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Enhancing Public Transportation: An Approach for Sustainable Urban Mobility System in Developing Countries
(With specific reference to Egypt)

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***Abstract*— Urban mobility is a major challenge for megacities in developing countries and Egypt as well. The transport network is required to be extended and improved to cover the new urban fabrics and connect them to the rest of the city because of the massive urban development and population growth. All around the world, public transport systems are trying to compete with private cars. The pattern of development and investment which is oriented to private cars must be changed to one in which urban design and infrastructure promote public transportation [1]. Availability, accessibility of public transit and intermodal connectivity are main challenges facing public transit sector.**

This paper explores and discusses different approaches in order to draw solutions and strategies for enhancing and improving public transit in the developing countries with specific reference to Egypt, including planning Integrated and complemented formal public transportation & paratransit, mapping Public Transit, first and last mile solutions and smart mobility solutions.

Challenges and potentials of applying these strategies and solutions relevance to the Egyptian context as one of the developing countries were identified, and recommendations for enhancing public transit systems.

Keywords*— Urban Mobility, Public transportation, integrated public transit, Mapping public transit, First and last mile solutions, intermodal connectivity, smart mobility

I. INTRODUCTION

People travel from one location to another on a daily basis for commuting or for other different reasons, this necessitates a reliable mobility system that promotes different modes of transportation. Walking, cycling, riding buses, and the underground were the most common ways of mobility in most cities in the previous century. As cities grew in the twentieth century, the expanded transport networks furthered urban development while also posing many obstacles for sustainability particularly in developing countries. Improving access to opportunities and services necessitates strong policy and transit infrastructure development [7].

An accessible public transportation system that is affordable, reliable, comfortable, frequent, and connected to other modes of transportation can increase city accessibility, encourage commuters to shift to public transit modes, and thus reduce reliance on private cars. In the coming decades, public transport will have an impact on our mobility patterns, urban structure, environmental, economic performance, and social equity [2]. In general, the intensity and mode of travel can have a significant impact on quality of life [1].

II. CURRENT SITUATION OF URBAN MOBILITY IN DEVELOPING COUNTRIES

Most of the cities in developing countries are car oriented. In Egypt, owning a private vehicles or motorcycles are a major aspiration for all residents, especially when public transportation is suffering from being risky, inhuman and insufficient. As urban economies grow in the last decades, the income of the upper and middle-class people increases as increase the ownership of private vehicles. This in turn reflected on increasing the number of vehicles, so does urban traffic congestion, and vice versa. On the other hand, most of the youth and residents of low and below middle income use public transport because they do not have access to private vehicles. In medium and large cities, public transport is the only way for people to get to work, school and public services. These locations are too far away to reach by walking/cycling. Unfortunately, formal public transportation doesn't meet resident's mobility needs properly [3].
Accordingly, many commuters depend on informal modes of public transit1* which called as "paratransit services" to fill

* In the developing countries, paratransit is also sometimes referred to as 'informal transport'. Using this terminology is not meant to indicate that 'paratransit' services are unplanned, as they often involve careful planning of vehicle allocations to routes and hours of service. However, it is referring to the fact that it is

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the shortage of the available formal modes as shown in Fig.1. Paratransit is an on-demand mobility service which is easily reached and accessed, covering all areas, especially where formal transport is unavailable. However, these informal transport systems are causing major problems such as increasing traffic congestion, road accidents, air and noise pollution.

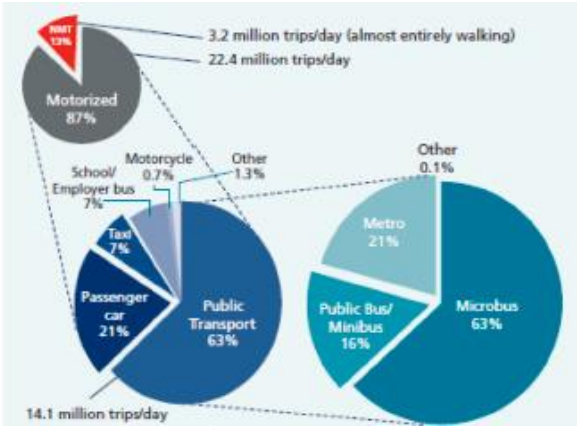

Fig. 1. The modal share of GCR, Egypt. An example of modal share in developing countries *[7]*.

III. THE CHALLENGES OF URBAN MOBILITY AND TRADITIONAL SOLUTIONS IN DEVELOPING COUNTIES

In developing countries and Egypt as well, cities are facing several challenges related to the urban mobility status including traffic congestion and accidents, climate change, environmental degradation, and high energy consumption besides the insufficient public transport services. More people produce more traffic, and more traffic increases congestion and other mobility challenges in cites. This comes at an enormous cost in terms of increased fuel consumption and time lost for commuters, as a result of the constant stop-and-go of vehicles [3]. Furthermore, the deficiency in the governance of public transit system, empowering institutions with decision making capabilities, adequate human and financial resources in most of the developing countries [4].

The traditional method for dealing with traffic congestion is to expand the road network capacity by building new highways and widening existing ones, this only works as a temporary solution. A few years later, these roads will become congested again, and the situation will deteriorate to the point where it will be impossible to build new roads due to a lack of land or an inability to expand the existing network. This is known as "induced traffic," and it occurs when increasing the supply of something makes people want it even more. In the early 1960s, this phenomenon has been noticed, it wasn't until recently that social scientists collected enough data to illustrate how this happens almost every time, we build new highways. A reverse effect of generating more traffic is the concept of "traffic evaporation" which refers to traffic disappearing when road space is reallocated from private vehicles to more sustainable forms of transportation such as walking, cycling, and public transportation [16].

frequently works by unregulated or illegal operators in the transportation sector.

Sustainable mobility approaches are promoting the shift of modes from private vehicles into public transportation systems. Furthermore, these approaches should also make efforts to improve and promote the public transit services so that people continue to use them, avoiding a negative shift backwards [7].

In this research we will focus on the availability, accessibility of public transit and the intermodal connectivity as main challenges facing public transit sector in most of the developing countries and Egypt.

IV. CHARACTERISTICS OF SUSTAINABLE URBAN MOBILITY:

The sustainability and adequacy of urban mobility systems could be defined through numbers of interconnected characteristics according to the United Nations definitions as shown in Fig. 2. By applying these characteristics to all modes of transport, decision makers will be able to identify the status of urban mobility systems and take the required actions to enhance them in order to achieve more sustainable urban mobility. Six main characteristics of sustainable urban mobility have been explored as follows [2]:

Fig. 2. Parameters of sustainable and adequate urban mobility systems [2]

A. *Affordability:*

It is a significant equity concern for transportation planning. It is important to ensure that the financial cost of travel is affordable for all passengers in order to ensure equal access to services and activities especially for those in disadvantaged situations. Therefore, to define and assess the affordability of mobility system, it is important to measure the percentage of the direct transportation cost to the income, as well as measure the opportunity cost of time spent in commuting.

B. *Availability:*

It is the most fundamental element of transport alternatives in terms of routes, times, and departure frequencies to meet the needs of residents. The departure frequency and consistency in relation to the distance individuals would have to walk to reach a mode of transportation can be used to measure availability.

C. *Accessibility:*

It is concerned with the compatibility of modes of transport as well as stations to the demands of various passenger groups including women, children, the elderly, and people with disabilities.

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D. Acceptability:

It is concerned with the traveler's standards and expectations of the form of transportation such as the quality of seating, noise level and considering climate conditions.

E. Safety:

It concerns may frequently discourage people from using public transportation. Concerns about safety extend beyond the safety of passengers on the mode of transportation to the levels of safety experienced in the station and on the way to the station.

F. Sustainability

Finally, the social, economic, environmental, and governance sustainability of urban mobility networks must be considered. The governance and institutional frameworks are among the most important pillars in establishing sustainable transportation policies that guide resource allocation and program implementation in order to achieve an adequate urban mobility system [2].

V. CLASSIFICATION OF PUBLIC TRANSIT IN DEVELOPING COUNTRIES:

People travel within and outside of the city using a variety of forms of transportation. These modes can be public or private, motorized or non-motorized, and have varying legal and operational systems as shown in Fig. 3 [6]. Public transportation modes could be classified through different ways. In this research we will discuss the classification according to type of service and the operating systems as below:

Fig. 3. example of different public and private transportation Modes, Egypt [8]

A. Public transit types according to service type:

There are three types of services that transportation modes can provide. The distinction between them is relating to their different stop patterns and frequency of operation [6]:

1) *Local Service:* It refers to serving all stops which are closely spaced, normally stopping every 300 m. The means stop often and so, they are naturally quite slow. These services are perfectly suitable for connecting people from their homes to nearby transit hubs, but not for far destinations.

2) *Rapid Service:* It refers to serving regular but widely spaced stops every 800 m, generally around the beginning and end rather than a continuous area along the whole line. Stops are more widely spaced for faster service, allowing for shorter commute times. These services are intended to connect nodes of activity, not to be provided at every location along the route. The efficiency and frequency of the service make it worth walking the extra distance to get there.

3) *Express Service:* It refers to serve a long nonstop segment to the destination. These run on routes with only two stops at the beginning and end of each segment. Large non-stop portions imply that they efficiently transport passengers to their destination. When there is a low population and employment density between the areas of interest, this type of service is suitable.

B. Public transit types according to operating system and time:

Public transit also may be classified as formal transit and on demand transit service including paratransit and peak only transit services:

1) *Formal transit service:* It refers to public transport services that have been planned by a government or an officially sanctioned private sector agency to be operated through specific timetables or headways. Ex: underground Metro, government and private company buses and minibuses.

2) *Paratransit service (on demand):* a flexible mode of passenger public transportation that does not adhere to established routes and/or schedules with flexible stops. It is often in the form of small- to medium-sized buses and shared taxis such as microbuses and Suzuki vans. Paratransit services are frequently associated in the developed world with demand-responsive 'dial-a-ride' systems for people with impairments [9].

3) *Peak only commuter service (on demand):* It represents on-demand transit service that operates according to a scheduled timetable or headways, it works only in peak hours and through working days such as: shuttles of private companies including Uber, Careem, etc. However, there is a clear difference between newly emerging services and existing ones as newly emerging services depend on using smartphones. this excludes a big section of the population. Furthermore, these new services are also expensive and are not viable for everyone [5].

VI. THE STRATEGIES OF ENHANCING PUBLIC TRANSPORTATION SYSTEMS IN DEVELOPING COUNTRIES:

This research explores different strategies to enhance public transit in terms of availability, accessibility, and connectivity with other different modes in order to achieve an integrated and sustainable mobility system in developing countries and Egypt as one of those countries which share same challenges. These strategies including:

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A. Planning Integrated and complemented formal public transportation& paratransit

The paratransit system makes up the bulk of public transport in many developing countries and often services central areas to fill the gap of public transportation networks and Coppenses the deficiencies and inadequacies or high costs of the formal transit system [10]. Their main advantage is providing door-to-door service which means reduced loading and unloading time, on-demand stops, and greater maneuverability in traffic [2].

It has been argued that public transport systems in developing countries should be considered as a whole, with paratransit and planned networks coexisting in a dynamic way. Recognizing the relevance and role of paratransit service networks can be beneficial to the whole public transportation system if properly managed and regulated. However, the context in which the solution is supposed to be implemented must be considered when selecting one or more planned and paratransit service interfaces [9]. There are many alternatives of the integration arrangement including separate roads, connecting corridors, shared corridors, peak-lopping and trunk and feeder approaches. In developing countries, the feeder-trunk-distributor model is commonly used for achieving integrated and complemented formal and paratransit services as shown in Fig. 4., this without ignoring the required upgrade for paratransit in terms of operations and business practices. this research explores the trunk and feeder model as one of the most popular in developing countries.

It is frequently used in recent and ongoing projects of developing the BRT system through high-demand corridors. On the other hand, in some cities where BRT-like systems were already constructed without the introduction of planned feeder services, paratransit operators shifted and changed their routes to provide feeder paratransit services to and from planned trunk service stops.

There are three approaches to planned-paratransit service integration through trunk and feeder arrangements including: reward schemes; feeder area licensing; and concessioning. This solution effectively divides demand into two distinct types of routes and services as the following [9]:

- The trunk-planned routes: serve longer distance connections using higher capacity and speed vehicles. It depends on stop spacing and the effectiveness of procedures that determine priority along links and at intersections.
- The feeder-paratransit routes: serve shorter local routes with smaller capacity vehicles (although not exclusively). The arrangement's design creates interchange stations where transfers are made.

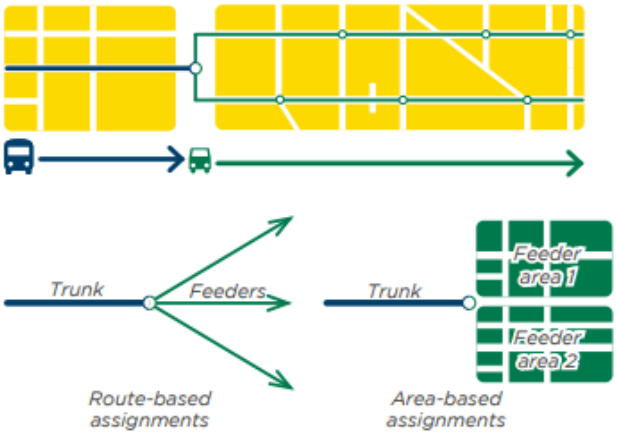

Fig. 4. Alternatives of Integration between planned and paratransit services, Feeder-trunk operations model [15]

Many developing countries in Africa have experienced different projects and approaches based on three main pillars (enable- improve- shift) to integrate paratransit as a main aspect in order to enhance the whole public transit system [6].

The experience of Dakar, the capital of Senegal sets a successful example for improving paratransit service (minibus). Policymakers adopted a process consisting of three stages as the following:

- Registration: represents the first stage in which operators were integrated into a system governed by local government through cooperatives.
- Establishment of routes: represents the second stage it established the route as the unit of regulation (rather than traditional bus models or operator licensing); In this stage, there was an agreement with the members to occupy the most lucrative routes within Dakar in exchange for scrapping old vehicles, paying a deposit for new vehicles and the introducing tickets paid by users.
- Permits: represents the third stage. Finally, permits that manage and improve quality by encouraging long-term investment security were introduced.

Moving to Egypt, despite paratransit's dominant role in the public transportation sector, one of the main challenges facing public transportation is not accepting paratransit as a primary mode in the whole transportation system and expanding it to support the entire public transport system. The majority of public transportation trips require one or more transfers, this articulates a fragmented feeder-trunk-distributor system of transportation [6].

B. Mapping public transit:

The process of collecting data of formal public transit networks is a major obstacle to improve accessibility, this called as “mapping city’s public transit”. There are 3 levels of mapping as shown in Fig.5. Every level considers collecting different type of data as the following:

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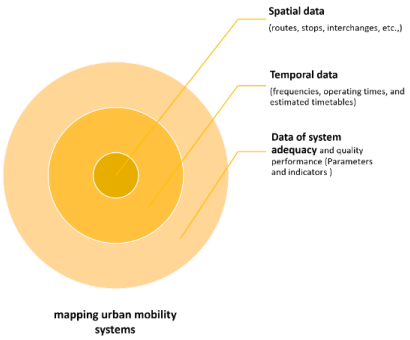

Fig. 5. Mapping urban mobility systems-the three levels of mapping and collecting data of cities urban transportation [2].

1) *First level (spatial data):* The most common level of mapping urban mobility networks relates to the collection of spatial data on routes and stops, as well as the creation of a record of stop names, stop structures, interchanges, and route pricing.

2) *Second level (temporal data):* This level includes collecting information regarding the frequency of transportation services, and their operating times by estimating timetables based on traffic and road conditions. Such mapping exercises clarify the intersection areas between the different modes of transportation, thus provide a comprehensive view of the transportation system.

3) Third level: This level includes collecting data on additional parameters and indicators related to adequacy of urban mobility system and the final perception of users of various modes of transportation through the broad and comprehensive urban mobility system. It extends beyond the system's spatial and temporal aspects to address system adequacy. The goal is to answer inquiries on a wider variety of issues [2].

To achieve goals of Mapping cities' transportation in the best ways, all dominant modes of transportation in the cities should be included. As the paratransit system in Developing countries is likely to be a core part of public transport networks, the need for improving come as a priority regardless of its difficulties and complexities. The frequent failure of collecting data and acknowledging the important role of paratransit networks as one of the most dominant modes of transportation is carrying many problems in terms of equity, access, and inclusive and effective planning. As a result, a growing number of bottom-up mapping projects of paratransit systems in some African cities such as Nairobi and Maputo (minibus) demonstrate that cooperative and comprehensive mapping can help make these minibuses more visible in planning. It also draws attention in a more realistic and comprehensive way to the importance of integration between different means of transport, minibus upgrading and passenger information. All of which are important but relatively marginalized aspects of achieving sustainable public transport. Furthermore, this data enables new, tangible tools for passengers, operators and planners as shown in Fig. 6. This will become even more significant as urban planners shift their focus away from large-scale transportation projects and towards more integrated multi-modal networks that promote access and equity. To sum up, poor data collecting and understanding of paratransit systems, which are relied on by the majority of developing countries to access cities and their opportunities is no longer an option in order to achieve sustainable mobility system. Moving to Egypt, although informal solutions based on technological apps, such as ride-sharing services and crowdsourcing tools, are commonly used, Nonetheless, the majority of new data sources and data-based services target private vehicles, strengthen the transport bias while disregarding the dominant paratransit sector that provide the majority of mobility services [2].

Fig. 6. *Mapping paratransit system, and example of prototype maps used in bus stops, Maputo [10].*

C. First and last mile solutions:

The lack of First and Last mile solutions have a major negative effect on public transit ridership. The issues of the first, last and only miles have existed since the beginning of the development of public and collective transit services as shown in Fig. 7 and 8. As cities grow or when the mobility infrastructure is undeveloped, with only a few routes that do not adequately cover the city, this problem became apparent as the length of the first/last/only mile' trips started to increase. The major challenge facing urban planners and service providers here is how to connect residents' pick-up location to the city's transit network or the desired destinations. The first and final (FL) miles of commuters are typically the weakest links in the city transport network that have to be developed prior to developing an integrated mobility system [7].

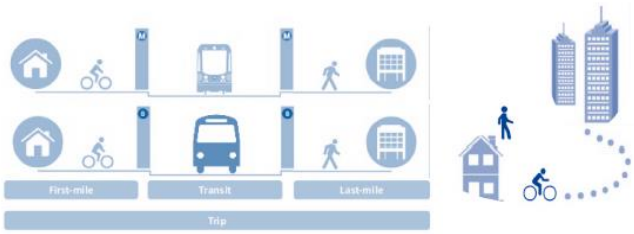

Fig. 7. *First and last mile concept vs. only mile concept [7].*

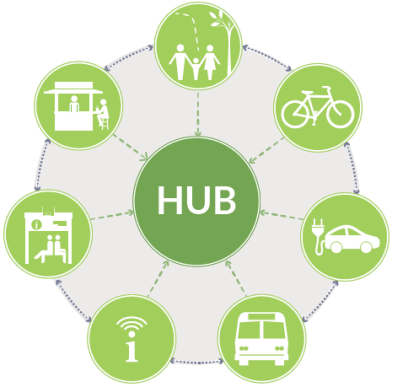

Fig. 8. *Multimodal connectivity and mobility hubs (Los Angeles city*

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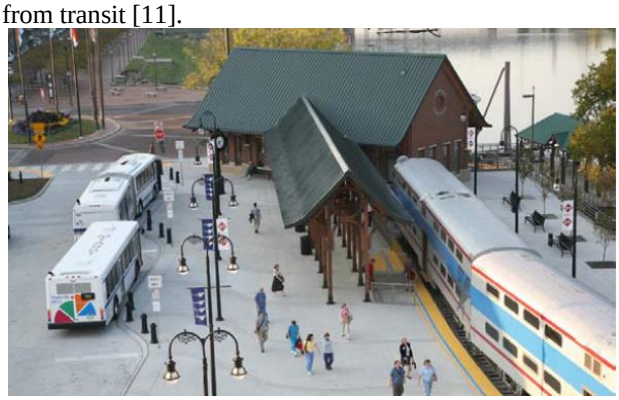
planning commission 2018).

The FL miles' trips are strongly affected by the local urban context. Factors including land-use, density, route length and surrounding environmental conditions. These factors also affect the type of mobility solution to the first and last mile issues. The mobility solutions could be active mobility solutions such as walking and cycling which is regarded as the primary first, last and only mile solution, or it can be non-active mobility using motorized or electrical vehicles. It can also be a private or shared means of transportation. Furthermore, these solutions may follow the principle of driving yourself or it can be addressed by modes in which the commuter is a passenger rather than a driver. Other approaches are using high technology solutions such as mobile applications-based services.

On the other hand, and relative to first and last mile solutions in developing countries, the principles of the development are required to be consistent with an overall long-range public transportation plan and based on multi-modal transportation. This in turn promotes public transportation projects and reduces dependency on private vehicles [12]. The design of Mobility hubs in deferent urban levels contributes to a responsive solution to first and last mile issues and achieving a multi modal and connected mobility system.

Features supporting multi modal connectivity include enhancing transfers between systems through design of Transit stops which facilitate the efficient transfer of passengers between different modes of transportation and across jurisdictions as shown in Fig.9. It also includes enhancing access for pedestrians and cyclists in station areas and provide qualified pedestrian infrastructure for them. Transit stations and station areas should be designed to prioritize pedestrian access while accommodating the needs of other users such as transit and motor vehicles. Streets should be designed with sidewalks and crossings that are comfortable to use, with frequent intersections and crossing points that provide multiple routing options and amenities that enhance the experience of walking and cycling to and from transit [11].



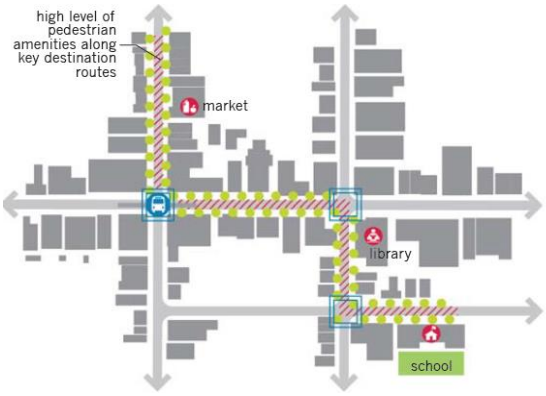


Fig. 9. *Easy transfers between systems. A pleasant pedestrian experience on routes to and from transit stations can help boost transit ridership [11].*

D. Smart mobility solutions:

Integrating information and communication technologies into the transport system through the implementation of strategies or policies for smart technologies has an important role in enhancing the overall efficiency of the transport system. Despite the lack of financial and technical resources in developing countries, the use of technology in transportation is an approach that cannot be overlooked, some applications of smart mobility solutions have a significant impact in supporting public transportation, such as: Integrated Ticketing System Passenger information system (PIS) and Transit Signal Priority (TSP) and others, This research explores the previous systems as the most common and associated with enhancing public transportation service as the following:

- Integrated Ticketing System: This system allows a person to make a journey that includes transfers between different modes of transportation with a single ticket used for the entire journey and including all modes. The integrated ticketing aims to encourage people to use public transport by facilitating the transfer between different modes of transport and boosting service efficiency. as shown in Fig.10.

Fig. 10. *Illustration of Integrated Ticketing System*
Source: https://www.leparisien.fr/economie/nouvelles-mobilites/le-maas-la-mobilite-urbaine-repensee-05-11-2020-4SNQZ75RGJAJRBDISYXH4OOPVA.php , accessed 24 April 2023

- Passenger information system (PIS): It is the operating tool responsible of giving a real time visual and audio information to passengers at stations and transfer facilities, either automatically or manually programmed.
- Transit Signal Priority (TSP): The purpose of TSP is to reduce transit vehicle stay time at traffic signals by using technology in controlling these signals through holding

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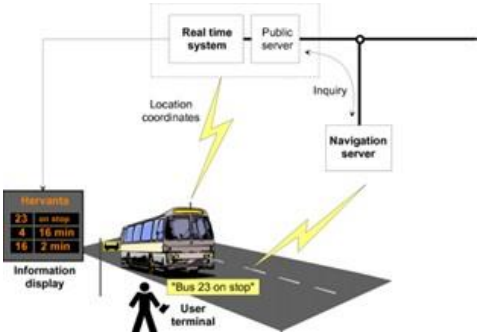
green lights longer or shortening red lights as shown in Fig. 11 [13].



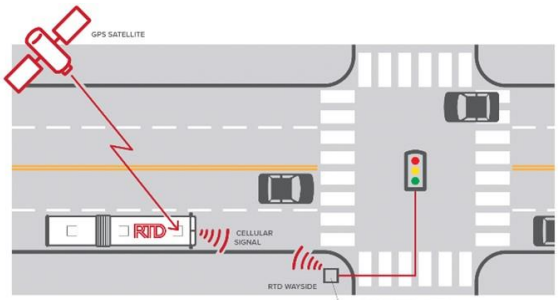


Fig. 11. Illustration of transit signal priority system [14].

VII. DISCUSSION:

Exploring the strategies of enhancing public transit in developing countries and discussing the capability of applying it in Egypt as one of those countries sharing relatively same potentials and deficiency in transportation system has revealed a set of potential and challenges as below in Table I.

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TABLE I. Challenges and potentials of applying strategies and solutions of Enhancing public transportation systems in Egypt

The strategies and solutions	Potential	Challenges
A. Planning Integrated and complemented formal public transportation and paratransit	• Filling the gap of formal public transit, this enhances the availability and accessibility of public transit. • Promote large new transportation projects like the Monorail and BRT, as paratransit could work as a feeder connecting passengers to and from the stations of these transportation projects. • Provide more equitable and sustainable public transport systems where paratransit operators has contributed to social inclusion. • The success of peak-only transportation services and the high increase of its demand in recent times rather than using private cars, indicates the possibility of success in similar paratransit service in case it meets passengers' satisfaction.	• Paratransit needs to be upgraded in terms of regulation, operations and business practices, ensuring safety and comfort for passengers. • Old vehicles also need to be replaced or upgraded. • The interface between the formal public transit and the paratransit must consider the context in which the solution is expected to be implemented in order to plan the suitable arrangement for the integration.
B. Mapping public transit	• Improve public transit accessibility, understanding and visibility through defining routes of different modes, stops allocation, timetables etc. • Provide Variety of transportation options, and ensure the ability to freely choose and define the suitable mode and /or route for passenger's destination considering money and time save.	• Shortage of data on basic spatial and temporal levels of formal public transport and paratransit networks. Sometimes it depends on word of mouth. • The gap of data caused by the multitude of actors in transportation sector in Egypt and lack of publicly available data. • Most of current data-based services (like informal solution based on technology apps) target private motorists and ignore the large paratransit sector. • Using technology for collecting data requires high financial resources and technical capabilities.
C. First& last mile solutions	• Provide various urban mobility solutions from and/or to the stations and stops of main public transportation modes to enhance accessibility of public transit and reduction of private cars use. • Enhancing Intermodal connectivity and accessibility of public transit.	• Large areas of urban communities, long distances and hot climate discourage active mobility solutions. • Poor infrastructure of pedestrian and cycling, other solutions such as park and ride are very expensive and limited. • Poor distribution of mobility hubs and the frequency of stops especially on Neighborhoods level.
D. Smart mobility solutions	• Simplifying the switching between transport modes, enhancing accessibility to public transit and encourage people to use public transport. • Provide real time data for transportation and applying transit signal priority system can save time and money wasted in transportation. It also helps to choose the better and nearest routes and modes. • Some of smart mobility solutions such as real time information are already implemented and experienced in some transportation service by private companies, indicating promising financial and economic result as it manages time and cost of transportation.	• Building digital infrastructure for smart mobility solutions requires high level of technical capabilities, maintenance and High cost of implementation. • Smart solutions are not suitable and usable for all groups of passengers in Egypt.

VIII. RECOMMENDATIONS

Therefore, and as per the observed challenges, recommendations are identified to Enhance public transportation systems for achieving sustainable urban mobility in developing countries with specific reference to Egypt as the following:

- Adopting strategies of integrating paratransit with formal public transit systems in developing counties in parallel to reforming it, instead of the services completely replace which is unmanageable in the current economic circumstances.
- Accepting, regulating, and licensing paratransit in developing countries and Egypt as an essential requirement to establishing a hierarchical improved network logic and integrated multi-modal public transport in order to reduce minimize the Journey Gap, and improving the public transport experience.
- Integrating paratransit operators into a system controlled and regulated by local governments, followed by registering drivers and providing permits is a key step in improving paratransit services. Operators would retain full commercial responsibility and would be subjected to basic requirements for vehicle safety and environmental standards, and stopping in their own stations and stops.
- upgrading Paratransit in terms of regulation, operations and business practices, ensuring safety and comfort for

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passengers. Old vehicles also need to be replaced or upgraded.

- Improving the basic levels of mapping including spatial and temporal data in formal public transportation and paratransit to be more visible and more understandable for passengers, this enhancing the accessibility of public transportation.
- Investing in digital infrastructures is necessity to enable the operational, information and communication technologies to contribute to the management and operation of urban transportation systems. information-sensing and wireless technologies for example have produced new data sources which contribute to enhancing urban transportation sector.
- Enhancing the mobility solutions for first and last mile issues through the improvement of pedestrian and cycling infrastructure and promote other solutions such as park and ride system.
- Ensuring transit within a 10-minute walk or cycle from home, reducing wait times for all journeys throughout the day, trip times and protecting transit from traffic congestion.
- Ensuring a balanced distribution of mobility hubs and the frequency of stops on different urban levels to meet travel demand of passengers.
- Promoting the urban context that oriented to public transportation and intermodal connectivity, reducing the dependency on private motorized modes.

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