexity.

Another benefit of this kind of partnership is the ability to access the expertise and innovation of the private sector. But there are associated disadvantages to use of P3s: higher transaction and private sector borrowing costs, public controversy generated by the appearance of promoting privatization, and increased complexity.

P3s come in many different forms, and the appropriate structure must be determined for each project. The public partner collaborates with – and oversees the work of – a consortium of private firms who are generally allocated some mix of the following project responsibilities: Design (D), Build (B), Finance (F), Operate (O) and Maintain (M). Design-Build (DB) is the most common delivery method for transportation P3s, followed by DBFOM (Design-Build-Finance-Operate-Maintain) and DBF (Design-Build-Finance). An important consideration is the degree of risk that is transferred to the private consortium when it is given more responsibilities, because risk transfer often results in higher costs if not carefully done. It is critical for a government agency to screen the project and develop a benefits case to determine if a P3 provides more benefits than a conventional delivery method. P3's projects do not automatically lead to lower costs or better projects.

To benefit from the P3 structure, an organization needs to have strong internal capacity to be able to properly structure the partnership and balance the technical and legal requirements, otherwise the project could be at risk, or the government could end up procuring an expensive, poorly suited or designed product. There are many examples in the transportation world of this happening.

> It is usually advisable to create a structure that has the involvement of local companies, as local understanding of the on-the-ground realities is critical.

With the lifting of US sanctions, the P3 option is a possibility for Sudan. As indicated above, it is often typical that the consortium winning the contract provides between 5% and 25% of the capital construction costs as an equity stake. The rate can sometimes be higher, but likely would not exceed 50%, as the private partners want to see the government's upfront financial investment as a guarantee of a long-term commitment.

As a result of the fact that these contracts typically include both upfront construction and long-term operations and maintenance, they tend to run for a minimum of construction time plus 5 to10 years of operations. The tying of operations/maintenance to the initial construction of the project forces the private company to consider the long-term costs of operating and maintaining the line, which typically leads to better design and quality.

LOCALIZING THE BRT TO MINIMIZE COSTS AND MAXIMIZE BENEFITS

Locally Sourced Material

The past history of Sudan's investments in transportation has illustrated the challenges (over a 20 to 40 year period) of importing parts and equipment. As much as possible, material used in the creation of a BRT should be procured in local market to cut costs, limit foreign currency requirements, increase local economic impacts, and reduce the likelihood of problems securing access to material for repairs and maintenance in the future.

From a long-term maintenance perspective, it would be critical to carefully source the equipment and vehicles required for whatever form of public transit is chosen, based on a full life-cycle analysis.

USING LOCAL EXPERTISE

Past experience with transportation projects in Khartoum has shown that, unless there is local expertise -- inherent or fostered -- proper operations and regular maintenance cannot be expected to continue much past the initial introduction phase.

It is critical that any transportation plan be shaped locally, and that there be a strong commitment to build local capacity from management to operations. This would be especially important if rail transportation were selected.

If a large enough project were advanced, there should be discussions about requiring assembly of the vehicles locally, as this is a fairly standard contract provision around the world. Producing vehicles locally would likely add 10% to 20% to the cost, but in addition to building local expertise, it would also offer the opportunity to build local capacity around repairing the vehicles. This would be instrumental in facilitating maintenance and long-term vehicle refurbishment, and would be especially necessary for rail vehicles.

In addition, a strategy for modifying the standard “off the shelf” vehicles to make them more robust, and easier to repair, should be reviewed and considered from a cost-benefit perspective. Changing the specs to adapt to the local environment -- for example improving the air conditioning capacity to deal with the heat -- and limiting the advanced electronic systems to make the bus more maintainable in a local context, would be a cost-effective life cycle choice.

In many jurisdictions around the world, large projects also have agreements (sometimes referred to as Community Benefits Agreements) that stipulate specific training and local hiring provisions. These agreements are useful to the project as they help create community buy-in, and a willingness to go through the inconvenience of the construction.

There is also the possibility of including in the Request For Proposals (RFQ) a requirement to partner with local companies for the construction and operation of the new transit system. Such a stipulation would increase the likelihood of the project's success as local know-how is essential and improves the long-term viability of the project. This would also promote a domestic industry that could respond to future RFPs for vehicle and system maintenance, or even construction of new lines.

TRANSPORTATION ECONOMICS AND HEALTH BENEFITS OF BRT

A BRT network in Khartoum would improve the mobility of residents, and lower the financial and time costs of transportation. However, there are additional economic and health benefits that can be derived from a BRT network once implemented. This section provides a short summary of how such analyses can be conducted.

Relative to salary levels, transportation costs in Khartoum are high, especially for people who are required, as part of their trip, to transfer and pay a second fare. These high costs can create barriers to employment and education, as well as generally reduce mobility.

The economic benefits of improving public transit are clear. By limiting the growth of private automobiles -- few of which are produced in Sudan -- and the use of diesel or gasoline, the automotive portion of foreign currency requirements would be reduced, leaving more money in the country to create new economic activities, as opposed to fueling foreign imports and jobs.

Similarly, by providing better public transit, traffic congestion would be reduced, allowing private cars and the transport of merchandise to move more quickly, and improving the air quality of Khartoum. Air pollution can lead to premature deaths, and place a greater economic burden on the City, reducing residents' working lifespans and putting pressure on the healthcare system.

THE ECONOMIC VALUE OF PUBLIC TRANSIT

The average fare per trip segment on Khartoum's current public transit, based predominantly on distance/size of vehicle, is from 2 to 3 pounds (Sudanese pound rates as of the fall of 2017 and 25-50 pounds in 2020). The average fare calculation is based on the estimation that haflas carry more than 75% of the public transit ridership in the Khartoum area. Twenty per cent of trips involve the passenger paying two fares or more on vehicles of some kind from rickshaws to haflas. It also takes into account that amjads and the like charge higher rates and buses lower, and that haflas have some time-of-day rate increases, such as the premium for late night service, and reductions for students.

The average fare calculation means that daily revenue from public transit in Khartoum is approximately $270,000 to $315,000 USD.

The total annual fare revenue from privately operated urban (non-interurban) mass transport – is likely around $85 million to $105 million.

Wages and local capital and operating expenditures in the transit sector (not including money spent on imported vehicles and parts which largely leave the economy) generate economic activity – through "direct", "indirect", and "induced" impacts – equal to around $2 billion to $3.2 annually (using standard GDP multipliers for transportation economic impacts). On top of that, the sector supports the movement of goods and people in the capital region essential to the functioning of the overall economy.

Based on the number of haflas and similar vehicles (40,000), it is estimated that there were upwards of 140,000 people working directly (3.5 people or their "full-time equivalent" per vehicle) in private transportation in Khartoum prior to 2019. Due to the economic troubles, these numbers have recently dropped. These are workers involved with every aspect of the various vehicles used for public transport (not taxis), from rickshaws to small passenger vehicles like amjads, to haflas, and larger buses. These workers include drivers, "cummsaries" (fare collectors), route advertisers, mechanics/other maintenance people, and others involved in transport.

When a government considers the impact a new capital project will have on the community, one of the variables it considers is the employment multiplier measure – the extent to which the new project generates "direct", "indirect" and "induced" jobs, or possibly loses them.

"Direct" jobs are related to the specific industry (building buses, constructing LRT lanes, etc.), while "indirect" jobs are those supporting the industry like spare parts or tires for the project's vehicles, or asphalt and concrete for the project's bus lanes or stations. "Induced" jobs are those that are a result of "direct"/"indirect" employee spending in the community. Transportation job-creation analysis always factors in all three sources of employment. Typically 1 "indirect" or "induced" job is generated for each direct job created. This means that the 140,000 "direct" jobs in the public transport field likely produces another 140,000 "indirect" and "induced" jobs, for a total economic impact of 280,000 jobs.

Those job totals make the transportation sector one of the largest employers in the Khartoum region helping to sustain over 740,000 people (at least prior to 2019), as it is assumed that every employed person supports an average of 3 additional family members with their wages. This means the current mass transport sector supports around 8% of the population the City.

HEALTH AND WELLNESS IMPACTS OF PUBLIC TRANSIT

This section is not intended to be a comprehensive review of health impacts of better transit, but to introduce the topic and set the stage for further discussion and research.

THE PROBLEMS WITH PRIVATE CARS:

Khartoum's rising private vehicle ownership and use create a heavy stress on its limited road infrastructure. Over three quarters of all vehicles registered in Khartoum in 2011 were private cars. This creates a serious challenge to improving already disorganized transit services, as private vehicles vie for more road space, and public transit spends longer in traffic jams.

Without a proportionate increase in pub-lic road network capacity, the increase in private vehicle traffic has resulted in higher traffic casualty rates, a typically unavoidable social consequence similarly seen in other highly-populated developing cities without an urban rapid transit system. Khartoum saw over 12 traffic-related deaths per 100,000 inhabitants in 2012 (most recent data), a dramatic increase from 9 deaths per 100,000 inhabitants in 2002.

Road accidents can be reduced when car trips are replaced with public transit and the total number of cars decrease. In a paper published in 2000, cities with higher per capita transit passenger miles saw lower levels of traffic fatalities (Litman, Todd. "Evaluating Public Transportation Health Benefits"). Other studies have shown that rapid transit is safer for both passengers and pedestrians, with one study demonstrating that commuters are 90% less likely to be involved in a crash when using public transportation. With these reduced traffic accidents and fewer recorded fatalities, scarce hospital beds could be freed up for other health needs, health costs would lower, and the number of repairs to vehicles and damaged roads diminish, easing the burden on the economy.

URBAN LIVEABILITY AND AIR QUALITY

Public transit also increases urban livability and quality of life through reduction of urban health problems commonly associated with air pollution generated by auto use and traffic congestion.

Studies of many highly congested cities in Africa have proven that air pollution affects all commuters irrespective of the mode of transportation, and that improved air quality could serve as a singular public health promotion strategy. Suspended air particulate concentration at Khartoum's busiest intersections already surpass WHO safety standards by 40 to 80 fold, which is critical as severe respiratory infections comprise one out of five diseases suffered by the city's inhabitants.

Likewise the use of public transportation has been shown to improve other overall health outcomes, including a lower Body Mass Index (BMI). In a paper studying the BMI of people who used public transportation (Rissel et. Al. “Physical Activity Associated with Public Transport Use – A Review and Modelling of Potential Benefits”), it was shown that the added exercise entailed in walking to and from transit stops significantly improved the health condition of transit riders.

Obesity due to lack of physical activity remains is a growing concern in Sudan and evidence from other rapidly expanding congested cities in Sub-Saharan Africa such as Lagos, Nigeria reveal the emerging importance of sustainable transportation modes in combating the increasing rates of motorization-led obesity. Simply walking 1km (the distance to and from rapid transit stops) can have a measurable benefit for people’s health.

RECOMMENDATIONS

This report has provided background information on Khartoum's transportation situation as well as providing an analysis of policy options available to the government. It has concluded that a BRT network would be the best technical solution to quickly improving the transportation situation in Khartoum for the average resident, as it would allow for timely, relatively non-disruptive, and inexpensive urban transit improvements. The recommendations on the following page are designed to provide a starting point for moving forward.

OUR RECOMMNEDATION:

1 The Government of Sudan (GoS) endorse BRT as the best technical solution to quickly improve transportation in the Greater Khartoum area, recognizing that a large surface or underground rail network would take many years to build and be cost prohibitive.

2 Prioritizing current and future transportation infrastructure resources on Bus Rapid Transit, instead of investments in road infrastructure, is the best path forward, recognizing that 85% or more of residents travel by mass transit or walking, and that investment in public transit would result in better economic, social and environmental outcomes.

3 The immediate start of work on a "pilot" BRT route of around 10km be authorized, acknowledging that funding for the pilot project may be possible by fundraising and in-kind donations coordinated by the Sudanese diaspora.

4 That the exact routing of a BRT pilot route should be decided based on a detailed ridership study and survey of the local conditions.

5 The pilot project be delivered as a Public Private Partnership (P3), with the government of Sudan providing the land for the route and the maintenance centre, along with the use of buses from the Khartoum General Transportation Authority, for a period of at least one year.

6 Further work be done to identify a possible future network of up to 250km of BRT that could be implemented over the next five years, to serve between 5 and 8 corridors.

7 The government work to get access to cell phone data that could be used to determine population demographics and mobility data in the absence of more detailed studies.

8 A review of the pilot project be conducted after one year to evaluate whether it is a success, and whether additional BRT routes should be established

9 The government consider setting up a dedicated unit with expertise in transportation and finance to oversee the BRT pilot and the possible development of a future BRT network and delivery method.

10 The GoS consider allowing innovative financing techniques like Tax Increment Financing or other associated development strategies to finance the government's contribution to the project.

SECTION H

APPENDIX

The Appendix provides both additional project details, and a glance at the history of transit in the Khartoum region in order to help contextualize the BRT pilot and network proposals.

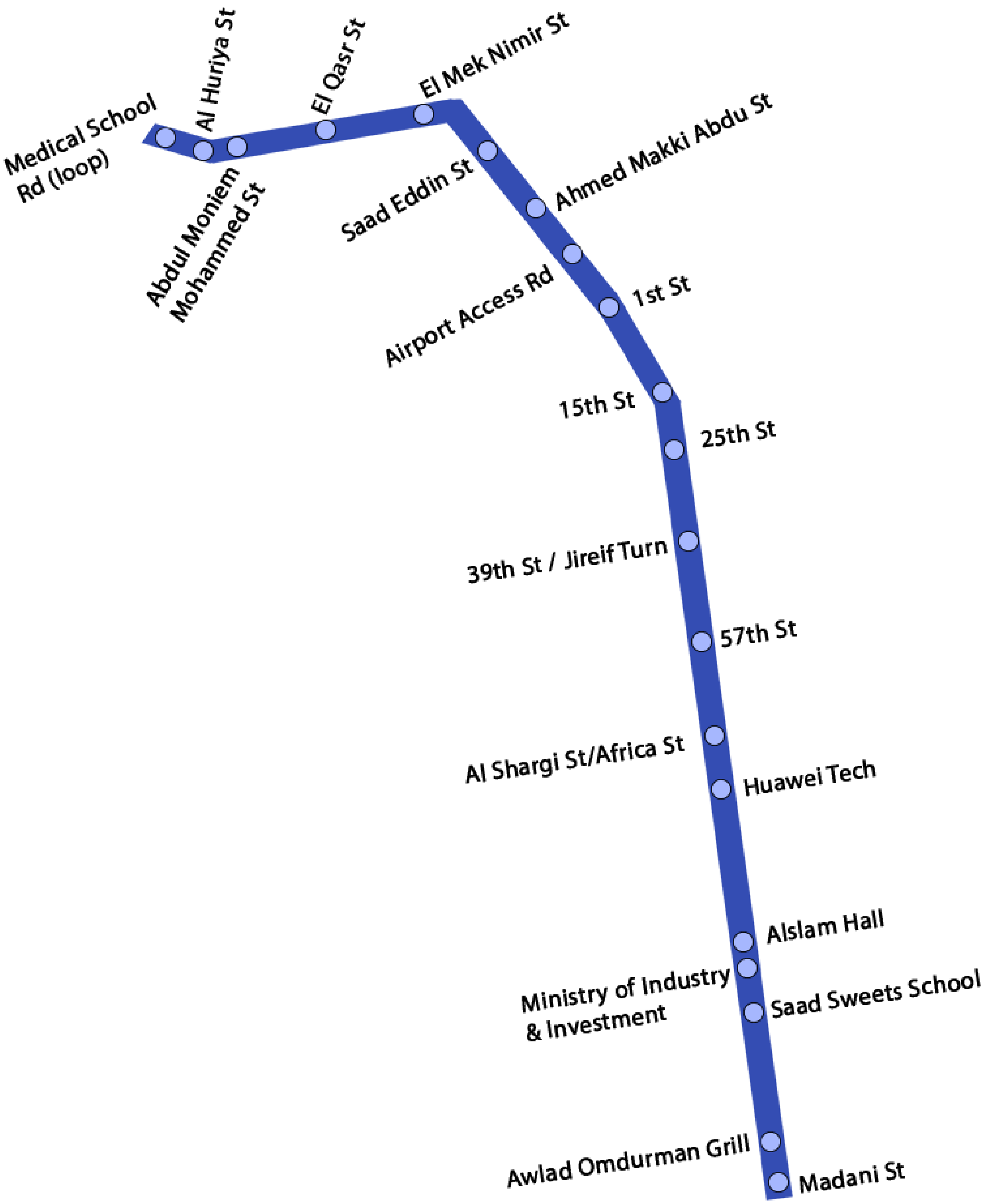
Appendix A: Stop Locations for Khartoum BRT Options

OPTION 1: AFRICA STREET (NORTH TO SOUTH)

One-Way Distance: 9.8 km

No. of Stops (one way): 20

Station names are place holders, with actual station names to be determined in consultation with the communit

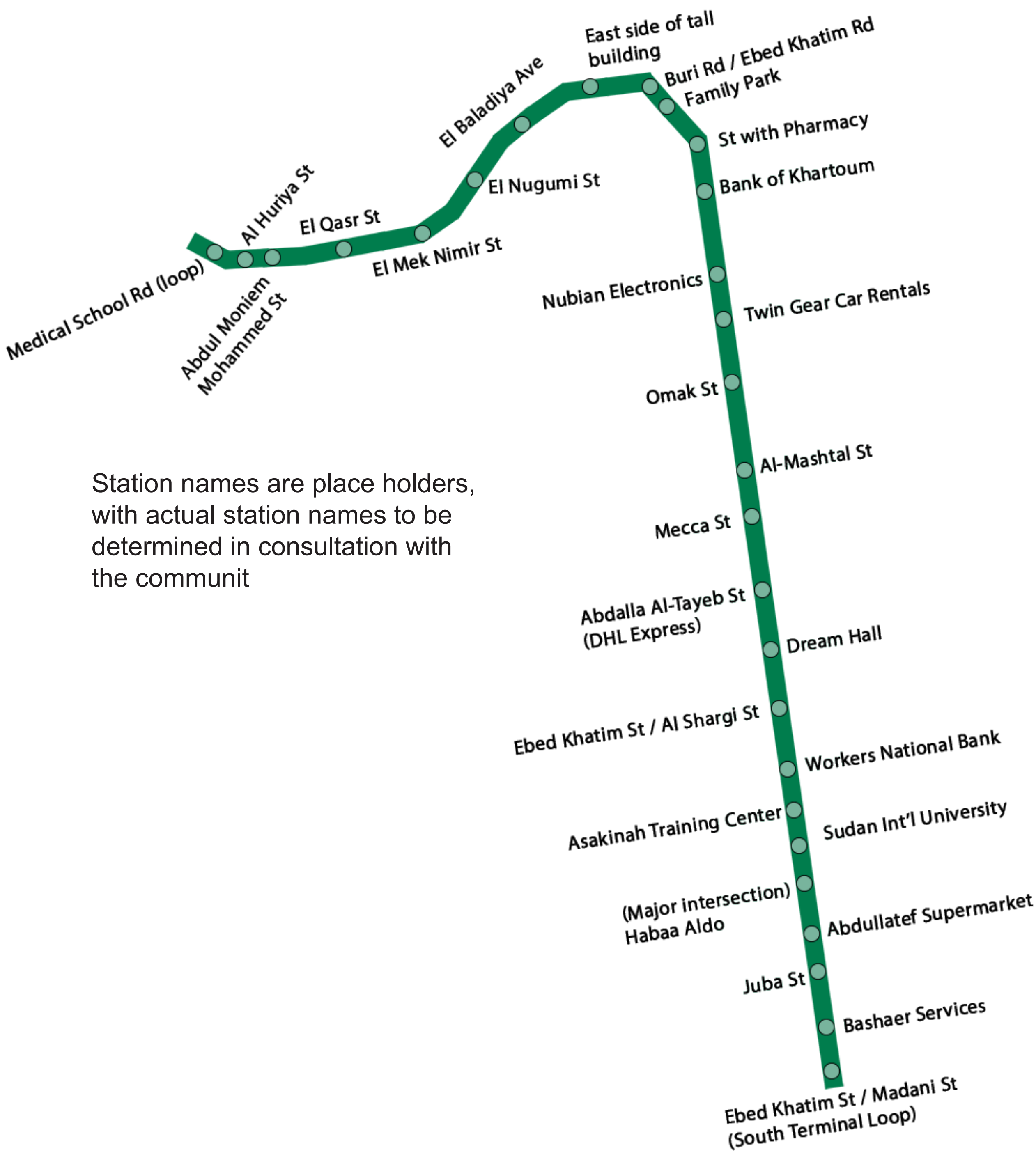


Appendix B: Stop Locations for Khartoum BRT Options

OPTION 2: EBED KHATIM STREET (NORTH TO SOUTH)

One-Way Distance: 13.0 km

No. of Stops (one way): 28



Station names are place holders, with actual station names to be determined in consultation with the communit

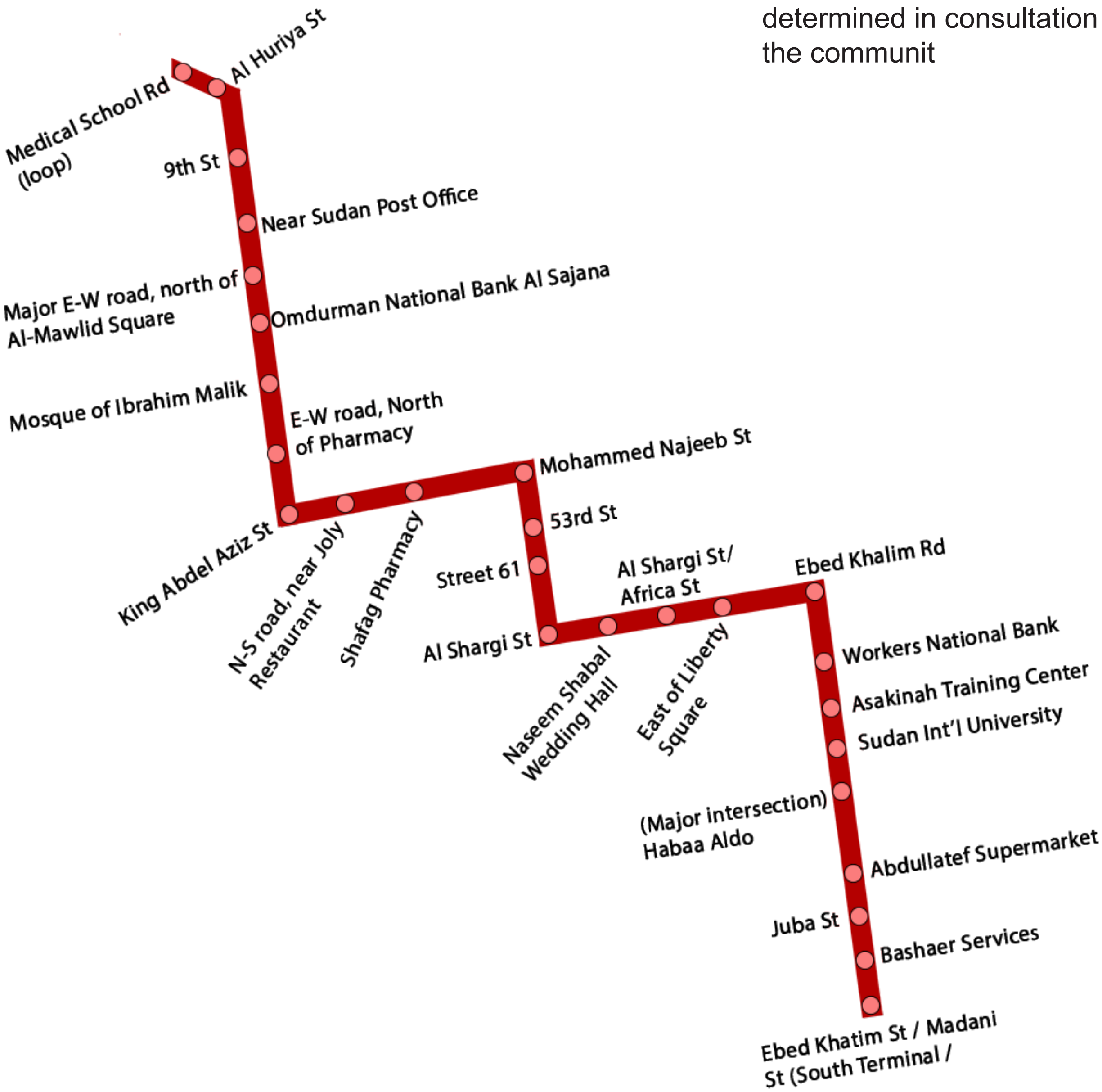
Appendix C: Stop Locations for Khartoum BRT Options

OPTION 3: MAXIMUM MARKET POTENTIAL, USING VARIOUS MAJOR ROADS, (NORTH TO SOUTH)

One-Way Distance: 11.5 km

No. of Stops (one-way): 27

Station names are place holders, with actual station names to be determined in consultation with the communit



Appendix D: Transportation History of the Khartoum Region

For the first part of the 20th century, Khartoum was a small city, where the distances between destinations were short and where people mostly lived close to their places of work.

However, despite its relatively small size, Khartoum got its first form of mass transit in 1904 when a steam “tram” running on rails was introduced. Ultimately, this was converted to an electric streetcar in 1928 that connected Khartoum with Omdurman and ran until 1962.

Tramway Station, Khartoum, Sudan

Khartoum TRAM, Khartoum, Sudan


KHARTOUM
Tramway Station
KHARTOUM CENTRAL

Sudan Railways, which was operated by the government-owned Sudan Railways Corporation (SRC) ran commuter rail-like service (trains inbound to Khartoum in the morning and outbound in the late afternoon) along rail lines running into Khartoum from the north and south.

> Buses were progressively added starting in the 1950's, and became the main form of public transit in Khartoum in the1960's and 1970's. At the beginning, these were run by government authorities and were increasingly augmented by small mini-buses that were run privately and evidently incorporated into a licensing system.

Khartoum began to grow quickly, adding new neighbourhoods, and organized government transportation could not keep up, as government transportation companies began to fail in the delivery of their mandate. With budget pressures in the 1970s, the bigger buses of organized transport were replaced by mini-buses as the main form of transportation in Khartoum.

This system is still in place, with around 40,000 "haflas" operating daily in Khartoum (as 2018) and forming the base of the public transit. However, they are increasingly struggling to carry the growing passenger demand while operating in heavy traffic. The "haflas" run regular routes, with on-board "cummsaries" who collect the (mostly-standardized) fares,, and shout out the route ("Stade", "Lefa", "Arabi", Etc.), along with hand signals to indicate the destinations.

The haflas have been augmented by other means of transportation, which have varied depending on economic and political circumstances. When gas/diesel prices have been high and imports of new vehicles limited, other modes like "dafars" -- trucks with rudimentary passenger cabins and benches welded onto the back -- or "tarahas" -- yellow taxis that run along busy streets and collect up to 4 passengers going in roughly the same direction for a set fare have appeared. More recently (before recent economic challenges starting in late 2019), these types of services have declined because vehicles and fuel have become more plentiful and wages higher in real terms than in the past.

In the last decade, the only government initiative to add transportation capacity was an attempt by the Wali of Khartoum to put into service regular 12m buses. While initially greeted with relief as they offered modern air- conditioned vehicles at lower fares than the haflas, they suffered from the same issues as existing transit options at the time -- namely having no defined stops, and doing pick-ups and drop-offs many more times than a regularized system allows. There was also no long-term maintenance plan, and the Chinese buses purchased were not able to withstand the challenges posed by the operational environment in Khartoum. Without enough trained mechanics or access to spare parts, most of these buses failed within 2-3 years of purchase. This clearly showed that there is a need for a full business plan prior to entering into any new public transit system.

Appendix E: Current Commuter Rail Initiative

Integrating the current Commuter Rail Initiative with a future BRT.

More recent fuel shortages, after a number of years with low cost and plentiful fuel have currently created huge disruptions and severe overcrowding on urban public transport in Khartoum, plunging the number of minibuses in service from 40,000 to 11,000 in 2019/2020. As a measure to contain the congestion crisis in the capital, the Sudanese Government has introduced a commuter rail service serving the capital from the northern and southern suburbs.

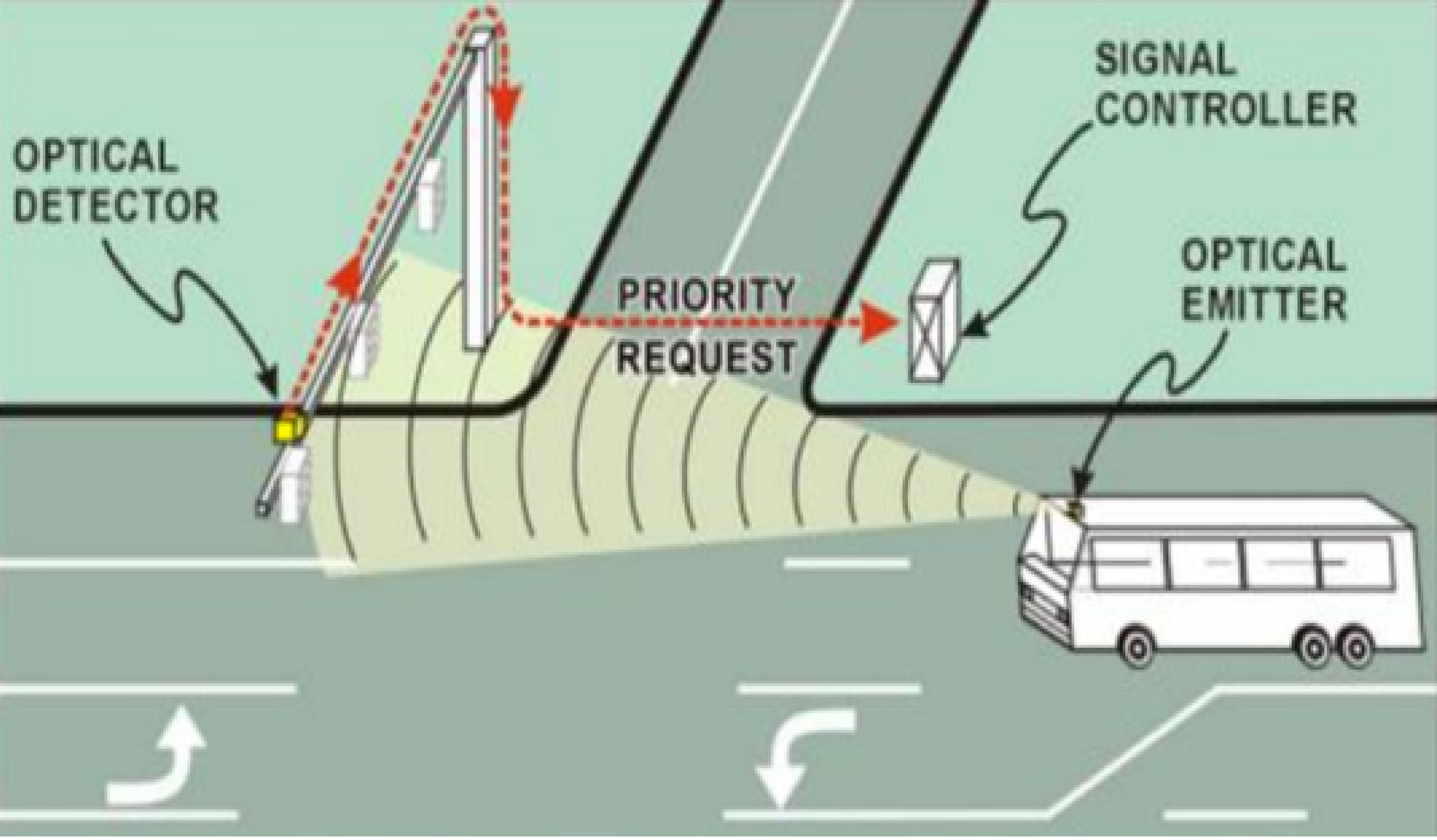
The northern line terminates at the Khartoum North Train Station in Khartoum Bahri, and the southern line at the Khartoum Train Station in downtown Khartoum. For each line, there are three to four inbound and three to four outbound trips for the morning and afternoon peak respectively, with capacity of 1,200 per train, 400 seated and 800 standing. The limited capacity of the commuter train service (i.e. 7,200 to 8,400 spaces on the train per day as compared to 2,500,000 daily urban public transport trips made in Greater Khartoum) demonstrates the need for a comprehensive urban public transport solution that goes beyond silo-based, corridor-specific intervention.

The commuter train lines have the potential to be upgraded for even higher frequencies and capacities (through upgrades in fleet electrification, double deck coaches, track works, signaling and level crossings), but evidence of best practices worldwide shows that the effectiveness of the commuter train service in alleviating the overall urban public transport system's overcapacity depends on its overall synergy with the existing rapid transit network. While no reliable cost estimates are available, rail projects, especially commuter trains, have hugely higher costs than bus based systems.

A rapid transit network typically consists of interconnecting urban rail (Metro, LRT) or bus (BRT) lines. A rapid transit line's closer distances between stops means it is more accessible for bus users, pedestrians and cyclists as compared to the commuter rail and generally is available at more times of the day. As a result, a commuter rail system will rely on the complementary rapid transit network to funnel and distribute passengers into the wider urban transportation fabric. In the long run, a comprehensive urban public transport network in Greater Khartoum would consist of both the northern and southern commuter lines and a wider rapid transit network, each complementing the other in providing a seamless journey for the region's diverse commuting needs.

Appendix F: Automated Transit Signal Priority (TSP)

The option of giving buses priority in intersections was discussed earlier in this report and two options were noted: one manual (using police or traffic officers), and the other automatic (using technology). TSP can result in substantial time-savings if well implemented and maintained. Extensive TSP as part of a large network of routes is probably not achievable using manpower, but



it would be possible for one BRT line, as part of a pilot project. Eventually a network would likely need to use one of several competing technologies that provide TSP, which will increase the capital costs and ongoing expenditures for maintenance of the system will be required.

Transit signal priority (TSP) can be given to buses or surface LRT at signalized intersections, permitting the faster transportation of many people in these large vehicles. Implementing this leads to substantially faster service, which allows the same bus to make more trips, thereby reducing the overall capital needs of the system.

How the automated TSP Works

Once the transit vehicle is detected by the intersection, the length of the traffic signal is dynamically adjusted to expedite its travel through the intersection. This typically requires specialized hardware in the form of a transmitter on the transit vehicle and one or more detectors at the intersection. This can also be accomplished with a GPS system on board the transit vehicles that communicates with a centralized signal system. There are two primary TSP strategies that can be employed:

1. Green Extension:

If a transit vehicle is approaching a green light and it would otherwise "just miss" it, the light can be extended up to a maximum value to allow the vehicle to pass through without stopping. This benefits a relatively small percentage of intersection crossings, although the benefit to the transit vehicle is large – an entire red cycle.

2. Red Truncation:

If a transit vehicle is stuck at a red light, the red cycle can be shortened by a predetermined amount to let the bus pass more quickly. This benefits a relatively larger percentage of intersection crossings, although the benefit to the transit vehicle is modest – only part of a red cycle.

One or both of these TSP strategies can be implemented to the benefit of the transit system.

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